NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.
POST-TRAINING PERFORMANCE
CRITERION DEVELOPMENT AND APPLICATION

A Comparative Multidimensional Scaling Analysis of the Tasks Performed
by Naval Aviation Electronics Technicians at Two Job Levels

Arthur I. Siegel
Douglas G. Schultz

Prepared for
Personnel and Training Branch
Office of Naval Research

by
APPLIED PSYCHOLOGICAL SERVICES
Wayne, Pennsylvania

under
Contract Nonr-2279(00)
March 1963
Best Available Copy
This study investigated the application of multidimensional scaling methods in the area of job performance. Supervisory personnel judged the similarity among all pairs of 29 tasks which had been designated as constituting the job of the Naval aviation electronics technician supervisor. The resulting scaled similarity estimates were analyzed by multidimensional scaling techniques.

This research supplemented an earlier study by providing further evidence that it is feasible and fruitful to apply multidimensional scaling methods to Naval job performance. Chief petty officers and petty officers, first class, in the aviation electronics technician rating perceived their work as involving nine basic dimensions, including all the dimensions underlying the job of strikers and petty officers, third class, in the rating.
ACKNOWLEDGMENTS

This study is part of a research program supported by the Personnel and Training Branch, Psychological Sciences Division, Office of Naval Research, under Contract Nonr-2279(00). All of the people who played a role in the first Applied Psychological Services' application of multidimensional scaling methods to job performance were equally important in the accomplishment of this project. In the Office of Naval Research, particular mention should be made of Dr. Glenn Bryan and Mr. John Nagay of the Personnel and Training Branch and Dr. Richard Trumbull, Head of the Psychological Sciences Division. In the Naval Air Technical Training Command, Memphis, the help and support of Dr. G. Douglas Mayo is again acknowledged. Liaison with the fleet was capably handled by LCDR F. S. Siddall of the Staff of the Commander Naval Air Force, U. S. Atlantic Fleet.

As in the previous study, Dr. David R. Saunders performed the factor analytic calculations on a high-speed computer. At Applied Psychological Service Miss Marita Viglione carried out the initial tabulations and scaling computations and Miss Gail Gensemer and Mrs. Estelle Siegel provided secretarial and administrative support.

We wish to express our gratitude to all these people for their important contributions to this project.

Arthur I. Siegel
Douglas G. Schultz

APPLIED PSYCHOLOGICAL SERVICE:
March 1963

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</table>
CHAPTER I

INTRODUCTION

Recent research carried out by Applied Psychological Services in the area of criterion development has emphasized the application of psychological scaling methodology to job performance measurement. Earlier studies had produced comprehensive, detailed check lists for evaluating the post-training job performance of Naval enlisted personnel in several technical specialties. Psychological scaling techniques appeared to offer promise as a means for constructing short, convenient-to-use instruments and for obtaining further insight into the basic structure of the job. The first efforts along these lines (Schultz and Siegel, 1961; Siegel and Schultz, 1962) examined the applicability of the Thurstone and Guttman scaling methods in performance criterion development.

The most recent report (Schultz and Siegel, 1962) described a multidimensional scaling analysis of the job performance of Naval aviation electronics technicians. In that report it was pointed out that job criteria have generally been found to be complex and multidimensional but that this problem area required further quantitative consideration and methodological exploration. In these respects, multidimensional scaling analysis seemed particularly appropriate, since its primary purpose is to determine the number and characteristics of the dimensions underlying the phenomenon which is being analyzed.
Although multidimensional scaling methods differ from unidimensional scaling methods in that the scales or dimensions are not defined for the judges by the experimenter, essentially they represent an extension of the traditional psychophysical scaling methods. Richardson (1938) was the first person to use multidimensional scaling; more recently the methods have been developed by a number of research workers and applied in a variety of situations.

Torgerson (1952, 1958), Messick (1956a, 1956b), and others have given the details of the derivative and computational procedures used in multidimensional scaling analysis. Its essential rationale and some of the technical issues involved were discussed in the previous Schultz and Siegel report (1962). In brief, the structure of multidimensional scaling rests upon estimates of the psychological distances among the stimuli being studied. These have usually been obtained on the basis of judgments, by appropriate subjects, of the over-all similarity between each stimulus pair included in the phenomenal descriptive constellation. The scale values resulting from these judgments are then taken as measures of the inter-stimulus distances in a Euclidean space and the central analytical problem become first, the determination of the number of axes, or dimensions, in the space and, second, the projections of the stimuli on the axes.

In the first application of multidimensional scaling techniques to the Naval job performance area (Schultz and Siegel, 1962), 18 tasks constituting the typical work performed by Naval aviation electronics technicians at the striker and petty officer, third class, level were analyzed. The job perceptions of supervisory
personnel in that rating formed the data substrate. Four basic job dimensions emerged from the analysis. The matrix of task loadings on the various dimensions suggested the names "electro-comprehension," "equipment operation and inspection (routine)," "electro-repair (simple)," and "electro-safety" for the four dimensions. It was felt that these dimensions described the technical job activities of the aviation electronics technician striker and petty officer, third class, adequately and meaningfully. Furthermore, it was concluded that the four dimensions possess characteristics such that it should be possible to develop unidimensional scales for the evaluation of individuals on each isolated and identified dimension.

The first study further indicated that it is feasible and fruitful to apply multidimensional scaling techniques to a job task constellation. In order to provide a firmer empirical base for the acceptance or rejection of this conclusion, application of the procedures to another set of job-task stimuli seemed desirable. For this purpose, attention was directed to the manner in which chief petty officers and petty officers, first class, in the Naval aviation electronics technician rating view their own job. The results of such a study would also permit a comparison, from the point of view of supervisory personnel, of the job dimensional characteristics at the supervisory and the journeyman* levels of aviation.

* Throughout this report the term "journeyman" is used to refer to a striker or a petty officer, third class, in the rating. The term "supervisor" refers to a chief petty officer or a petty officer, first class.
electronics technicians and thus throw light on the basic structure of the rating as a whole.

**Purposes of the Present Study**

The specific purposes of the present study paralleled those of the first application of multidimensional scaling techniques in the job performance area (Schultz and Siegel, 1962). They were to: (1) explore further the feasibility of applying standard multidimensional scaling procedures to a job task constellation, (2) investigate more fully specific methods for applying these techniques in the work oriented situation, and (3) determine the number and the nature of the dimensions of the job of the Naval aviation electronics technician supervisor. A fourth purpose was to compare the dimensional structure of the aviation electronics technician job at the supervisory and the journeyman levels.
CHAPTER II

DEVELOPMENT AND ADMINISTRATION OF TASK LIST

Since the study presented here was very similar in purpose to the previous Applied Psychological Services' investigation into the aviation electronics technician's job (Schultz and Siegel, 1962), some of the preliminary work for both programs was carried out in parallel and there was overlap in content and style between the data collection forms used. Therefore, to make this description complete some material from the previous report is reviewed in this chapter.

Preliminary List of Tasks

In order to provide the "raw material" for the multidimensional analysis, it was necessary to derive a list of tasks which could be said to constitute the job of chief petty officer and petty officer, first class, in the Naval aviation electronic technician (AT) rating. The tasks were to be stated in behaviorally oriented terms with sufficient detail to reflect adequately the work performed, yet with sufficient generality to make feasible the required similarity judgments. In addition, reference to specific equipment was to be avoided so that neither general nor specific "equipment" factors would be generated.

A preliminary list was developed, based largely on three previous Applied Psychological Services' studies of aviation electronics technicians (Richlin, Siegel and Schultz, 1960; Schultz and Siegel, 1961; Siegel and Schultz, 1962). Since those studies had concentrated on journeyman level personnel it was necessary to
supplement the list with tasks that were thought, from Applied Psychological Services' background in the field, to be performed by AT supervisors but not by the lower level personnel. The complete preliminary list of 40 tasks has been presented in the previous report by Schultz and Siegel (1962).

**Final Selection of Job Tasks**

The 40 tasks were assembled in booklet form. The booklet was administered, in two groups, to 23 instructors in the AT school at the Naval Air Technical Training Command in Memphis, Tennessee. It could be assumed that these men knew the job under consideration since they were chief petty officers or petty officers, first or second class, in the AT rating and all had recently arrived at the school from Fleet duty. On the average, the instructors had about 7-1/2 years of military experience in electronics or electrical work, had about 5-1/2 years experience as an AT and had been assigned as an AT to about 2-1/4 different squadrons during their careers.

On the cover page, the booklet gave the following explanation of purpose and directions:

> The purpose of this questionnaire is to determine the specific tasks AT's perform in the Fleet. We want to obtain a list of the jobs done by a representative sailor in this rating.

> First, look over the list to get an idea of what tasks are included. Then:
1. Go through the list and check in the column labeled "AT Striker/3rd Cl." all the tasks which are normally and customarily performed by Striker and Third Class AT's in the Fleet.

2. Go back and place a check in the second column next to all the tasks which are normally and customarily performed by First Class and Chief AT's in the Fleet.

You may know of a particular sailor who has done some of the listed tasks, even though most AT's do not do them. Or, in a particular squadron with which you are familiar, the AT's may perform certain duties not normally performed by most of the men in the rating.

The administrator emphasized that such tasks were not to be checked.

The directions concluded,

If there are any tasks normally performed by AT's in the Fleet which are not included in the questionnaire, please write them in under "Other" on the last page. Be sure to check whether these tasks are done by Strikers and Third Class men or by First Class men and Chiefs or by both.

This final instruction permitted the addition of any important AT activities which had been omitted inadvertently from the initial group of 40 tasks.

Before the men began working on the booklets, the administrator again stressed the point that a complete picture of the job as it is actually performed was wanted, rather than as it is supposed to be performed according to any criterion whatsoever. After the men had finished the form, an informal discussion was held to determine their estimate of the over-all completeness of the list and to obtain suggestions about such matters as the wording of the tasks. From the comments made during these sessions, it appeared that there was
general agreement among these "experts" that their responses reflected the work done by AT's in the Fleet accurately and adequately.

The instructors added no significantly new tasks in the spaces provided for "other" tasks. The consensus clearly indicated 29 of the 40 tasks as constituting the AT job at the chief petty officer and petty officer, first class, level. The other items were checked with varying frequencies but 19 or more of the judges agreed that the 29 tasks were performed by AT supervisors. These data, therefore, strongly supported the conclusion that the AT supervisory job was perceived by these widely experienced men as comprising the 29 tasks they had checked.

The following 29 tasks, therefore, formed the basis for the multidimensional scaling analysis of the job performance of Naval aviation electronics technician supervisor:

1. Standing watch
2. Performing major inspections of avionic equipments
3. Operating avionic equipments
4. Using safety precautions on equipment
5. Using proper safety precautions for self
6. Performing inflight maintenance on avionic equipments
7. Repairing malfunctioning parts/equipment in shop
8. Following block diagrams for avionic equipments
9. Using schematics for standard circuits in avionic equipments
10. Using schematics for complex circuits in avionic equipments
11. Analyzing standard circuitry in avionic equipments

12. Analyzing complex circuitry in avionic equipments

13. Troubleshooting/isolating malfunctions in avionic equipments

14. Making out reports (failure, etc.)

15. Using maintenance manuals

16. Using inspection and operation manuals

17. Operating standard test equipment for determining malfunctions in avionic equipments

18. Operating specialized test equipment for determining malfunctions in avionic equipments

19. Using ASO catalog and Section R allowance list for replacement parts

20. Employing electronic principles involved in the maintenance of avionic equipments

21. Knowing relationship to other related equipment of avionic equipments

22. Instructing others in the operation of avionic equipments

23. Instructing others in the inspection of avionic equipments

24. Instructing others in the maintenance of avionic equipments

25. Supervising operation of avionic equipments

26. Supervising inspection of avionic equipments

27. Supervising maintenance of avionic equipments

28. Keeping record of maintenance usage data

29. Assigning duties to personnel
A comparison of the above list with the analogous list from the journeyman level analysis reveals that nine tasks were included in both lists. These tasks, which are performed by both supervisors and journeymen in the AT rating, according to the judges, are: standing watch, operating avionic equipments, using safety precautions on equipment, using proper safety precautions for self, following block diagrams for avionic equipments, using schematics for standard circuits in avionic equipments, making out reports (failure, etc.) using inspection and operation manuals, and operating standard test equipment for determining malfunctions in avionic equipments. The tasks done only by the strikers and petty officers, third class, involve the simpler duties such as "housekeeping" chores, routine line operations, routine inspections, removal and replacement, and preventative maintenance. On the other hand, the chief petty officers and petty officers, first class, carry out a variety of more complex activities such as major inspections, troubleshooting and repair, operating test equipment, using schematics and analyzing circuitry, as well as administrative duties such as supervising, instructing, keeping records and assigning duties.

The Multidimensional Scaling Form

The 29 tasks designated as comprising the AT supervisory job were arranged in a booklet, called Form C of the Technical Task Inventory, so that estimates of the similarity between each pair of tasks could be obtained, in group administrations, from judges. At the top of each page, 1 of the 29 tasks was shown. Below it at the left side of the page, from 1 to all (28) of the remaining
tasks were listed. Since the psychological distance between each pair of tasks was judged in only one direction, i.e., from task A to task B and not from task B to task A, it was not necessary to show a task on later pages after it had been used at the top of a page. The tasks on any page were listed in a random order which was varied from one page to another.

To the right of each item there appeared a scale running from 1 to 11. The scale points 1 and 2 were described as representing a judgment of "very similar"; points 3, 4, and 5, as representing "moderately similar"; points 7, 8, and 9, as representing "moderately different"; and points 10 and 11, as representing "very different." Scale point 6, in the middle of the range, was unlabeled. The booklet page which contained all the tasks is shown as Table 1; a sample of the other pages is shown in Table 2.

The directions asked the subject to compare each task listed with the one shown at the top of the page and then to "indicate by a check in the appropriate column to the right how similar or different the two tasks are." After three illustrative responses, two comparisons were presented for respondent practice. The complete cover page of the form, including the directions, is shown in Table 3.

The order of the pages in the booklet was determined from a table of random numbers, so the number of tasks listed from one page to the next could differ markedly. Four different random page orders were used, the forms being intermixed for administration to the subjects.
## Table 1
Page of the Technical Task Inventory, Form C. Containing all Tasks

<table>
<thead>
<tr>
<th>Task Description</th>
<th>Very Similar</th>
<th>Moderately Similar</th>
<th>Moderately Different</th>
<th>Very Different</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructing others in the maintenance of avionic equipments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using safety precautions on equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Following block diagrams for avionic equipments</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Supervising maintenance of avionic equipments</td>
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<tr>
<td>Knowing relationship of avionic equipments to other related equipment</td>
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<tr>
<td>Performing inflight maintenance on avionic equipments</td>
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<tr>
<td>Using ASD catalogs and Section R allowance list for replacement parts</td>
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<td></td>
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<tr>
<td>Using inspection and operation manuals</td>
<td></td>
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<tr>
<td>Performing major inspections of avionic equipments</td>
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<tr>
<td>Making out reports (failure, etc.)</td>
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<td></td>
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<tr>
<td>Operating specialized test equipment for determining malfunctions in avionic equipments</td>
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<tr>
<td>Using maintenance manuals</td>
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<tr>
<td>Operating avionic equipments</td>
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<tr>
<td>Analyzing complex circuitry in avionic equipments</td>
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<tr>
<td>Supervising operation of avionic equipments</td>
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<td></td>
<td></td>
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<tr>
<td>Operating standard test equipment for determining malfunctions in avionic equipments</td>
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<tr>
<td>Supervising inspection of avionic equipments</td>
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<tr>
<td>Analyzing standard circuitry in avionic equipments</td>
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<tr>
<td>Using schematics for complex circuits in avionic equipments</td>
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<tr>
<td>Employing electronic principles involved in the maintenance of avionic equipments</td>
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<tr>
<td>Keeping record of maintenance usage data</td>
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<tr>
<td>Instructing others in the operation of avionic equipments</td>
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<td></td>
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</tr>
<tr>
<td>Using proper safety precautions for self</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Assigning duties to personnel</td>
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<td></td>
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<tr>
<td>Standing watch</td>
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<tr>
<td>Using schematics for standard circuits in avionic equipments</td>
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<td></td>
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<tr>
<td>Troubleshooting/isolating malfunctions in avionic equipments</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Table 2
Sample Page of the Technical Task Inventory, Form C

<table>
<thead>
<tr>
<th>INSTRUCTING OTHERS IN THE MAINTENANCE OF AVIONIC EQUIPMENTS</th>
<th>VERY SIMILAR</th>
<th>MODERATELY SIMILAR</th>
<th>MODERATELY DIFFERENT</th>
<th>VERY DIFFERENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervising maintenance of avionic equipments</td>
<td>1 2</td>
<td>3 4 5</td>
<td>6</td>
<td>7 8 9</td>
</tr>
<tr>
<td>Making out reports (failure, etc.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using schematics for standard circuits in avionic equipments</td>
<td></td>
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<tr>
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<td></td>
</tr>
<tr>
<td>Operating specialized test equipment for determining malfunctions in avionic equipments</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Analyzing standard circuitry in avionic equipments</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Performing major inspections of avionic equipments</td>
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<td></td>
</tr>
<tr>
<td>Instructing others in the inspection of avionic equipments</td>
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<td></td>
<td></td>
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<tr>
<td>Using proper safety precautions for self</td>
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<td>Operating avionic equipments</td>
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<td>Troubleshooting/isolating malfunctions in avionic equipments</td>
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<tr>
<td>Using maintenance manuals</td>
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<td></td>
</tr>
<tr>
<td>Following block diagrams for avionic equipments</td>
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</tr>
<tr>
<td>Operating standard test equipment for determining malfunctions in avionic equipments</td>
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</tr>
</tbody>
</table>
TECHNICAL TASK INVENTORY

The purpose of this questionnaire is to compare various tasks performed by AT's in the Fleet.

One task is shown at the top of each page. Below it is a list of other tasks. Beside each task in the list is a scale running from very similar to very different. You should compare each task in the list with the one at the top of the page and indicate by a check in the appropriate column to the right how similar or different the two tasks are. There are no "right" or "wrong" answers to this Inventory; your best judgments of similarity are the only "right" answers.

Before you begin, open the booklet and look over the pages briefly to get an idea of what tasks are included. Notice that the pages have different numbers of tasks listed. Then start working at the beginning of the booklet. Try to vary your check marks so that some appear in all eleven columns. Do not hesitate to use the extreme responses numbered 1 and 11, if you feel any comparison deserves one of them.

EXAMPLE

DRIVING AND OPERATING NC-5

FUELING PLANES
TESTING TUBES
SOLVING CIRCUIT EQUATIONS
PERFORMING PREFLIGHT INSPECTIONS OF AVIONIC EQUIPMENTS
USING MAINTENANCE MANUALS

The first check means that the person completing the Inventory thinks that "fueling planes" is moderately similar (to the degree indicated by a "3") to "driving and operating NC-5." The second check means that the person answering feels that "testing tubes" is moderately similar (to the degree indicated by a "5") to "driving and operating NC-5." According to the check on the third line, "solving circuit equations" is very different from "driving and operating NC-5." You may or may not agree with this person. Try filling in the last two lines yourself.

WHEN YOU HAVE FINISHED, CHECK BACK TO MAKE CERTAIN YOU HAVE PLACED A CHECK NEXT TO EACH TASK IN THE LIST ON EVERY PAGE.

PREPARED BY
APPLIED PSYCHOLOGICAL SERVICES
WAYNE, PENNSYLVANIA

UNDER CONTRACT NONR 2275(06)
WITH THE
OFFICE OF NAVAL RESEARCH
Subjects

The subjects used in this study were the same as those of the previous multidimensional analytic study. There were 31 chief petty officers and 34 petty officers, first class, in the Naval aviation electronics technician (AT) rating. The squadrons to which the raters were assigned and their locations are presented in Table 4, which is repeated from the earlier report. The subjects' military experience in electronics or electrical work averaged 11.2 years. They had been AT's for an average of 8.3 years and had been assigned as an AT to an average of 3.8 squadrons.

Administration

Form C of the Technical Task Inventory was administered to the subjects in the same group sessions as Form S of the Inventory used in the earlier study. Form C was completed first, followed by Form S. The last booklet the subjects completed was the Technical Circuit Inventory, another multidimensional scaling form employing equipment as stimuli rather than tasks. The analysis of this third form will be presented in a later report.

A brief, general description of the research project was given by the administrator at the beginning of the session. A short break was permitted after the second form was completed. A few biographical facts were requested on a sheet given the subjects after the break. No time limits were imposed, but almost all the subjects completed the three booklets before the end of the scheduled three hours.
<table>
<thead>
<tr>
<th>Location</th>
<th>Squadron</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norfolk</td>
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<td>29</td>
</tr>
<tr>
<td></td>
<td>HS 3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>HS 7</td>
<td>2</td>
</tr>
<tr>
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<td></td>
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</tr>
<tr>
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<td>2</td>
</tr>
<tr>
<td></td>
<td>VRF 31</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>VS 26</td>
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</tr>
<tr>
<td></td>
<td>VU 6</td>
<td>3</td>
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<tr>
<td>Oceana</td>
<td>VA 42</td>
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<tr>
<td></td>
<td>VA 75</td>
<td>1</td>
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<tr>
<td></td>
<td>VF 101 Det. A</td>
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</tr>
<tr>
<td></td>
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<td>1</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>65</strong></td>
</tr>
</tbody>
</table>
As mentioned in the previous report no difficulty was encountered in
achieving understanding by the subjects of what they were to do. Almost no ex-
planation was required outside of the directions on the booklets; thus the forms
were essentially self-administering.

Although the supervisors were able to accomplish the rating easily, several
of them said informally that they did not see what specific purposes analysis of the
data would serve. Some also mentioned that their concept of the similarity scale
might have been altered as they worked through the first form, the analysis of
which is reported here.
CHAPTER III

THE MULTIDIMENSIONAL SCALING ANALYSIS

In multidimensional scaling analysis, the scaled values associated with the subjects' similarity estimates are viewed as measures of the psychological distances between the stimulus pairs. In this study, the category widths on the similarity scale used were not explicitly stated for the judges either in the directions for the Technical Task Inventory or in the labeling of the scale itself. However, it seemed reasonable to assume that the judges perceived the scale category widths as equal; this assumption considerably simplified the required computations and probably introduced no gross distortions into the dimensional structure.

Under the assumption of equal category widths, it was possible to use the method of equal appearing intervals to obtain the inter-task distances. In this method the median judgment on the scale is taken as the scale value of the stimulus. In the present application, the median judgment on the similarity scale with regard to each task pair was calculated to be the scale value for that pair; the scale value, i.e., the median, was then viewed as the relative psychological distance between those two tasks. For each of the 406 task pairs of Form C of the Technical Task Inventory, the median of the 65 values checked by the subjects is presented in Table 5.
|    | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   | 15   | 16   | 17   | 18   | 19   | 20   | 21   | 22   | 23   | 24   | 25   | 26   | 27   | 28   | 29   |
|----|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 1  | 3.40 | 2.91 | 6.50 | 4.47 | 10.18| 5.70 | 3.95 | 3.67 | 3.58 | 4.03 | 3.25 | 1.78 | 4.75 | 6.11 | 3.30 | 7.36 | 3.90 | 4.48 | 4.00 | 3.25 | 5.25 | 1.61 | 8.72 | 2.83 | 4.12 | 7.21 | 2.56 | 3.61 |     |
| 2  | 0.86 | 0.30 | 4.58 | 10.27| 5.13 | 3.68 | 4.73 | 4.31 | 3.88 | 3.31 | 2.25 | 5.13 | 6.21 | 2.42 | 8.21 | 3.60 | 5.83 | 4.65 | 4.41 | 4.72 | 1.97 | 8.75 | 2.91 | 4.77 | 9.02 | 1.85 | 4.22 |     |
| 3  | 8.45 | 4.09 | 10.19| 6.32 | 4.54 | 4.60 | 4.82 | 4.41 | 3.83 | 2.54 | 5.17 | 4.77 | 2.96 | 8.57 | 5.75 | 5.38 | 5.63 | 5.25 | 5.19 | 2.46 | 8.59 | 1.52 | 4.63 | 7.83 | 1.83 | 4.00 |     |
| 4  | 4.23 | 10.10| 9.04 | 6.38 | 7.57 | 8.66 | 8.21 | 8.65 | 8.64 | 9.11 | 8.23 | 9.31 | 2.50 | 2.88 | 9.02 | 8.36 | 7.10 | 8.30 | 8.95 | 8.50 | 6.23 | 8.00 | 2.43 | 8.19 | 7.17 |     |     |
| 5  | 9.96 | 4.71 | 3.10 | 4.20 | 4.91 | 5.83 | 3.75 | 5.21 | 4.27 | 4.21 | 4.94 | 6.10 | 0.90 | 4.44 | 5.25 | 5.00 | 4.58 | 5.08 | 7.92 | 2.93 | 3.83 | 8.57 | 4.27 | 3.58 |     |     |
| 7  | 2.72 | 2.22 | 4.42 | 3.46 | 4.38 | 4.55 | 2.77 | 1.00 | 3.95 | 8.13 | 4.55 | 1.81 | 2.56 | 2.32 | 2.03 | 4.68 | 4.81 | 5.32 | 4.38 | 7.61 | 4.32 | 4.50 |     |     |
| 8  | 2.82 | 2.33 | 3.68 | 3.61 | 3.65 | 3.64 | 2.98 | 4.06 | 8.67 | 4.75 | 2.68 | 4.21 | 3.79 | 2.94 | 3.05 | 7.42 | 3.95 | 3.31 | 7.08 | 4.23 | 3.45 |     |     |
| 9  | 3.10 | 3.10 | 2.88 | 3.69 | 2.05 | 2.46 | 4.50 | 9.05 | 4.89 | 2.78 | 0.67 | 2.96 | 2.88 | 4.17 | 8.15 | 4.95 | 3.39 | 9.04 | 5.88 | 7.57 |     |     |
| 10 | 4.71 | 3.79 | 1.98 | 5.57 | 4.68 | 4.37 | 9.11 | 4.18 | 2.68 | 4.05 | 4.50 | 5.10 | 1.35 | 8.81 | 3.65 | 4.17 | 8.68 | 3.41 | 2.58 |     |     |
| 11 | 3.08 | 2.10 | 1.80 | 2.08 | 2.88 | 7.06 | 3.13 | 4.29 | 3.63 | 1.39 | 2.69 | 2.72 | 6.92 | 2.96 | 4.53 | 7.28 | 2.35 | 3.06 |     |     |
| 12 | 2.77 | 4.59 | 4.21 | 1.61 | 8.56 | 4.81 | 2.50 | 4.63 | 4.94 | 5.42 | 2.43 | 9.32 | 3.05 | 4.32 | 8.69 | 2.95 | 3.95 |     |     |
| 13 | 4.77 | 4.50 | 2.70 | 8.88 | 3.88 | 3.86 | 3.94 | 3.58 | 4.77 | 1.43 | 7.36 | 1.92 | 3.65 | 8.14 | 1.42 | 2.97 |     |     |
| 14 | 1.72 | 4.23 | 7.31 | 4.32 | 4.25 | 4.05 | 2.82 | 1.59 | 4.41 | 5.50 | 4.88 | 2.83 | 4.23 | 8.42 | 4.61 | 4.79 |     |     |
| 15 | 4.95 | 8.75 | 5.64 | 1.58 | 2.42 | 3.83 | 3.06 | 4.89 | 7.17 | 4.74 | 4.42 | 9.02 | 4.86 | 4.25 |     |     |
| 16 | 8.54 | 4.17 | 2.50 | 4.36 | 4.47 | 4.72 | 1.60 | 0.18 | 4.00 | 4.04 | 8.25 | 3.21 | 4.23 |     |     |
| 17 | 4.68 | 8.68 | 8.00 | 6.05 | 6.71 | 7.56 | 8.75 | 7.32 | 8.79 | 1.44 | 8.06 | 7.94 |     |     |
| 18 | 4.79 | 6.10 | 5.00 | 4.72 | 2.32 | 9.18 | 1.60 | 3.75 | 6.45 | 2.75 | 1.74 |     |     |
| 19 | 2.45 | 4.59 | 4.70 | 4.41 | 7.80 | 6.00 | 3.70 | 8.50 | 5.75 | 4.85 |     |     |
| 20 | 2.97 | 3.32 | 4.50 | 7.19 | 4.91 | 3.94 | 9.39 | 6.28 | 6.42 |     |     |
| 21 | 1.77 | 3.17 | 2.54 | 3.35 | 3.50 | 4.85 | 3.47 | 4.03 |     |     |
| 22 | 4.58 | 3.31 | 4.37 | 1.97 | 6.17 | 4.35 | 4.23 |     |     |
| 23 | 8.36 | 1.25 | 3.21 | 7.05 | 1.64 | 1.25 |     |     |
| 24 | 8.25 | 8.06 | 8.44 | 7.65 | 7.50 |     |     |
| 25 | 3.77 | 7.50 | 0.88 | 2.43 |     |     |
| 26 | 8.19 | 4.08 | 4.13 |     |     |
| 27 | 8.90 | 7.88 |     |     |
| 28 | 2.28 |     |     |     |     |

Table 5

Relative Inter-Task Distances, Form C of Technical Task Inventory
(Obtained from group of 65 subjects)
The Reliability of the Inter-Task Distance Estimates

There have been only a few reports of the reliability of the distance judgments in multidimensional scaling. Using successive intervals procedures with 20 colors as stimuli, Helm (1960) ran one subject through the experiment a second time after an interval of three weeks. The product-moment correlation coefficient between the two sets of judgments was .87. In addition, as a standard part of Helm's experimental procedure, after all the stimulus pairs had been reacted to once, the first 20 pairs were immediately readministered. Helm reported that marked changes in scale value assignments were rare. Also, he used a warm-up of 10 or so repeated estimates if part of the experiment was completed on a second day, with little change occurring in category placement of the colors.

The issue of whether the inter-stimulus distance as judged from stimulus A to stimulus B is the same as the distance as judged from B to A involves not only judgment reliability but also the question of whether the data fit the requirements of a Euclidean space model. Messick (1956a) and Schultz and Siegel (1962) found that this non-directional characteristic was present in their data, implying both judgment reliability and the presence of a model requirement.

As mentioned above, Form C of the Technical Task Inventory, used in the study described here, had nine items also appearing in Form S, which applied to the striker's job. It was possible, therefore, to compare the scale values for the distances among these nine items, first as derived from Form C and second as derived from Form S. In Form S both the A-to-B and B-to-A judgments were
made; the one which matched that included in Form C was used for the reliability determination.

The means and standard deviations of the 36 distance estimates among these nine stimuli are presented in Table 6. In general, the scale values are displaced upward (toward the "different" end of the scale) and are slightly less scattered when the distances are estimated for a second time. However, the correlation coefficient between the two sets of scale values is .94. It would appear therefore, that the ranking of the distance judgments remained the same but that the entire reference scale shifted as the men worked through more ratings. When these findings are tied in with the facts that (1) some of the men said they thought this had happened to them and (2) the A-to-B and B-to-A estimates derived from Form S (the second form administered) were almost identical, there is a strong suggestion that it takes the judges a while to settle the type of judgment here involved into a stable frame of reference. To eliminate any distortions introduced by this tendency, it would probably be wise, whenever possible, to give the judges a number of practice trials before they are asked to make ratings which are used in analyses. It will be recalled that two practice ratings were provided on the cover page of Form C of the Technical Task Inventory; apparently more than this number are required. Also, since four random page arrangements were employe a particular task pair appeared in different parts of the booklet for various subjec subgroups. Any pronounced effect resulting from an item's position should thus have been minimized when all the subjects were pooled for the analysis. The
results discussed above appeared in spite of this precaution. The varied page arrangement had also been used with Form S of the Technical Task Inventory, to reduce the position effect.

**Table 6**

Means and Standard Deviations of Inter-Task Distances Judged on Two Different Forms of the Technical Task Inventory at the Same Administration

<table>
<thead>
<tr>
<th>Form C (N = 36)</th>
<th>Form S (N = 36)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>5.51</td>
</tr>
<tr>
<td>S.D.</td>
<td>2.46</td>
</tr>
</tbody>
</table>

It should be mentioned that the determination of the proper additive constant to set the obtained scale values on a ratio scale will, to some extent, correct for the problem discussed here. However, if the reference scale is actually shifting from one rating to the next, this adjustment procedure cannot be expected to take care of the difficulty entirely.

**The Dimensionality Analysis**

Starting with the scaled inter-task distances shown in Table 5, the usual multidimensional scaling procedures were followed. First, the Messick-Abelson (1956) general solution to the additive constant problem was applied to the data in order to obtain a value which could be added to the original scaled distances in order to achieve a ratio, rather than merely an interval, scale as required by the
analytical model. This constant was found to be +3.10. The smallest judged distance in Table 5 is 0.67; accordingly the smallest corrected inter-task difference became +3.77.

The matrix of corrected scale values was converted to a matrix, $B^*$, of scalar products of the vectors to points with an origin at the centroid of the stimuli. The $B^*$ matrix is given in Appendix A of this report.

The $B^*$ matrix was factored by the method of principal components to produce the matrix, $F$, presented in Appendix B. The rank of matrix $F$ is nine. The matrix of residuals, after extraction of the nine dimensions from the matrix $B^*$ is given in Appendix C.

The nine axes of matrix $F$ were rotated to orthogonal, simple structure as tested by the normal equamax criterion, an analytical solution to the rotation problem developed by Saunders (1962). The transformation matrix is presented in Table 7 and the final matrix of projections of the stimuli (tasks) on the rotated axes is presented in Table 8.

**Interpretation of Dimensions**

**Dimension I.** The tasks with the highest projections (loadings) on the first dimension are shown in Table 9. The positive end of this dimension appears to involve the maintenance and troubleshooting of avionic equipments, while the negative end involves the routine use of reference materials and record keeping. Since the positive direction calls for problem solving as related to the diagnosis of malfunctions in electronic equipment and the maintenance of electronic equipment,
<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>-0.52</td>
<td>-0.41</td>
<td>-0.34</td>
<td>0.00</td>
<td>-0.13</td>
<td>0.46</td>
<td>0.46</td>
<td>0.05</td>
<td>0.08</td>
</tr>
<tr>
<td>II</td>
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<td>0.40</td>
<td>-0.52</td>
<td>-0.50</td>
<td>0.17</td>
<td>-0.07</td>
<td>0.06</td>
<td>-0.18</td>
</tr>
<tr>
<td>III</td>
<td>0.12</td>
<td>-0.03</td>
<td>0.03</td>
<td>0.61</td>
<td>-0.59</td>
<td>-0.30</td>
<td>0.24</td>
<td>0.34</td>
<td>-0.08</td>
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<td>-0.28</td>
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<td>V</td>
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<td>-0.06</td>
<td>-0.11</td>
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<td>-0.06</td>
<td>-0.40</td>
<td>0.54</td>
<td>-0.54</td>
</tr>
<tr>
<td>VI</td>
<td>0.06</td>
<td>0.35</td>
<td>-0.41</td>
<td>0.06</td>
<td>-0.51</td>
<td>0.40</td>
<td>-0.44</td>
<td>-0.29</td>
<td>0.00</td>
</tr>
<tr>
<td>VII</td>
<td>0.38</td>
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<td>-0.03</td>
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<td>0.24</td>
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<td>0.44</td>
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<td>IX</td>
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<td>-0.03</td>
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<td>-0.10</td>
<td>-0.43</td>
<td>-0.48</td>
<td>-0.31</td>
<td>0.29</td>
</tr>
</tbody>
</table>
Table 8

Final Matrix of Projections of Tasks on Dimensions

<table>
<thead>
<tr>
<th>Task No.</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
</tr>
</thead>
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<td>0.72</td>
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<td>0.61</td>
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<td>-0.93</td>
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<td>1.80</td>
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<td>2.99</td>
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<td>-0.60</td>
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<td>1.04</td>
<td>-0.35</td>
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<td>0.01</td>
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<td>-4.75</td>
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<td>-4.69</td>
<td>1.10</td>
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<td>3.37</td>
<td>1.87</td>
<td>2.73</td>
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<tr>
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<td>-0.00</td>
<td>-0.71</td>
<td>1.59</td>
<td>4.43</td>
<td>-0.28</td>
<td>0.97</td>
<td>0.48</td>
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<td>1.12</td>
<td>-0.74</td>
<td>1.92</td>
<td>-1.32</td>
<td>0.01</td>
<td>2.38</td>
<td>-3.64</td>
<td>-1.89</td>
</tr>
<tr>
<td>20</td>
<td>1.08</td>
<td>-1.33</td>
<td>0.63</td>
<td>-5.11</td>
<td>-0.48</td>
<td>0.63</td>
<td>-0.32</td>
<td>0.40</td>
</tr>
<tr>
<td>21</td>
<td>-0.34</td>
<td>0.37</td>
<td>-0.00</td>
<td>-0.01</td>
<td>-3.40</td>
<td>0.78</td>
<td>1.44</td>
<td>1.50</td>
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<td>-1.58</td>
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<td>0.03</td>
<td>-2.32</td>
<td>-0.03</td>
<td>1.32</td>
<td>0.21</td>
</tr>
<tr>
<td>23</td>
<td>2.81</td>
<td>1.97</td>
<td>-1.44</td>
<td>1.34</td>
<td>0.26</td>
<td>-0.81</td>
<td>1.52</td>
<td>0.99</td>
</tr>
<tr>
<td>24</td>
<td>-1.22</td>
<td>-4.58</td>
<td>0.24</td>
<td>0.99</td>
<td>-6.57</td>
<td>1.04</td>
<td>3.73</td>
<td>0.23</td>
</tr>
<tr>
<td>25</td>
<td>0.85</td>
<td>1.52</td>
<td>-0.36</td>
<td>1.08</td>
<td>1.72</td>
<td>-2.63</td>
<td>1.31</td>
<td>0.50</td>
</tr>
<tr>
<td>26</td>
<td>0.36</td>
<td>0.42</td>
<td>-0.93</td>
<td>0.12</td>
<td>0.79</td>
<td>0.53</td>
<td>-0.15</td>
<td>-0.92</td>
</tr>
<tr>
<td>27</td>
<td>-5.12</td>
<td>0.22</td>
<td>-4.71</td>
<td>3.14</td>
<td>-1.55</td>
<td>3.80</td>
<td>1.76</td>
<td>-0.71</td>
</tr>
<tr>
<td>28</td>
<td>1.63</td>
<td>0.96</td>
<td>0.51</td>
<td>2.35</td>
<td>0.43</td>
<td>-3.35</td>
<td>0.04</td>
<td>1.25</td>
</tr>
<tr>
<td>29</td>
<td>3.04</td>
<td>-0.73</td>
<td>0.40</td>
<td>3.98</td>
<td>1.49</td>
<td>-0.28</td>
<td>0.49</td>
<td>-0.04</td>
</tr>
</tbody>
</table>
Table 9

Tasks with Highest Projections on Dimension I

<table>
<thead>
<tr>
<th>Task No.</th>
<th>Loading</th>
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</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>+ 4.42</td>
<td>Performing inflight maintenance on avionic equipments</td>
</tr>
<tr>
<td>29</td>
<td>+ 3.04</td>
<td>Following block diagrams for avionic equipments</td>
</tr>
<tr>
<td>23</td>
<td>+ 2.81</td>
<td>Troubleshooting/isolating malfunctions in avionic equipments</td>
</tr>
<tr>
<td>13</td>
<td>+ 2.47</td>
<td>Employing electronic principles involved in the maintenance of avionic equipments</td>
</tr>
<tr>
<td>5</td>
<td>- 2.46</td>
<td>Using inspection and operation manuals</td>
</tr>
<tr>
<td>17</td>
<td>- 4.88</td>
<td>Making out reports (failure, etc.)</td>
</tr>
<tr>
<td>27</td>
<td>- 5.12</td>
<td>Keeping record of maintenance usage data</td>
</tr>
<tr>
<td>4</td>
<td>- 5.40</td>
<td>Using ASO catalog and Section R allowance list for replacement parts</td>
</tr>
</tbody>
</table>
the name assigned to this dimension is "electro-cognition."

**Dimension II.** The two tasks with the highest positive loadings on this dimension, as seen in Table 10, relate to aspects of equipment repair in the shop. Since shop work represents the central and most complex repair process, this dimension is designated "electro-repair (complex)" to differentiate it from the "electro-repair (simple)" dimension extracted in the journeyman level study.

**Dimension III.** Three of the four tasks with positive loadings in Table 11 involve instructional activities. There is little doubt that the third dimension is "instruction."

**Dimension IV.** Table 12 presents the tasks with the highest loadings on the fourth dimension. Although the positive direction on the dimension involves some kind of ability in understanding diagrams and circuitry, the precise nature of that portion of the axis is not very clear. The negative direction obviously is a safety factor. This dimension is called "electro-safety."

**Dimension V.** The tasks with negative loadings listed in Table 13 provide the basis for naming this dimension. These four tasks are all essentially the management of personnel involved in serving in a maintenance capacity. Therefore, the name "personnel relationships" was chosen for the fifth dimension.

**Dimension VI.** The group of tasks associated with negatively oriented loadings presented in Table 14 suggest that dimension VI relates to the understanding of the principles of electronic circuitry. The tasks with the high positive loadings are generally more simple, routine duties. This dimension is assumed
Table 10

Tasks with Highest Projections on Dimension II

<table>
<thead>
<tr>
<th>Task No.</th>
<th>Loading</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+4.01</td>
<td>Repairing malfunctioning parts/equipment in shop</td>
</tr>
<tr>
<td>13</td>
<td>+2.38</td>
<td>Employing electronic principles involved in the maintenance of avionic equipments</td>
</tr>
<tr>
<td>17</td>
<td>-2.07</td>
<td>Making out reports (failure, etc.)</td>
</tr>
<tr>
<td>24</td>
<td>-4.58</td>
<td>Assigning duties to personnel</td>
</tr>
<tr>
<td>6</td>
<td>-7.30</td>
<td>Standing watch</td>
</tr>
</tbody>
</table>
Table 11

Tasks with Highest Projections on Dimension III

<table>
<thead>
<tr>
<th>Task No.</th>
<th>Loading</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>+ 4.93</td>
<td>Instructing others in the operation of avionic equipments</td>
</tr>
<tr>
<td>7</td>
<td>+ 3.41</td>
<td>Supervising operation of avionic equipments</td>
</tr>
<tr>
<td>14</td>
<td>+ 2.99</td>
<td>Instructing others in the inspection of avionic equipments</td>
</tr>
<tr>
<td>11</td>
<td>+ 2.27</td>
<td>Instructing others in the maintenance of avionic equipments</td>
</tr>
<tr>
<td>4</td>
<td>- 2.34</td>
<td>Using ASO catalog and Section R allowance list for replacement parts</td>
</tr>
<tr>
<td>6</td>
<td>- 2.99</td>
<td>Standing watch</td>
</tr>
<tr>
<td>17</td>
<td>- 4.69</td>
<td>Making out reports (failure, etc.)</td>
</tr>
<tr>
<td>27</td>
<td>- 4.71</td>
<td>Keeping record of maintenance usage data</td>
</tr>
</tbody>
</table>
Table 12

Tasks with Highest Projections on Dimension IV

<table>
<thead>
<tr>
<th>Task No.</th>
<th>Loading</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>+3.98</td>
<td>Following block diagrams for avionic equipments</td>
</tr>
<tr>
<td>27</td>
<td>+3.14</td>
<td>Keeping record of maintenance usage data</td>
</tr>
<tr>
<td>28</td>
<td>+2.35</td>
<td>Analyzing standard circuitry in avionic equipments</td>
</tr>
<tr>
<td>6</td>
<td>-4.71</td>
<td>Standing watch</td>
</tr>
<tr>
<td>20</td>
<td>-5.11</td>
<td>Using proper safety precautions for self</td>
</tr>
<tr>
<td>9</td>
<td>-5.50</td>
<td>Using safety precautions on equipment</td>
</tr>
<tr>
<td>Task No.</td>
<td>Loading</td>
<td>Task</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>18</td>
<td>+4.43</td>
<td>Using maintenance manuals</td>
</tr>
<tr>
<td>4</td>
<td>+2.98</td>
<td>Using ASO catalog and Section R allowance list for replacement parts</td>
</tr>
<tr>
<td>5</td>
<td>+2.68</td>
<td>Using inspection and operation manuals</td>
</tr>
<tr>
<td>17</td>
<td>+2.36</td>
<td>Making out reports (failure, etc.)</td>
</tr>
<tr>
<td>7</td>
<td>-2.00</td>
<td>Supervising operation of avionic equipments</td>
</tr>
<tr>
<td>22</td>
<td>-2.32</td>
<td>Supervising inspection of avionic equipments</td>
</tr>
<tr>
<td>21</td>
<td>-3.40</td>
<td>Supervising maintenance of avionic equipments</td>
</tr>
<tr>
<td>24</td>
<td>-6.57</td>
<td>Assigning duties to personnel</td>
</tr>
</tbody>
</table>
### Table 14

**Tasks with Highest Projections on Dimension VI**

<table>
<thead>
<tr>
<th>Task No.</th>
<th>Loading</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>+3.80</td>
<td>Keeping record of maintenance usage data</td>
</tr>
<tr>
<td>17</td>
<td>+3.37</td>
<td>Making out reports (failure, etc.)</td>
</tr>
<tr>
<td>6</td>
<td>+3.00</td>
<td>Standing watch</td>
</tr>
<tr>
<td>19</td>
<td>+2.38</td>
<td>Operating avionic equipments</td>
</tr>
<tr>
<td>4</td>
<td>+2.29</td>
<td>Using ASO catalog and Section R allowance list for replacement parts</td>
</tr>
<tr>
<td>25</td>
<td>-2.63</td>
<td>Using schematics for standard circuits in avionic equipments</td>
</tr>
<tr>
<td>28</td>
<td>-3.35</td>
<td>Analyzing standard circuitry in avionic equipments</td>
</tr>
<tr>
<td>3</td>
<td>-4.38</td>
<td>Using schematics for complex circuits in avionic equipments</td>
</tr>
<tr>
<td>2</td>
<td>-4.58</td>
<td>Analyzing complex circuitry in avionic equipments</td>
</tr>
</tbody>
</table>
to be the "electro-comprehension" dimension found in the study of striker and third class AT's. An alternate name in both studies could be "electronic circuit analysis."

**Dimension VII.** Table 15 contains the six tasks with the highest loadings on the seventh dimension extracted. The thread running through the three tasks with negative values is clearly operating various equipment and the highest loading is associated with the operation of more complex equipment. Therefore, this dimension is labeled "equipment operation (complex)."

**Dimension VIII.** Although this dimension does not appear to be as clear as the others, in terms of the task loadings presented in Table 16, the negative orientation of the axis seems to involve the use of supporting reference materials. This dimension is, therefore, tentatively named "using reference materials."

**Dimension IX.** As can be seen from the tasks listed in Table 17, the negative direction of this dimension relates to various aspects of inspecting avionic equipment. The emphasis here seems to be on the more important inspection activities, rather than on the simpler, more routine inspections. As a result, the name selected for this dimension is "equipment inspection (complex)."

**Comparison of Two Job Levels within the Aviation Electronics Technician Rating**

Since the previous study by Schultz and Siegel (1962) extracted the factors of the aviation electronic technician job at the level of strikers and petty officers, third class, a comparison can now be made between the journeyman level and the
### Table 15

Tasks with Highest Projections on Dimension VII

<table>
<thead>
<tr>
<th>Task No.</th>
<th>Loading</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>+4.27</td>
<td>Using ASO catalog and Section R allowance list for replacement parts</td>
</tr>
<tr>
<td>24</td>
<td>+3.73</td>
<td>Assigning duties to personnel</td>
</tr>
<tr>
<td>6</td>
<td>+2.43</td>
<td>Standing watch</td>
</tr>
<tr>
<td>19</td>
<td>-3.64</td>
<td>Operating avionic equipments</td>
</tr>
<tr>
<td>12</td>
<td>-3.77</td>
<td>Operating standard test equipment for determining malfunctions in avionic equipments</td>
</tr>
<tr>
<td>16</td>
<td>-4.75</td>
<td>Operating specialized test equipment for determining malfunctions in avionic equipments</td>
</tr>
</tbody>
</table>
### Table 16

Tasks with Highest Projections on Dimension VIII

<table>
<thead>
<tr>
<th>Task No.</th>
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<tr>
<td>11</td>
<td>+3.56</td>
<td>Instructing others in the maintenance of avionic equipments</td>
</tr>
<tr>
<td>17</td>
<td>+2.73</td>
<td>Making out reports (failure, etc.)</td>
</tr>
<tr>
<td>4</td>
<td>-2.02</td>
<td>Using ASO catalog and Section R allowance list for replacement parts</td>
</tr>
<tr>
<td>8</td>
<td>-3.22</td>
<td>Knowing relationship of avionic equipments to other related equipment</td>
</tr>
<tr>
<td>5</td>
<td>-3.36</td>
<td>Using inspection and operation manuals</td>
</tr>
</tbody>
</table>

- 35 -
### Table 17

Tasks with Highest Projections on Dimension IX

<table>
<thead>
<tr>
<th>Task No.</th>
<th>Loading</th>
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</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>+ 3.48</td>
<td>Using ASO catalog and Section R allowance list for replacement parts</td>
</tr>
<tr>
<td>22</td>
<td>- 2.93</td>
<td>Supervising inspection of avionic equipments</td>
</tr>
<tr>
<td>14</td>
<td>- 3.43</td>
<td>Instructing others in the inspection of avionic equipments</td>
</tr>
<tr>
<td>26</td>
<td>- 4.46</td>
<td>Performing major inspections of avionic equipments</td>
</tr>
</tbody>
</table>
supervisory level AT job in terms of the underlying dimensions seen by the supervisors as constituting each job.

Nine meaningful dimensions resulted from the examination of the chief petty officer's job, while only four were found in the study of strikers. Thus, it can be concluded that the supervisory personnel's job is based on a more heterogeneous substrate than is that of the striker. This is not merely a matter of performing more tasks within the same dimensional framework but of serving more functions of a basically different kind. The additional performance dimensions of the chief petty officer's job are electro-cognition (maintenance-troubleshooting), instruction, personnel relationships, and using reference materials.

The four job dimensions at the journeyman level are also present at the higher level. Electro-comprehension and electro-safety appear to be essentially similar in character in each case. But as one moves from the lower to the higher level job, routine equipment operation and inspection breaks into two independent dimensions, each involving more complex requirements. For example, the inspection portion of the strikers' dimension is characterized by the performance of preflight and postflight inspections of avionic equipment, while the chief petty officers' dimension is characterized by the performance of major inspections. In addition, the electro-repair dimension differs in complexity at the two job levels. For the striker it consists primarily of removing malfunctioning parts and equipment from planes and replacing them after repair; for the chief petty officer, on the other hand, this dimension refers to repair work on malfunctioning
parts and equipment in the shop, involving knowledge of appropriate electronic principles.

Thus, in general, the job of chief petty officer and petty officer, first class, in the aviation electronics technician rating is seen by the supervisors, on the basis of this research, to encompass all the activities that are performed by strikers and petty officers, third class, in the rating but at a more complex level and, in addition, to include several functions which are not performed by strikers.

Discussion

The dimensional organization of the AT rating defined by the results of the present research seems reasonable, both in its own right and in comparison with the results of the journeyman level study. The nine dimensions describe obviously important parts of the AT supervisory job. Men at the chief petty officer level should know the basic technical skills such as operation, inspection, and repair, yet have a deeper understanding of the basic principles and possess a higher skill level than would be expected of a less experienced technician. In addition, it is apparent that a supervisor is called upon to instruct and serve other functions involving personnel relationships.

The characteristics of the dimensions extracted appear to lend themselves to the construction of unidimensionally scaled instruments for measuring each dimension separately. Since several of the dimensions represent higher levels of factors also present in the striker and petty officer, third class, AT job, it may be possible to develop single scales in these cases to cover the whole range of
activities encompassing the two job levels. In electro-safety, there are probably minor differences between the two job levels, so the same unidimensional scale would be applicable. A methodology for constructing job task performance instruments which meet the Thurstone and/or Guttman scalability requirements is available from previous research (Schultz and Siegel, 1961; Siegel and Schultz, 1962).

It might be argued that, for purposes of evaluating the job performance of individual chief petty officers, the perceptions of their superiors, i.e., commissioned officers or warrant officers, should be analyzed as the basis for selecting the dimensions along which the evaluations should be made. However, good personnel practice would suggest acceptance of the job criterion by both the worker—in this case, the chief petty officer—and his superior—the commissioned officer or the warrant officer. Acceptance will very likely be enhanced if both parties perceive the job as involving the same dimensions. Thus, the current study may be viewed, in part, as one step in the development of evaluative instruments for non-commissioned AT supervisors.

Two important points regarding multidimensional scaling procedures should be kept in mind in evaluating findings resulting from their application. First, the outcomes, i.e., the dimensions, are initially determined by the form and adequacy of the input data. In the present investigation the goal was to provide the judges with a group of tasks that would include all the important work activities of aviation electronics technicians at the chief petty officer and petty officer, first class, lev
As a result, the dimensions are defined in terms of work activities, rather than other possible types of input information, such as equipment used, equipment worked on, or worker-requirements.

Second, the clarity and validity of the resultant dimensional structure in some instances may depend upon the appropriateness of certain decisions about technical matters which are made as the analysis is proceeding. The choice of method used to scale the stimulus pair judgments and the issue of the advisability of a transformation of the scaled inter-stimulus distances (Helm, Messick, and Tucker, 1961) are two examples of such matters which have been previously mentioned.

In both the earlier study of the striker's job and in the current study, several dimensional spaces appeared to fit the data reasonably well from the psychometric viewpoint. In the report of the first study (Schultz and Siegel, 1962) it was mentioned that application of the Messick-Abelson solution for the additive constant led initially to eight, instead of the eventually chosen four dimensions. In the present work, in addition to the analysis described here, a four dimensional solution was arbitrarily imposed on the data. The resultant dimensionality appeared to possess psychometric consistency and reasonableness. In both studies the ultimate criterion used in selecting a final solution was the overall meaningfulness, precision, and clarity of the dimensions extracted, as manifested in the tasks with the highest loadings on the dimensions. In each study, however, a solution involving a different number of dimensions could have been justified on the basis of the empirical data and would have produced defensible conclusions.
CHAPTER IV

SUMMARY AND CONCLUSIONS

Summary

The study described in this report represents a second application of multidimensional scaling methods in the area of job performance criterion development. The results of the first application of the methods to job related stimuli (Schultz and Siegel, 1962) suggested that the job performance of Naval aviation electronics technicians at the striker and petty officer, third class, level comprised four basic dimensions. Since a contention that multidimensional scaling can be useful for analyzing a job task constellation was supported, it seemed desirable to carry out a further study, this time applying the techniques, for comparative purposes, at a different job level.

The objectives of this study, therefore, paralleled those of the earlier program. They were to: (1) explore further the feasibility of applying standard multidimensional scaling procedures to a job task constellation, (2) investigate more fully specific methods for applying these techniques in the work oriented situation, (3) determine the number and the nature of the dimensions of the job of the Naval aviation electronics technician (AT) supervisor, and (4) compare the dimensional structure of the aviation electronics technician's job at the supervisory level with that of the same rating at the journeyman level.

The procedures followed in the present work were very similar to those of
the previous investigation. The same subjects were involved and there was com-
munality among the forms used. Initially a list of tasks which were thought to
include all the job activities typically performed by Naval aviation electronics
technicians was submitted to a group of men experienced in the rating. It was the
consensus of this group that 29 of the listed tasks constituted the job of chief petty
officer and petty officer, first class. Of the 29 tasks, 9 were also included in the
group comprising the striker’s job, as revealed in the previous study. A number
of the simpler tasks were designated as being done only by strikers and the
generally more complex tasks only by chief petty officers.

A booklet was prepared, so that all possible pairs of the 29 tasks could be
rated along an eleven-point similarity scale. The analysis, by the method of
equal appearing intervals, of the data resulting from administration of this bookle
to a group of chief and first class petty officers in the AT rating produced scale
values for the task pairs.

Taking the scale value for each task pair as the psychological distance
between that pair, multidimensional procedures that have been frequently used
were followed. The Messick-Abelson solution to the additive constant problem wa
first applied, in order to obtain a value which could be added to the scaled distance
so that they could refer to a true zero point. A matrix of scalar products was thei
computed from the corrected scale values and factored by the method of principal
components. The factor matrix was rotated to orthogonal simple structure accor
ing to the equamax criterion.
A spatial structure of nine dimensions was determined as underlying the distance system defined by the inter-task data. The nine dimensions were named "electro-cognition," "electro-repair (complex)," "instruction," "electro-safety," "personnel relationships," "electro-comprehension," "equipment operation (complex)," "using reference materials," and "equipment inspection (complex)."

It was pointed out that all four dimensions found in the earlier analysis of the AT striker's job were represented among these nine dimensions. Two of the common dimensions were essentially similar at the two job levels, while the other two were characterized by more complex activities at the supervisory level. In addition, the chief petty officer's job includes several functions not performed by strikers.

In view of several technical problems that are involved, the results of both the current study and the earlier study should be looked upon as subject to further verification, refinement, and clarification. Nevertheless, the general picture of the two job levels in the AT rating that they define appears to be reasonable and useful. In particular, the characteristics of the extracted dimensions would appear to make it possible to develop unidimensional, scaled criterion instruments for the separate dimensions. Such measures could be applied in the evaluation of the job performance of individuals in each of the independent kinds of job performance behavior.

Conclusions

Further evidence is provided by the results of the research described in this report that it is feasible and fruitful to apply multidimensional scaling
techniques to Naval job performance. The methods developed generate the appropriate basic data required by the multidimensional models.

The following conclusions are indicated with regard to the specific job studied:

1. The work performed by chief petty officer and petty officer, first class, aviation electronics technicians is perceived by men at that level in the rating as involving nine basic dimensions. The dimensions are tentatively named "electro-cognition," "electro-repair (complex)," "instruction," "electro-safety," "personnel relationships," "electro-comprehension," "equipment operation (complex)," "using reference materials," and "equipment inspection (complex)."

2. The characteristics of the nine extracted dimensions would appear to make it possible to develop unidimensional scales for the evaluation of individual technicians on each dimension.

3. The job of chief petty officer and petty officer, first class, in the aviation electronics technician rating encompasses all four of the basic dimensions that are represented in the striker and petty officer, third class, job. However, the supervisory personnel perform at a generally more complex level and, in addition serve several functions which are not engaged in by the journeyman level personnel.
REFERENCES


Messick, S. J. Some recent theoretical developments in multidimensional scaling Educ. psychol. Measmt., 1956, 16, 82-100. (b)


APPENDIX A

Appendix A presents the matrix $B^*$
Appendix A

Matrix $\mathbf{B}^*$ of Scalar Products with Origin at Centroid of Stimuli

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
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<td>-5.6857</td>
<td>-1.0201</td>
<td>28.2792</td>
<td>10.7208</td>
<td>5.0185</td>
<td>24.5864</td>
<td>7.8431</td>
</tr>
<tr>
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<td>5.2964</td>
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APPENDIX B

Appendix B presents the matrix $F$
Appendix B

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### Appendix C

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