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NEW TECHNIQUES IN TASK ANALYSIS

Joe Silverman

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NEW TECHNIQUES IN TASK ANALYSIS

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SUMMARY AND CONCLUSIONS

Problem

This research is directed toward the investigation of recent developments in techniques of task analysis. Because of methodological problems associated with the development of training curricula, the analysis of man-machine systems, and occupational analysis, it has been proposed that a task taxonomy be developed. Such a taxonomy would indicate the inherent similarities between tasks, independent of their environment, and pave the way for improvements in training, billet structure developments, and improved manpower utilization.

Background and Requirements

There have been numerous attempts at developing task taxonomies--both quantitative and qualitative. At present, the results of these efforts have not been comprehensive enough, nor suitable for use throughout the Navy. Because of recent developments in other sciences, a small effort was devoted to investigation of the possible application of these new techniques to personnel systems problems in the Navy.

Approach

Problems of task classification can be approached more systematically through methods of numerical taxonomy than through traditional techniques. Numerical taxonomy places the procedures of task comparison and classification on an operational and quantitative basis. This makes it possible for the Navy to objectively and precisely evaluate its billet and rating structure.

Findings, Conclusions, Recommendations

Since this research was initiated a short time ago, with a modest budget, the primary effort has been devoted to an investigation of the state-of-the-art. As a result of this initial inquiry, it is concluded that the application of techniques of numerical taxonomy to problems of task analysis is warranted because of its usefulness in helping to solve problems relating to the Navy's personnel systems.

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NEW TECHNIQUES IN TASK ANALYSIS

INTRODUCTION

In the course of research concerned with personnel and occupational systems, it has become increasingly clear that the foundation for future occupational analyses depends, in large part, upon developments in techniques of task analysis. The purpose of this report is to briefly examine the present state-of-the-art in task analysis and indicate some of the techniques which appear to be promising in terms of practical payoff to the Navy.

Methods of task analysis are usually tailored to the specific purpose of a research effort and, as a result, such methods of analysis cannot easily be generalized to other problems. Furthermore, although the research literature on task analysis is abundant, most of it does not focus on problems of occupational and personnel systems. Instead, research in this area has been primarily concerned with job design and job analysis, training psychology, man-machine systems, occupational reengineering, small group research, work measurement, and problems of industrial engineering. The basic analytical framework of much of the task analysis has focused on the study of elements or technical operations in a task.

TASK TAXONOMY

In recent years, human factors analysts and training psychologists have called for a taxonomy of tasks to provide a breakthrough in the state-of-the-art. The reasoning behind this is as follows. Currently, techniques of task analysis require that every task performed in a system or job be treated as a unique entity or aspect of the work. For example, two tasks that are identical in terms of the kind of work performed may still differ in the kind of equipment involved, environmental factors affecting the task, type of ship, operational conditions, and a multitude of other factors. Thus, the "alignment of a transceiver" can differ considerably from one type or model of transceiver to another, from one ship type to another, from underway conditions to in-port conditions, from one electronics technician to another, etc. As a result, task analysis of even one job or man-machine system can involve the study of an enormous number of tasks and their elements. In training personnel to operate and maintain modern weapons and support systems, the development of a curriculum based on such complex and extended task analyses becomes unusually difficult.

As a result, it has been proposed that research be performed to systematically classify tasks in terms of critical generalizable variables, characteristics, and attributes inherent in the task--independent of the setting or environment of the task. By classifying the behaviors required in performing a task, and training personnel in the basic abilities implied by those behaviors (rather than the specific technical elements in a task), it is contended that curricula may be made more realistic in terms of task demands. Also, a task analysis based on selected categories or dimensions of task behavior provides a breakthrough by eliminating the necessity for repeatedly developing and analyzing long, detailed task lists or inventories. A set of such categories of task behavior has been called a taxonomy.

A taxonomy involves the systematic differentiation, ordering, relating, and naming of type groups within a subject field. In these terms, the classification of naval ships is a kind of taxonomy wherein ships are grouped by class, type, and overall purpose (e.g., 2200 class; DD type, combatant purposes). Similarly, tasks may be ordered into groups on the basis of their relationships and distinctive names or nomenclature applied to those groups.

The taxonomic process involves the following steps:

1. Collecting samples of phenomena.
2. Describing essential features or elements.
3. Comparing phenomena for similarities and differences.
4. Developing a set of principles governing the choice and relative importance of elements.
5. Grouping phenomena on the basis of essential elements into more and more exclusive categories and naming the categories.
6. Developing keys and devices as a means of recognizing and identifying phenomena.

There have been many attempts at developing taxonomies based on the common behavioral elements in tasks. Few of these have been the result of the systematic taxonomic process described above. Some efforts have been empirical--relying on correlations of task behaviors or learning demands, and then factor analyzed to determine the behavioral categories or dimensions underlying the subject tasks. Others have employed an "arm-chair" approach based on their accumulated research experience. Perhaps, this is why there have been such a variety of taxonomies developed to date.

The Appendix contains a number of examples of task taxonomies, developed for different purposes and employing different techniques. Generally, these task classifications do not yet hold great promise for

current operational use in task analysis. Many of them cannot be replicated by independent investigators, or cannot be validated, or have serious problems regarding reliability. In short, they are either in a rudimentary stage of development or intuitive in nature--and cannot be evaluated scientifically. Nevertheless, there are techniques of task analysis that do appear promising. These techniques derive from the simultaneous publication in 1957 of several papers by biological taxonomists. In common, these articles advocated the use of a more scientific approach to the problem of classifying biological organisms. It is not surprising that the advent of the computer had an important role to play in the development of these techniques.

NUMERICAL TAXONOMY

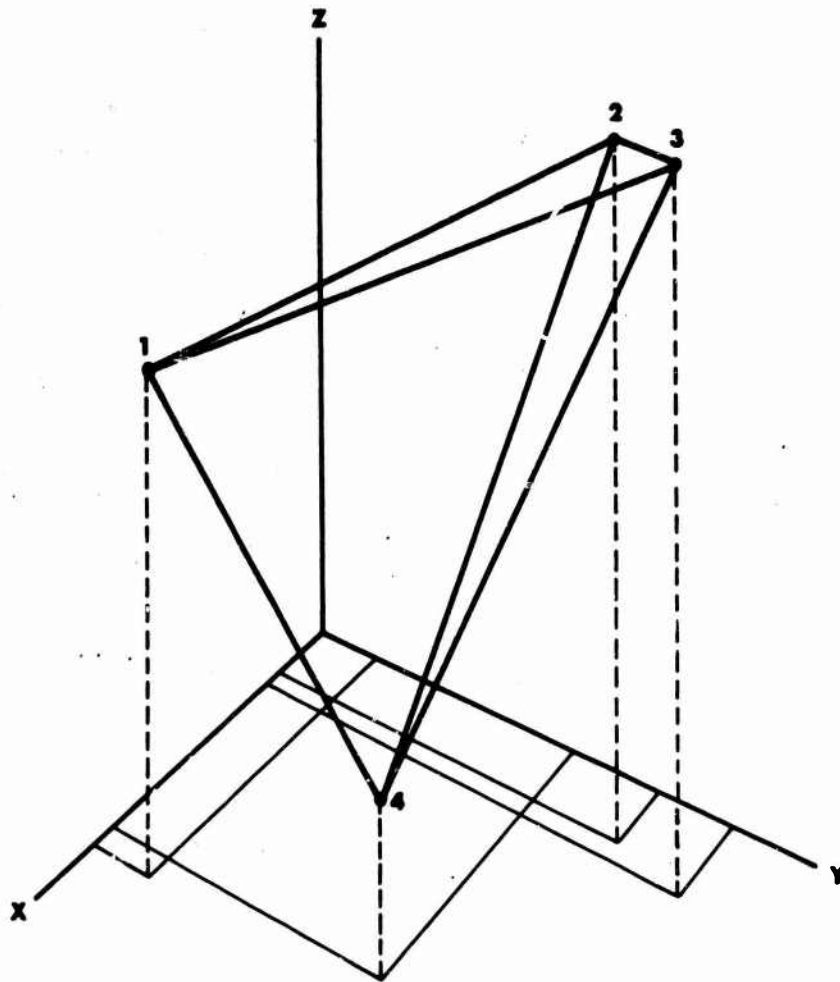
Problems of task classification, like those of biological classification, can be approached more systematically through methods of numerical taxonomy than through traditional techniques based on the judgment of different investigators. Numerical taxonomy places the procedures of task comparison and classification on an operational and quantitative basis.

In developing an occupational classification, for instance, it is necessary to compare a sample of jobs in terms of a large number of tasks performed in those jobs. With the use of a computer, it is possible to make these comparisons on the basis of a numerical yardstick which measures the precise similarity of one job to another, as indicated by the similarity of the tasks performed in each. Jobs can then be grouped into a hierarchical arrangement of occupational categories by reference to their numerical similarity and distance from one another. Conceptually, the procedures involved are relatively simple.*

First, all the tasks and billets to be classified are arranged in a data matrix, and the similarities between all possible pairs of billets are then computed based on all the tasks. One way of representing similarity is the distance between billets in a multidimensional space, as shown in Figure 1.

*This discussion of the procedures involved in a numerical taxonomy of tasks has been adapted from Sokal, R. R., "Numerical Taxonomy," Scientific American, Vol. 215, No. 6, December 1966, pp. 106-116.

Figure 1. Distance Between Billets Based on Task Similarity



In the example above, the similarity between all possible pairs taken from four billets (points 1, 2, 3, and 4) is estimated on the basis of three tasks, which are represented by the three coordinates (axes X, Y, and Z). The four billets are then plotted into this three-dimensional space according to their state, or value, for the three characters. Similar billets are plotted much closer to one another than dissimilar ones. In any real case there will, of course, be more than three tasks, and a multidimensional space--called a "hyperspace"--would be necessary.

After the similarities between pairs of billets are evaluated by the computer, they are printed out in a "similarity matrix," which shows the mutual similarity values of every billet. Each billet can then be grouped on the basis of its similarity to some billets and its dissimilarity with others. For more precise classifications, a variety of numerical clustering procedures have been developed, and these procedures are routinely carried out on the computer after the similarity matrix has been calculated.

The results of numerical classification can be represented by means of a "phenogram." These tree-like diagrams indicate the similarity between billets or occupational groupings containing more than one billet. Figure 2 shows a two-dimensional representation of the results of a numerical classification. Although this diagram distorts the original multidimensional relationships produced by the similarity matrix, as shown in Figure 1, it does reflect the similarity level at which different billets are grouped. Moreover, it shows the classification of billets into occupational groupings or ratings, and at what levels this grouping takes place.

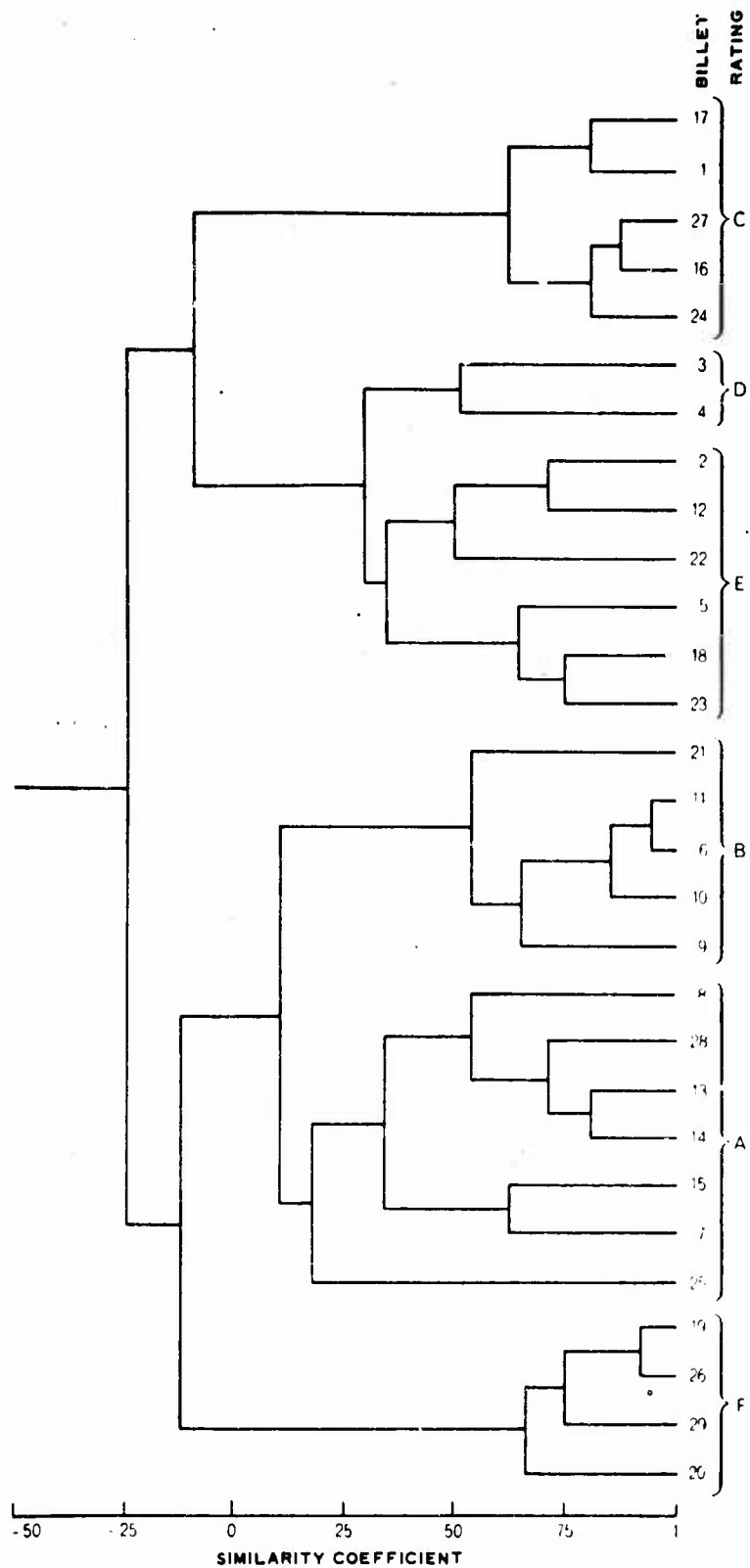
NAVAL APPLICATIONS OF NUMERICAL TAXONOMY

The application of such techniques of task analysis as numerical taxonomy to problems of Navy personnel systems has great potential in a number of areas. At the present time, the Navy's rating structure is based on qualitative differences. As a result, there is no way in which billets can be compared and contrasted numerically. Also, there is at present no system to evaluate a rating for its internal similarity. Because of this, the Navy cannot objectively and precisely evaluate its rating and billet structure. Any occupational classification structure undergoes changes over time due to the impact of technological development and the requirement for new and different occupations. Numerical taxonomy provides a set of techniques which makes it possible to systematically adjust the Navy's occupational structure to reflect changes in the fleet.

By bringing the rating and billet structure into closer adjustment with the work performed in the fleet, the potential for improved manpower utilization is increased considerably. In measuring the similarities and differences between billets, information is provided about the areas and extent of commonality existing among those billets. This information can be used in a number of ways.

First, training efforts can be consolidated to reflect areas of common core among different billets and different ratings. For example,

Figure 2. Phenogram of a Hypothetical Billet Structure



there is considerable similarity in the tasks performed by the Machinist's Mate and the Engineman. Yet there are schools and training manuals for training personnel in each of these ratings--and there is substantial overlap in the subjects covered between the two ratings.

Second, the data produced by a numerical task analysis of current ratings and occupational classifications, provide a specific, precise, and quantitatively valid basis for evaluating and justifying the Navy's skill requirements. In the face of competing demands for the nation's manpower resources, and the Defense Department's continuing demand that the services objectively demonstrate their respective personnel requirements, the use of techniques which can numerically support and validate skill requirements becomes imperative.

Third, the precise measurement of billet relationships would enable the Navy to man new ship types without increasing total manpower. This is made possible through improved manpower utilization in the current structure of skills employed in the fleet.

In the past two or three years, applications of numerical taxonomy to problems of classification have expanded beyond the traditional concerns of biology to many other areas of interest. It has been used to classify soils and diseases, legislative voting records and oil-bearing strata, archeological artifacts and languages, socioeconomic neighborhoods and psychological types, and even television programs. It seems clear that the potential of this technique of task analysis warrants its adaptation for use in the Navy.

As a result, this Activity plans to pursue a relatively small effort in the further investigation of the applicability of numerical taxonomy in the Navy during fiscal year 1968. Because of the size of this effort, the preparation of a report on the progress of this research is not planned until the end of fiscal year 1968.

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APPENDIX

EXAMPLES OF TASK TAXONOMIES

Structure of Worker Functions*

<u>Things</u>	<u>Data</u>	<u>People</u>
Observing	Observing	Observing
Learning	Learning	Learning
Handling	Comparing	Taking Instructions- Helping
Feeding-Offbearing	Copying	Serving
Tending	Computing	Speaking-Signalling
Manipulating	Compiling	Persuading, Diverting
Operating-Controlling	Analyzing	Supervising, Instruct- ing
Driving-Controlling	Coordinating	Negotiating
Precision Working	Synthesizing	Mentoring
Setting Up		

*Department of Labor, Bureau of Employment Security, Work Performed Manual, Sept. 1959.

Task Taxonomy: Inventive Approach*

Scanning function for exposing an individual's perceptive apparatus to task-inciting cues in the environment, or as generated by himself.

Identification of relevant cues function.

Interpretation of cues according to "meaning" or implication apart from the physical nature of the cue itself.

Short-term memory for holding together, during a task cycle, the fragments of information that will be acted upon as a unit of information.

Long-term memory--symbolic or automatic or a combination of both--that associate stimulus with response.

Decision-making--divergent and convergent, computational or statistical, and so on. Response selection or formulation in the absence of a sufficiently dominant association between the cue pattern, the response pattern, and the pattern of purpose.

Effect or response--outputs that do work on the environment, including symbolic work.

*Miller, R. B., SDD Development Laboratory, IBM Corp., Task Taxonomy: Inventive Approach, Draft of paper for American Psychological Association Convention, Sept. 1965, Session entitled: Task Taxonomy and Its Implications for Military Requirements.

Basic Types of Human Functions in Systems*

Sensing

Identifying

Interpreting

Compound Functions

Coding

Scanning and Detection

Monitoring

Tracking

Troubleshooting

*Gagne, R. M., "Human Functions in Systems," pp. 35-73, in Gagne, R. M., (Ed.), Psychological Principles in System Development, Holt, Rinehart, and Winston, New York, 1962.

Learning Task Characteristics*

Element Characteristics (S and R)

Number and sequence

Limits

Meaning

Relational Characteristics

Pattern of linkages

Input-Output qualitative relationship

*Stolurrow, L. M., The Classification of Learning Tasks: A Systems Approach, Memo Report 12. Univ. of Illinois: Training Research Laboratory, 1960.

Behavior Taxonomy of Tasks: Correlational-Experimental Approach*

Psychomotor Factors

Control Precision
Multilimb Coordination
Response Orientation
Reaction Time
Speed of Arm Movement
Rate Control
Manual Dexterity
Arm-Hand Steadiness
Wrist-Finger Speed
Aiming

Physical Proficiency Factors

Extent Flexibility
Dynamic Flexibility
Static Strength
Dynamic Strength
Explosive Strength
Trunk Strength
Gross Body Coordination
Gross Body Equilibrium
Stamina

*Fleishman, E. A., American Institutes for Research, Development of a Behavior Taxonomy for Describing Human Tasks: A Correlational-Experimental Approach, Paper at APA Convention, Sept. 1965.

Task Classification for Information on Human Learning*

- | | |
|--------------------------------|-------------------------------|
| 1. Classical conditioning | 7. Successive discrimination |
| S-R association | Relative discrimination |
| Simple association | Choice discrimination |
| 2. Paired associates | Paired comparison |
| S-R association | 8. Tracking |
| Simple association | Continuous adjustment |
| 3. Serial learning | 9. Skilled act |
| Procedural task | (single criterion response) |
| Procedures | 10. Simple skill |
| 4. Absolute discrimination | (multiple criterion response) |
| Absolute judgment | 11. Concept formation |
| Stimulus rating | 12. Problem solving |
| 5. Ranking | Decision making |
| 6. Simultaneous discrimination | Troubleshooting |
| Relative discrimination | Medical diagnosis |
| Choice discrimination | Thinking |
| Paired comparison | |

*Cotterman, T. E., Task Classification: An Approach to Partially Ordering Information on Human Learning, WADC Tech Note 58-374, January 1959.

Basic Activities of Tasks or Task Attributes*

Procedure Following: performing a sequence of discrete steps, each of which has an identifiable beginning point and ending point.

Continuous Perceptual Motor Activity: observing displays and operating controls continuously in order to maintain a specified relationship between an object under the operator's control and other objects, not under the operator's control.

Monitoring: observing a display, or displays, or a portion of the environment, either continuously or by means of scanning, in order to detect a specified kind of change.

Communicating: receiving information and/or sending information in words or other sets of symbols.

Decision Making or Problem Solving: piecing together facts, opinions, and other information and arriving at a conclusion about what action to take.

Non-task-related Activity: activities which occupy the worker's attention but do not contribute directly to the accomplishment of the task.

*Folley, J. D., Jr., Development of an Improved Method of Task Analysis and Beginnings of a Theory of Training, Tech. Rept: NAVTRADEVCEEN 1218-1, June 1964.

Taxonomy of Task Demands*

Demonstrable: no demand for learning, but simply the trainee's demonstration of task performance.

Iterative: execution of demonstrable steps in appropriate sequences--typical of procedural tasks where trainee is required to retain and reproduce the order of the steps and perform each step singly.

Discriminative: includes subdemands for detection and identification which require learning.

Manipulative: trainee learns novel coordinated, time actions, which may or may not be associated with a discriminative demand.

Deductive: decision-making tasks in which trainee must learn to select specific procedures appropriate to the particular instance, on the basis of deducing them from rules, principles, and general procedures.

*MacCaslin, E. F., Human Resources Research Office, A Tentative Taxonomy of Task Demands, Paper presented at the American Psychological Association Convention, Sept. 1963.

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