HUMAN APTITUDE ABILITY ASSESSMENT TECHNIQUES FOR SYSTEM DESIGNERS

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ABSTRACT

Modern weapon systems are increasing in sophistication and man-machine interface complexity, while the manpower pool to operate and maintain these systems is decreasing in terms of both numbers of individuals and the aptitudes, abilities and skills those individuals bring into the Army. This situation leads to the necessity of considering human resources as a parameter of weapon system design, but such an effort is severely handicapped by a lack of efficient and reliable techniques that can be used by designers to estimate the human resource implications of their designs. The Army Research Institute (ARI) is currently pursuing a research program to develop a human aptitude/ability assessment technique for use during weapon system design. The basic approach is a taxonomy similar to that developed by Fleishman but computerized for greater efficiency and with heavier emphasis on cognitive factors. Research concerns within this project include: whether a branching or an exhaustive assessment technique is more effective, what is the appropriate level of analysis jobs or tasks, should the method of qualitative analysis be discrete or continuous, and what is the effect of having different types of users of the assessment procedures.

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I. INTRODUCTION

The Army presently has a weapon system modernization program underway which is so large in scale that even the former head of the Army Force Modernization Coordination Office, General Lawrence (1979), has voiced concern about the Army's ability to absorb the impact of this "bow-wave of modernization." Unfortunately, this modernization program is taking place in a period of a severely constrained resource, namely, a people constraint. We know from census data (Bureau of the Census, 1977) there will be fewer 18-24 year olds between 1980 and the late 1990s, so the Army can expect persistent shortages of qualified recruits to operate and maintain these technologically advanced systems. As a consequence, the Chief of Staff of the Army, General Meyer, is quoted as saying that we have become a hollow Army, principally because of manpower shortages, (National Review 1980). While the sharp decline in the size of the future pool can hardly be questioned, there has been a good deal of controversy regarding a similarly sharp decline in the quality of both the recent military accessions, and conceivably, the future military manpower pool (Rimland and Lawson, 1980). Numerous examinations are now underway to assess this particular "supply-side deficit." For example, the opening panel of this 23rd Annual Conference of the Military Testing Association is entitled: "Profiling the Aptitudes of the Current Mobilization Population." In all, there is a growing concern among the manpower, personnel and training (MP&T) community, that when we finally know the true dimensions of the quality issue, and couple it with the known quantity shortfall, the bow-wave of modernization may in reality be a tsunami.

The problems of human resource supply and demand considerations during the force modernization program are further aggravated by the increasing sophistication and man-machine interface complexity. The long-term impact of this increase in complexity is not fully understood but preliminary studies (i.e., Kerwin and Blanchard, 1980; GAO Report 1981) suggest that increasing the sophistication of a weapon system often leads to an increase in the skills and abilities of the people required to operate and maintain that system. Since it appears that these highly skilled individuals may be in particularly short supply it is possible that sufficient quantities of individuals with the required aptitudes, abilities, and skill levels will not be available to effectively operate, maintain, and support the new and developing weapon systems (Kerwin and Blanchard, 1980).

Anticipating what the world will be on the supply-side, it becomes imperative that we work toward producing a detailed picture of the demand-side characteristics. In the past, skilled manpower for military systems were provided after hardware was delivered to the military unit. Personnel selection and training was accomplished as a form of reaction to the demands of the equipment. Today, because of the problems cited above, there is a dire need for human resource planning which will permit us to predict manpower requirements during system development. Success in doing this will permit us to compare supply to demand and allow us to use human resource data as criteria in system design. Such data will provide us the means for making judgments about (a) the impact of design alternatives on our human resource pool, as well as (b) judgments about the constraints our human resource pool imposes on design alternatives (Askren, 1976). Let us take a moment here to briefly sketch-in how this might be done and to highlight a critical problem which must be overcome if we are to achieve this goal.

System design begins with a statement of purposes for the system; one or more "missions" the system is expected to perform. The purposes set the stage for the derivation of what the system's characteristics will be, i.e., mission profiles. Following the determination of system requirements and mission profiles, a functional analysis is undertaken which attempts to allocate functions between men and machines (see Figure 1). The traditional method for allocating functions between men and machines is to consider the relative superiority of the machine (e.g., microsecond response times; precise performance on boring, repetitive operations, etc.) or the human component (e.g., handling unanticipated occurrence; ability to reason inductively, etc.) in performing a particular function and assign that function accordingly.

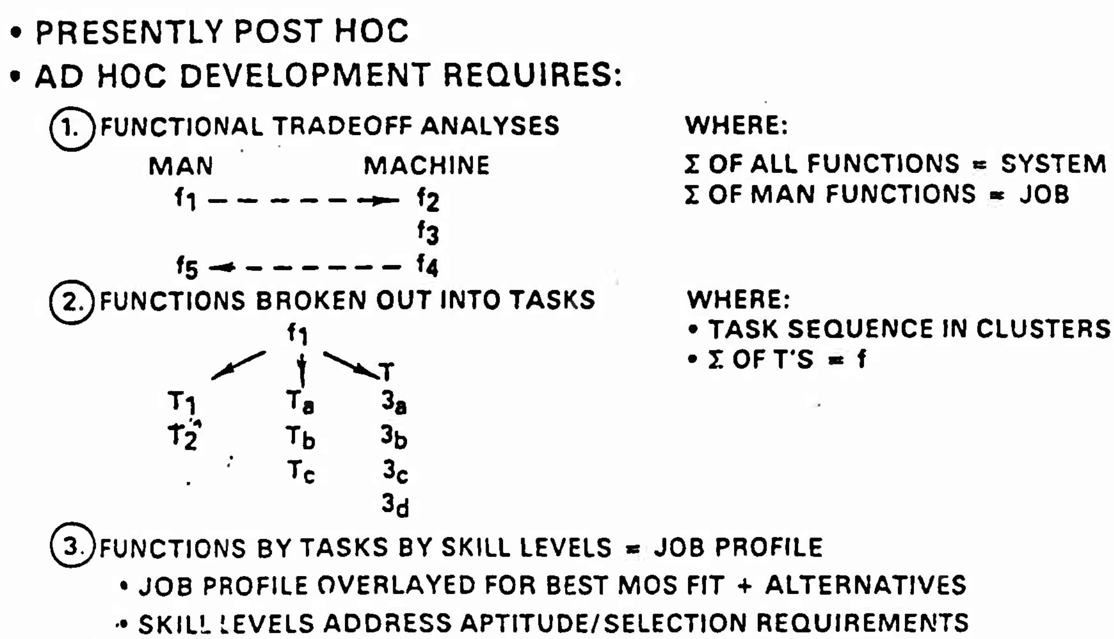

Figure 1: Graphic illustration of how functional allocation/tradeoff analysis data leads to task analysis which, in turn, provides a basis, early in system design for MOS best fit and/or skill level determination and/or aptitude/selection requirements.

Given the specification of the functions to be performed by the man in the system, it is now possible to break down the functions into component tasks. The classic definition of task is that of Miller (1953): "A group of discriminations, decisions and effector activities related to each other by temporal proximity, immediate purpose and a common man-machine output." The elements of a task are, therefore, the stimulus to the operator, which triggers performance of the task, the required response to that stimulus (i.e., the performance criterion), a procedure for performing the response (which includes the equipment to be utilized for performing the task), and a goal or purpose (mission element) that organize the whole.

Now it merits comment that even though the designer routinely goes through a functional allocation/task analysis procedure in the front-end design process, these data typically are not used (although they could be) as detailed input for early MP&T considerations. Data, usually at the functional level, may be considered late in the life cycle of the system (Milestone II and beyond), to provide a reasonable estimate of the quantity of people the system will require, but these data contribute little to the quality determinations. Usually a post hoc determination is made in terms of military occupational speciality (MOS) requirements (quasi-quality determination) with only a "guestimate" of skill requirements (e.g., in terms of grade E-4, E-5, etc.). Numbers of people, by MOS and grade level, are thus selected in a somewhat "artistic" post hoc fashion. What is needed is a refined technique for making ad hoc determinations. This overall relationship is briefly summarized in Figure 1.

One way to achieve this goal is to use the early functional/task analysis data to provide a "job profile." This job-profile could then be overlayed on multiple MOS profiles to provide best, and alternate fits. But to the extent that the new job does not overlay precisely on an extant MOS, we are faced with a crucial problem....in the words of Meister (1976): "How does one derive from task characteristics, guidelines for operator selection and training and for prediction of operational performance?" He goes on to say (p. 101): "Despite written guides, the derivation of selection and training requirements is still largely an intuitive process."

What follows is a description of our attempt to resolve the problem of translating functional/task analysis data into behavioral components, such as aptitudes and skills, and to remove this process from the intuitive realm of art and to attempt to transform it into a behavioral science.

II. BASIC APPROACH

As part of its investigation into the broad range of manpower, personnel, and training (MP&T) issues in weapon system acquisition, the Army Research Institute (ARI) is currently pursuing a research program to develop a technique that can be used by system designers to estimate the human resource implications of their designs. This effort entails the development of a computer-based assessment procedure to aid in identifying and quantifying estimates of the human aptitudes/abilities of projected tasks implied by system design concepts.

One of the first problems encountered by this project was the realization that there is no uniformly applied term referring to the human attributes under investigation. This problem is illustrated in Figure 2. Not only do different researchers, in this case Dunette (1976) and Fleishman (1975), use different terms to describe similar or equivalent concepts, but similar or identical terms are often used to describe distinct concepts. Thus, while Dunette uses the term ability to refer to a fairly specific cognitive trait, Fleishman uses the same term to refer to a general trait that can be either cognitive or physical.

DEFINITIONS

	DOMAIN	
GENERAL	COGNITIVE/PERCEPTUAL	PHYSICAL/MOTOR
	VERBAL EXPRESSION APTITUDE (DUNETTE) ABILITY (FLEISHMAN)	MANUAL DEXTERITY SKILL (DUNETTE) ABILITY (FLEISHMAN)
SPECIFIC	PUBLIC SPEAKING ABILITY (DUNETTE) SKILL (FLEISHMAN)	HAMMER A NAIL SKILL (DUNETTE) SKILL (FLEISHMAN)

Figure 2: Definitional discrepancies within the realm of human resource requirements.

To try to minimize this confusion, it was decided to use the term aptitude to refer to the human resource traits of interest and then systematically define what is meant by the term. Aptitude will be used to refer to a general characteristic of an individual that affects his or her performance on a task or set of tasks. Aptitudes are assumed to be the result of a multitude of factors and therefore, are enduring traits that are difficult or impossible to alter through cost-effective training. Consequently, aptitude requirements should be of crucial consideration during weapon system development since any discrepancy in aptitude between the manpower required by a system and the personnel available to operate and maintain that system will be very difficult to overcome.

The basis or starting point of the current approach to the analysis of aptitude requirements is the extensive research of Fleishman (1972, 1975) in the identification of basic human aptitudes or abilities and their relationship to performance on a wide range of tasks. A particular advantage of using the Fleishman approach is that his basic procedure has been extended (Mallamad, Levine and Fleishman, 1980) to utilize binary decision-flow diagrams to assist in identifying the aptitude requirements of jobs and tasks. These decision flow-diagrams are structured in a binary (yes, no) format to reduce the information processing and decision-making demands on the analyst. The diagrams (see Figure 3) contain information relating to critical characteristics of an aptitude that suggest either its presence or absence and help differentiate that aptitude from similar aptitudes. A yes/no decision is required at each node in the decision flow structure. To aid in these decisions a list of task examples which are relevant to the aptitude in question is provided at each decision point. The diagrams function to determine the presence or absence of

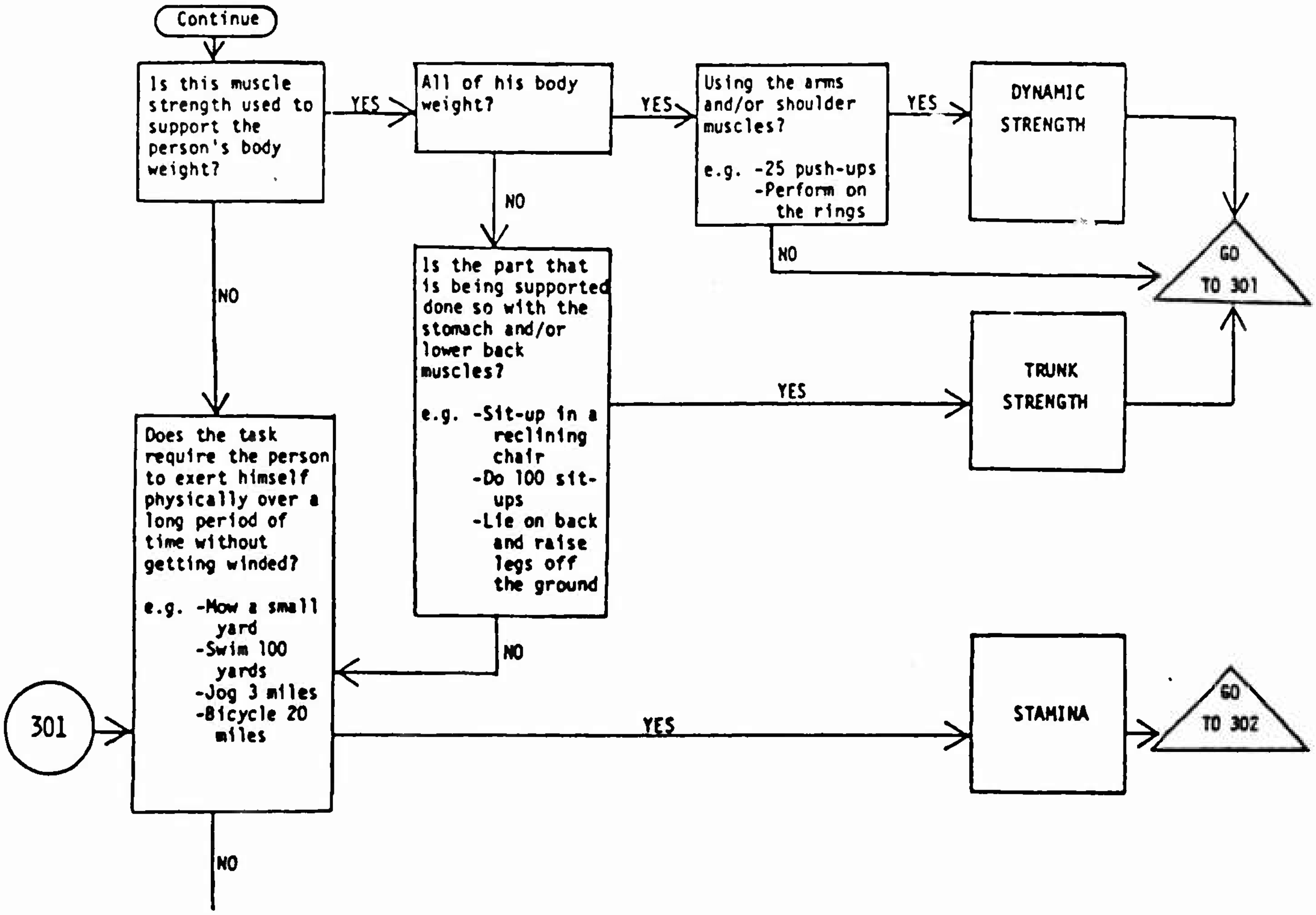

Figure 3: An example of a portion of the binary decision flow diagrams (from Mallamed, Levine, and Fleishman, 1980).

an aptitude judged to be necessary for task or job performance. Each diagram can then be further supplemented by a rating scale (see Figure 4) which may be used to quantify the relative level of a particular aptitude required to perform a given job or task.

The present developmental effort is designed to build and expand on the results of Fleishman and others in developing an aptitude oriented taxonomy that can relate tasks to their aptitude requirements (Fleishman, 1975; Mallamad et al, 1980; Siegel, Federman and Welsand, 1980) in a procedure that can easily be used by weapon system designers.

III. COMPUTERIZED APTITUDE ASSESSMENT

The first phase of this project, currently being developed in conjunction with McFann Gray and Associates, will result in a research tool based on Fleishman's structured procedure mentioned above but computerized for greater accuracy and efficiency. This system will utilize a standard portable CRT display and off-the-shelf microcomputer components. The disc-based software will be in modular format in both its initial and upgrade versions. The software will consist of three basic elements: a binary decision flow skeletal

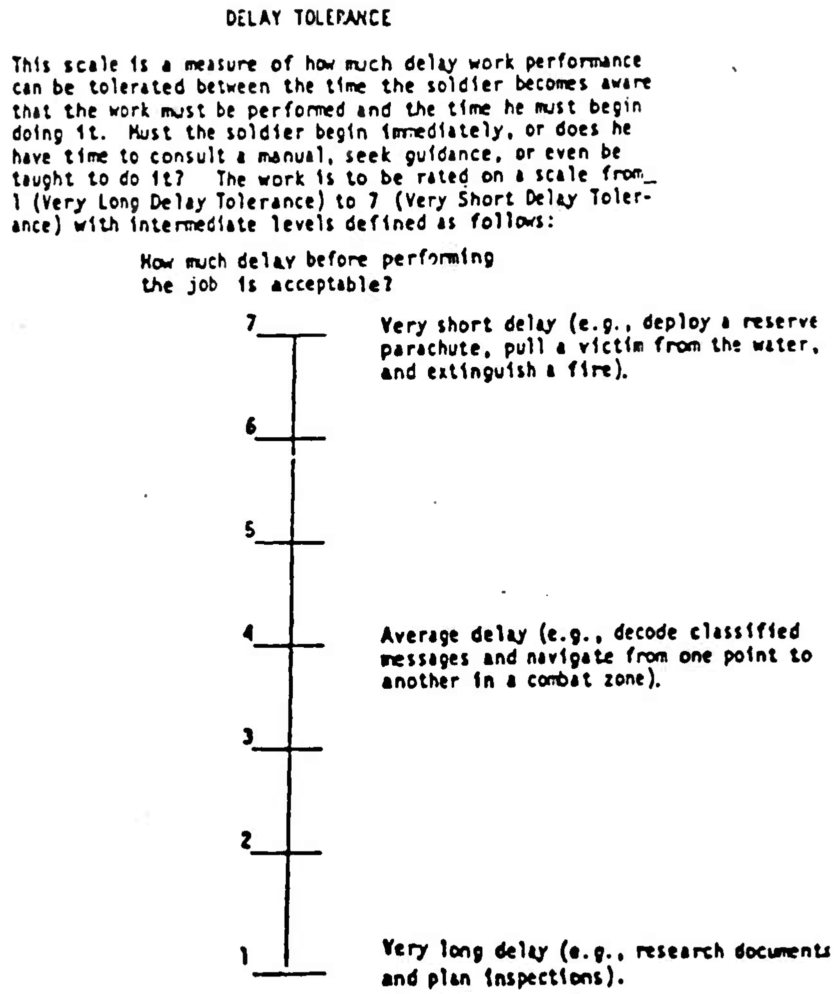

Figure 4: An example of an aptitude rating scale (from Fleishman, 1975).

structure, the capability for a variety of types of rating scales and task examples, and data aggregation, processing, reduction and analysis routines.

The immediate goal of the project is to refine this aptitude assessment methodology and to adapt its use to an Army environment. Initially this will entail the redefinition of the task exemplars and rating scale anchors to render them more appropriate to Army tasks. Other developmental considerations that will be addressed are outlined in Figure 5 adapted from Siegel et al (1980).

The research issues during the initial phase of development will be concerned primarily with structural and procedural variables such as rating scale format, rater variability, and task and job descriptions. The development, refinement and adaptation of the aptitude assessment technique will gradually shape the instrument to its dual function as a computer-based decision aid for system designers and a research tool for further analysis of the human aptitude/ability requirements of Army jobs and tasks.

Reliability--the scheme should be amenable to psychometrically reliable data acquisition methods.

Validity--the sheme should be based on acceptable constructs relevant to Army job content, and seem reasonable to the Army users.

Practicality--the scheme should be relatively simple to apply and interpret and should not place undue time requirements on operational personnel.

Scalability--the technique should allow for the assignment of a magnitude value to the estimate of aptitude requirements.

Understandability--the scheme must be readily apparent and comprehensible to Army users.

Combatabilty--the scheme should be fully compatable with the Army task structure.

Comprehensiveness, generality, and flexibility--the scheme should be applicable to the full range of tasks involved in Army jobs.

Cost-effective--the taxonomy should have characteristics that permit it to be embedded within a scheme that is relatively inexpensive to employ.

Figure 5: Developmental considerations.

Eventually this project should result in a reliable and efficient technique for use during the early stages of weapon system development as an aid to the system designer and developer in assessing the aptitude requirements associated with the operation, maintenance, and support tasks implied by new equipment design. Successful adaption and use of the assessment aid will help to identify potential areas of excessive demand on human capability and performance. Also, the aid will be useful in the development of aptitude profiles similar to the MOS task derived classification scheme.

IV. ADDITIONAL INPUTS

The long range value and utility of the project briefly described in this paper will be enhanced by the results of a number of related research efforts currently under way. Among these is the renewed interest in the investigation of the relationship between human aptitude and human performance (Christal, 1980; Imhoff and Levine, 1981). While there has been extensive effort and some success in attempting to relate pencil and paper aptitude measures to training and ultimately to field performance, there has been very little effort devoted to the examination of aptitudes, training, and performance relationships, especially in the area of cognition. A greater understanding of these relationships will contribute greatly to the further development of task taxonomies for use in interpretation and prediction of human performance (Fleishman, 1975). Collateral efforts in the development of improved techniques for the translation of system design specifications to functional requirements, and operator and maintainer tasks will contribute to our understanding of the impact of material design characteristics on the human resources in terms of the aptitudes and skills required of those tasks.

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