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HUMAN PERFORMANCE, JOBS, AND SYSTEMS PSYCHOLOGY--
THE SYSTEMS MEASUREMENT BED

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HUMAN PERFORMANCE, JOBS, AND SYSTEMS PSYCHOLOGY--THE SYSTEMS MEASUREMENT BED *

BRIEF

The major hypothesis concerns the way aptitudes, job demands, and surrounding conditions coalesce to yield varying levels of performance.

The conceptual background for the hypothesis includes: 1) a taxonomy of jobs containing cognitive variance (responses more objectively characterized as right or wrong) and noncognitive variance (responses less objectively characterized as desirable or undesirable); 2) the ad hoc nature of values and goals (quality output, safety of operation, quantity output, etc.); 3) the great variety of styles of behavior (authoritarian, forceful, democratic, permissive, cautious, risk-taking, etc.) by which individuals and organizations seek to achieve and do achieve goals.

Styles of behavior and values and goals are considered ad hoc by the investigator. To the extent that such variance enters into criterion determination, it is proposed that for many applied purposes including systems development, the criterion should be a given rather than the yield of preceding predictors, and the criterion should be explicitly specified with respect to both cognitive and noncognitive variance. The systems measurement bed--constructed for research purposes to contain situational tests and exercises--can be designed to yield such criterion measures and measures related to the human factors variables.

And most importantly, in certain jobs (probably more complex or less structured jobs) as performed by groups of individuals whose effectiveness is greater than would be expected based on the usual linear combination of empirically validated aptitude measures, there occurs an intensification of capability that goes beyond the use of a relatively high level of one aptitude to compensate for a lesser level of another aptitude. This major hypothesis, tested and supported in appropriate samples, highlights the complex of performance as a function of abilities. Crucial to productive experimentation in the framework of the systems measurement bed is the participation of performers who are experienced and even "expert" in the job situation under scrutiny.

The theoretical discussion, the hypothesis developed and tested, and the resultant research considerations strongly affirm that the generation of principles for the understanding of pertinent human behavior in certain jobs (e.g., electronics specialists, high level jobs in complex information systems, military commanders and leaders) seems to demand a special research framework. The research framework which meets such a requirement is the systems measurement bed.

*This is an abstract of the presidential address given by Dr. J. E. Uhlaner before the Division of Military Psychology of the American Psychological Association at the annual convention in Miami, Florida in September 1970.

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From the very beginning of the establishment of U. S. military psychology in 1917 there has been a continuing preoccupation with the prediction of effective military behavior, particularly with the prediction of adequate and expert job performance. Under the leadership of Dr. Robert M. Yerkes, the Army Alpha and Beta were intended as an aid--and indeed did aid--in meeting the personnel management requirements of accepting or rejecting and sorting personnel. This preoccupation with prediction was carried into the World War II era which saw AGCT developed under the leadership of Dr. Walter Van Dyke Bingham and the beginnings of differential classification efforts when the U. S. Army and the U. S. Army Air Corps attempted to gain greater useful capability from the total manpower pool (Uhlaner, 1968).

By 1950, the armed services had moved to the development and use of a common screening procedure for induction and enlistment, the Armed Forces Qualification Test (Uhlaner, 1952).

Preoccupation with the prediction of a variety of human behaviors after World War II led to a broadened interest in the management of manpower through training and planned job experience (changing the performer). With greater sophistication of machine and weapons technology, human engineering or modification of the job and surrounding conditions (changing the stimulus) became a necessity. More recently, the concepts of organizational psychology (changing the noncognitive stimuli) have gained popularity.

This paper concerns itself with jobs, human factors variables, and systems psychology with the objective of predicting and managing military human performance in the present era.

Joining many of my colleagues in industrial and military psychology, I have been increasingly aware that for many jobs, and particularly those involving noncognitive elements, our prediction research has not been yielding the substantial predictability so desired by both management and researchers.

My concern is with the limited usefulness of information coming out of many personnel research studies, particularly research studies dealing with selection, the prediction of human performance, and the measurement of aptitudes and abilities for differential classification (Uhlaner, 1967). This concern has been voiced by others. For example, Ghiselli (1966) has recently stated that "though some few specific tests do give reasonably good prediction of job proficiency in the industrial occupations as a whole, the general picture is one of quite limited predictive power."

Various reasons are given for the low validity coefficients obtained:

1. The studies were carried out on present employees after they had been on the job long enough so that the gross failures had been eliminated, thus restricting the range of ability both on the tests and on the job.

2. The criterion was highly unreliable or fractional or impossible to measure in its appropriate entirety.

3. The predictive validation supplied answers which no longer applied to the current situation.

To my way of thinking, such "reasons" tend to perpetuate the fond hope that the next study will support the assumption that the true validity coefficients are higher, repeating the usual predictor-criterion covariance cycle again and again.

The researcher has a tendency to emphasize the psychological content and approach with which he has become accustomed to dealing and which have tended to yield "successful" results (as with the drunk who, having dropped his keys in the dark alley, takes up the search for them under the lamppost) without adding much in the way of new understanding and insight. Such research.has tended to yield fractionated approaches which have left the decision-maker less and less satisfied with the human factors systems impact (Uhlaner and Drucker, 1964).

If the military research psychology specialty is selection, then the promise has been that the inventive and technical genius of the researcher will devise tests, instruments, and other predictors--cognitive and non-cognitive--which will have meaningful validity for the criterion of effective behavior and effective work performance.

If the military research psychology specialty is training, then the promise has been that the inventive and technical genius of the researcher will devise training methods and programs, whether at the school or on the job, for reasonable cost, which will offer the sponsor the means of modifying the behavior of the trainee and of providing the trainee with appropriate knowledge and skills, irrespective of the abilities he starts with.

If the military research psychology specialty is human engineering, then the promise has been that the inventive and technical genius of the researcher will devise the appropriate modification of stimulus or stimuli relevant to a specific man-machine system so as to make it possible for the man to perform effectively--perhaps irrespective of limitations of ability and training, and ideally at minimum cost.

If the military research psychology specialty is organizational psychology, perhaps with a dash of social psychology, then the promise is that the inventive and technical genius of the researcher will devise appropriate modifications of the "motivational" environment; such modifications would utilize incentive and leadership styles so as to lead to more effective behavior and work performance of teams and groups and military organizations irrespective of the individual abilities of the workers, their training, and the engineering excellence of the machine.

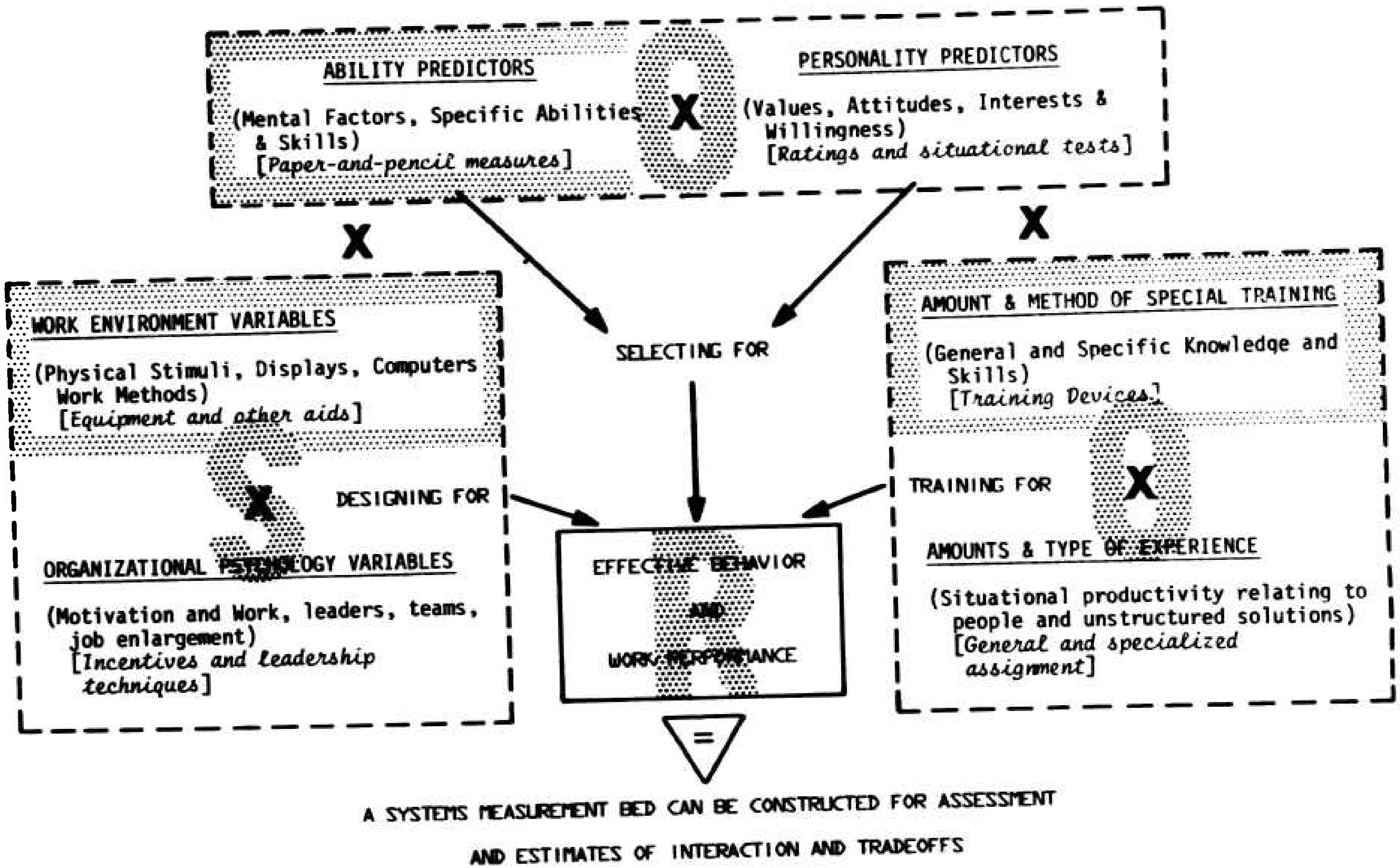
Fundamental to the understanding of the human factors system is the recognition that the effective behavior and work performance desired in a particular situation may be achieved in a great variety of ways--admittedly for varying costs (Schema I). If more talented applicants are selected, the treatment (training) accorded them may be simplified, and the equipment may require less human engineering attention. On the other hand, less capable individuals may require longer and more skillful treatment (training and experience) and better human-engineered equipment.

Not only are there interactions between selection variables and treatment variables (training and experience) and job design variables (equipment, environment, and organization), but there are interactions within a domain, such as between cognitive and noncognitive variables within the selection domain. Any of the above conditions and resulting performance may be further modified--one way or another--by the kind of supervision and leadership provided in the work situation and by many other variables too numerous to mention here.

The amount of research reported which examines these interactions is thus far quite meager. A few efforts studying such interactions have appeared and point, in my opinion, to the fruitfulness of examining more extensively interactions and trade-offs of human factors system variables.

In its 1969 SPECTRUM studies, HumRRO examined the interactions between aptitude level and training techniques for tasks of varying complexity. The results can be viewed as pointing up some practical considerations on which to base trade-offs between time and effort spent in training and level of performance desired. Men of lower aptitude required more training time to reach a specified level of performance, as well as different instructional methods--more guidance, more repetition, more prompting--than did the upper level groups. On a composite measure of Basic Training performance, 33 percent of the low aptitude groups compared to 66 percent of the high aptitude groups scored above the median. In some tasks, groups differed only in rate of learning; in others, they differed both in rate of learning and final level of performance. Not all recruits labeled "low aptitude" were slow learners on all tasks. On each task, a few showed performance typical of middle or high aptitude groups. To quote the authors:

"The college graduate and the low Category IV simply cannot be reached by the same instructional vehicle. However, these same studies confirm the meagerness of current knowledge on how to go about designing appropriate strategies for the various levels of aptitude. This is a serious gap in the technology of training and education" (Fox, Taylor and Caylor, 1969).



Scheme I. Conceptualization of interactions of human factor system variables as related to human performance effectiveness

In 1964, from data on 48 Army School courses, estimates were made in a BESRL study of the expected success in training of enlisted men with AFQT scores in the 10th to 30th percentile (Category IV). It was estimated that substantial numbers of Category IV men could successfully complete Army School courses for MOS of moderate or low difficulty level. However, to keep attrition in a given course at a permissible level, supplementary aptitudes in specified areas would have to be required (Helme, 1964).

Now I would like to move to another type of job which enables me to highlight a set of interactions other than the ones just discussed.

The job of leader well illustrates the need to consider carefully the influence of the ad hoc situation and styles of behavior on job performance. By ad hoc situation is meant the specification of the purposes and conditions that, over a short or a long period of time, demand an action. Values and styles of behavior may dictate the action. As styles of behavior may be persistent or changeable, so the ad hoc situation may vary as a function of innumerable factors including, most importantly, value patterns. As in virtually all jobs where the noncognitive element is prominent, the leader has choice of actions in achieving the mission objective. How he goes about carrying out the objective is dictated in part by <u>his style of behavior</u>, in part by <u>his value system</u>, and in part by the <u>ad hoc situation</u>.

The job of leader has high noncognitive demands; thus, there exists a great variety of styles of behavior and value system combinations for achieving goals. In addition, the variations in value systems on the one hand, and in situations on the other lead to numerous varieties of behavior that a leader can adopt to achieve his objectives. This reasoning holds even when the leaders have all been brought to a minimum adequacy level of cognitive competence by initial selectivity and training.[1] My model does not assume one style of leadership per se as right or wrong nor one style of leadership as required to achieve a given goal, unless the other factors of the ad hoc situation and other pertinent parameters are specified. Authoritarian versus participative management styles, for example (Schema II), in themselves are not considered effective or ineffective styles.

It is believed that if noncognitive and situational elements are to be taken into account, an experimental research environment must be created which lies somewhere between school and job. We need an effective way of relating the noncognitive with the cognitive in a design which makes it possible to specify at the start a great many of the interactions <u>dictated by the applied setting</u>.

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[1] Actually, we know that in learning a specific body of knowledge, cognitive measures show decreased validity as more and more learning takes place. When a group of individuals have all been brought to a minimum adequate level of cognitive competence, then a host of factors other than cognitive lead to differences in performance.

Pattern of Supervisory Behavior or Style	Characteristics of Tasks & Jobs To Be Performed	Employee Characteristics	Job Environment	Situational Organizational Climate	Goals	Enhancement of Group Morale
Benign authoritarian[1] Job-centered High initiating structure Firm but fair instructions and discipline Consistent behavior	Tasks and jobs highly structured Routinized and amenable to automation "Human engineering" tends to be applicable Jobs tend to be "frozen" Short training requirements	Relatively unskilled Relatively uneducated Relatively rigid and compulsive Anxious and insecure Good followers	Stressful Rapid response required Monotonous "High initiating structure" Physical and psychological fatigue more common	Authoritarian Acceptance of authoritarianism as way of efficient production Often many layers and "boxes" Emphasis on initiating structure for efficiency	Specific and definitive Short term Group goals common Deadlines and production measures important	Goody program of rewards Fairly concrete rewards and punishment: group progress highlighted (lower end of need hierarchy) Organization provides supervisors high in initiating structure Group cohesion through extracurricular activities Unambiguous instructions and objectives Fringe benefits

"High leaders"[3]: Use appropriate behavior style and content and initiate structure effectively, taking into account characteristics of the tasks, of those led, and of the situation--applying correct amount and type of consideration.[4]

Pattern of Supervisory Behavior or Style	Characteristics of Tasks & Jobs To Be Performed	Employee Characteristics	Job Environment	Situational Organizational Climate	Goals	Enhancement of Group Morale
Democratic,[2] participative, or employee-centered High consideration for employee	Structure of tasks looser Problems defined by employee Opportunity for ego-involvement, self-actualization Intrinsic motivation Extensive training requirements	Creative, highly versatile, educated Independent broad thinkers; want to help set goals	Non-stressful Liberal time requirements Can be exciting and interesting Low level of fatigue	Democratic Employees resist being fitted into a mold Few layers Emphasis on effective interpersonal relations	Broad, even ambiguous Long term Goals usually acceptable to followers Group goals and individual values may conflict	Emphasis on instrinsic motivation Reward & punishment at upper end of need hierarchy: individual progress recognized through status and prestige Tolerance of individual values: employee participation in setting of general goals Group cohesion by specialty of work

NOTES:
1. "Tyrannical" authoritarian leadership can be considered "sick" form, or it could be looked at as the extreme of no consideration.
2. Laissez faire leadership is no leadership at all.
3. From a "Systems Psychology" point of view--neither authoritarian nor democratic is better in a vacuum: rather, the job, the situations, and the employees must be considered against a criterion fashioned to "predict" specified outcomes, such as high productivity, high morale, minimum turnover, minimum grievances. Even within a given situation, different styles of behavior may be equally effective.
4. Supervisor's role with respect to consideration would affect the outcome like a moderator variable.

Schema II. Styles of leadership behavior related to selected system variables

The research approach proposed utilizes the systems measurement bed. In a sense, the military has for a long time intuitively designed systems measurement beds. A good example is the military maneuver, which attempts to deal with a large number of factors, including men, equipment, organizations, tactics, and doctrine to test operational readiness. Early in the 1950's, BESRL began an effort using such concepts in the study of relationships involving team performance within squads. Of specific interest here is that such an approach helped in the measurement of the performance of the squad (Havron, Fay, and McGrath, 1952).

The school setting gives highly useful results where cognitive content is dominant. But for the study of many important jobs, a setting is required in which noncognitive content can make its influence felt. In devising a systems measurement bed, we steer a course somewhere between the school and the real job situation.

Establishment of a systems measurement bed calls for a great deal of subject-matter expertise. Situations have to be designed, scenarios written, measurement strategies devised, computer programs prepared. Appropriate experienced personnel have to be identified to serve as subjects. Finally, all these concepts, materials, and procedures have to be built into a logistically feasible physical space, either a computerized laboratory or a large terrain suitably varied and instrumented. In such a bed, we can build in the ad hoc factors we feel are most relevant and especially the specifications of the criteria.

The systems measurement bed can bring together the job and performance variables of importance in a research setting for the purpose of gaining insights for predicting and managing (military) behavior in furtherance of specified goals (missions). It is particularly vital to represent noncognitive as well as cognitive input and to guard against the tendency to reduce observation and measurement to a preponderance of the cognitive.

The type of results obtained with a systems measurement bed is indicated in Schema III. Factor analysis (Helme, 1970) of measures of specific leadership behaviors obtained in a situational context yields a better understanding of the military leadership job. The behaviors which showed some generality across more than one activity fell into two major domains, combat leadership on the one hand and technical/managerial on the other. For both kinds of leader, there was heavy cognitive content, represented in the combat leader by his knowledge of tactical skills, in the technical/managerial leader by technical skills. In the combat leader, the heavy noncognitive element rested upon forcefulness in the command of men, personal resourcefulness, and persistence in accomplishment of the mission. The noncognitive element in technical/managerial leadership was evident in an Executive Direction factor, plus--as in combat leadership--a Mission Persistence factor. The specific behavioral/situational loadings on the factors shown in Table 1 are believed to be very useful in providing basis for the summary statement in the middle of Schema III, namely, that:

"High" leaders use appropriate behavior style and content, and initiate structure effectively, taking into account the characteristics of the task, of those led, and of the situation--applying the correct amount and type of consideration.

Other examples of systems measurement beds as developed by BESRL are in the areas of surveillance systems (Figure 1) and command and control systems. Earlier similar efforts which led to this kind of approach were the OSS of World War II, the Air Force systems research efforts carried out by Rand and continued by the Systems Development Corporation (Chapman, Kennedy, Newell, and Biel, 1959), and the Bell Telephone Company assessment centers (Bray, 1966).

To date, such simulated environments have tended to tap cognitive elements more than noncognitive. Emphasis on obtaining objective measures--in many ways our traditional heritage, and a powerful one--has led inevitably to emphasizing problems that have a high agreement right-wrong, hence favoring cognitive problems. To build the noncognitive into systems measurement beds, taking into account styles of behavior and specified situations of the job environment--forcefulness in command of men, risk-taking in executive behavior, deliberate cautious driving--requires, in my opinion, a major shift in our thinking. At this point, I believe we have a tendency even in the systems measurement bed to tap cognitive variance--in the interest of reliable measurement, of course.

As indicated in Schema IV, we can now state that the systems measurement bed enables the researcher to specify required styles of behavior and goals to yield human factor systems data.

Quite fundamental to an understanding of human performance effectiveness in systems settings (Uhlaner, 1960) is the job--or more accurately the tasks which constitute the job demands. As shown in Schema IV, a major classification along cognitive-noncognitive dimensionality is proposed. Although conceptually every job has both cognitive and noncognitive aspects, these exist in differing degrees. As a working definition, the cognitive content of a job consists of right or wrong responses, while the noncognitive has an ad hoc quality consisting of styles of behavior and value judgments often subjectively determined. The latter behavioral interactions influence the individual or organizational goals and relate to individual or group hypothesized expectancies.

When I speak of the cognitive content of a job, I am concerned with a right or a wrong response to a stimulus. Once a few rules are set, most observers would agree to the number of X's on a screen, or to the correct sum of a column of figures, or to a particular solution to an equation. Of course, the rightness or wrongness is not absolute. The probability that the consensus is correct may be set at some agreed upon high p, of say .99.

Type of Leadership Required	Factors of Abilities or Behaviors	Valid Measures of Aptitudes	Training Thru Schooling	Training on the Job	Characteristics of the Leadership Task
Combat Leadership	Tactical skills Command of men Personal resourcefulness Mission persistence	a General learning ability a Technical information tests b Peer ratings b Superior ratings d Interview (structured) c Background information Situational performance ratings (combat situation)	Formal schooling on tactics Summer Camp, ROTC Situational problems (combat) Motivational content (values, nobility of defense, patriotism, etc.)	Instructor in Infantry School Platoon leader Company commander "Combat" experience or experience in situations in an Officer Evaluation Center	High stress Quick time response critical Firm, however fair, styles of behavior Consideration appropriate to needs of the men and situations. Food, supplies, safety for those led Initiating structure demands high
Technical/ Managerial Leadership	Technical skills Executive direction Mission persistence	a General learning ability a Technical information tests b Peer ratings b Superior ratings c Background information Situation performance ratings (technical situations)	Formal schooling on technical subjects Management theory and practice Applied psychology participative management Motivational content (values, strength thru technical superiority, etc.)	Instructor or on assignments--AMC, CDC, or R&D Action officer in technical area R&D lab director DCSLOG, top R&D assignments or experience in situations in an Officer Evaluation Center	Intellectual creativity Greater mix with civilian values More opportunity for participative management Consideration related to individual needs, e.g. prestige status.

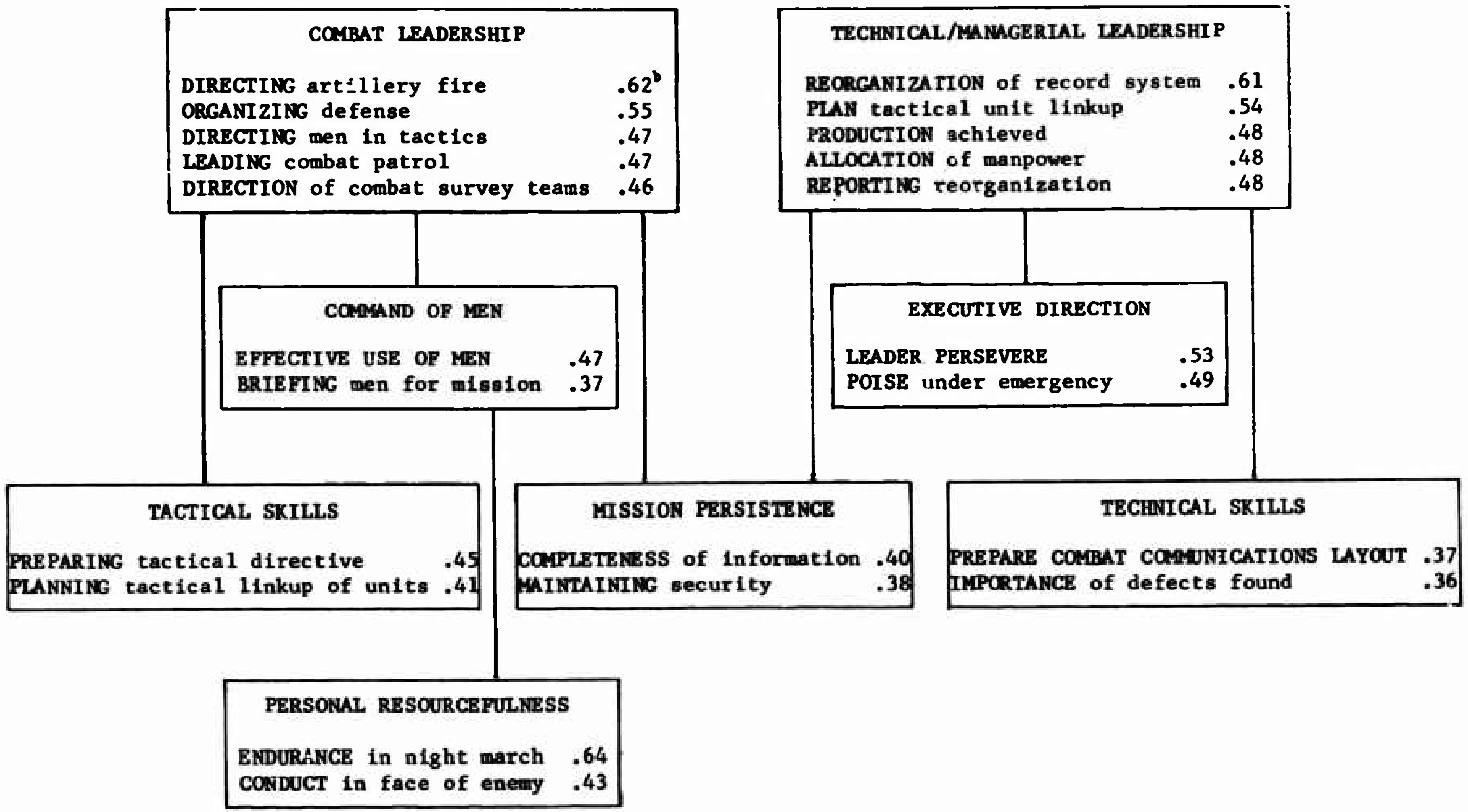
"High" leaders use appropriate behavior style and content, and initiate structure effectively, taking into account the characteristics of the task, of those led, and of the situation--applying the correct amount and type of consideration.

[a] Validity much higher in school or training situation than in job situation
[b] Validity in job situation (moderate amount) .50 or so
[c] Validity in job situation (small but significant) .25 or so
[d] Validity is very small but significant for obvious characteristics, e. g. voice, hearing

Schema III. Selected human factor variables related to combat and technical military leadership

Table 1

FACTORS IN LEADERSHIP BEHAVIOR IN A VARIETY OF SITUATIONAL DEMANDS[a]



[a]From Helme, Wm. H. Identification and career development of officer leaders. BESRL Briefing Supplement. July 1970.

[b]Factor loadings from factor analysis of measures of performance in Officer Evaluation Center situational exercise under simulated combat conditions.

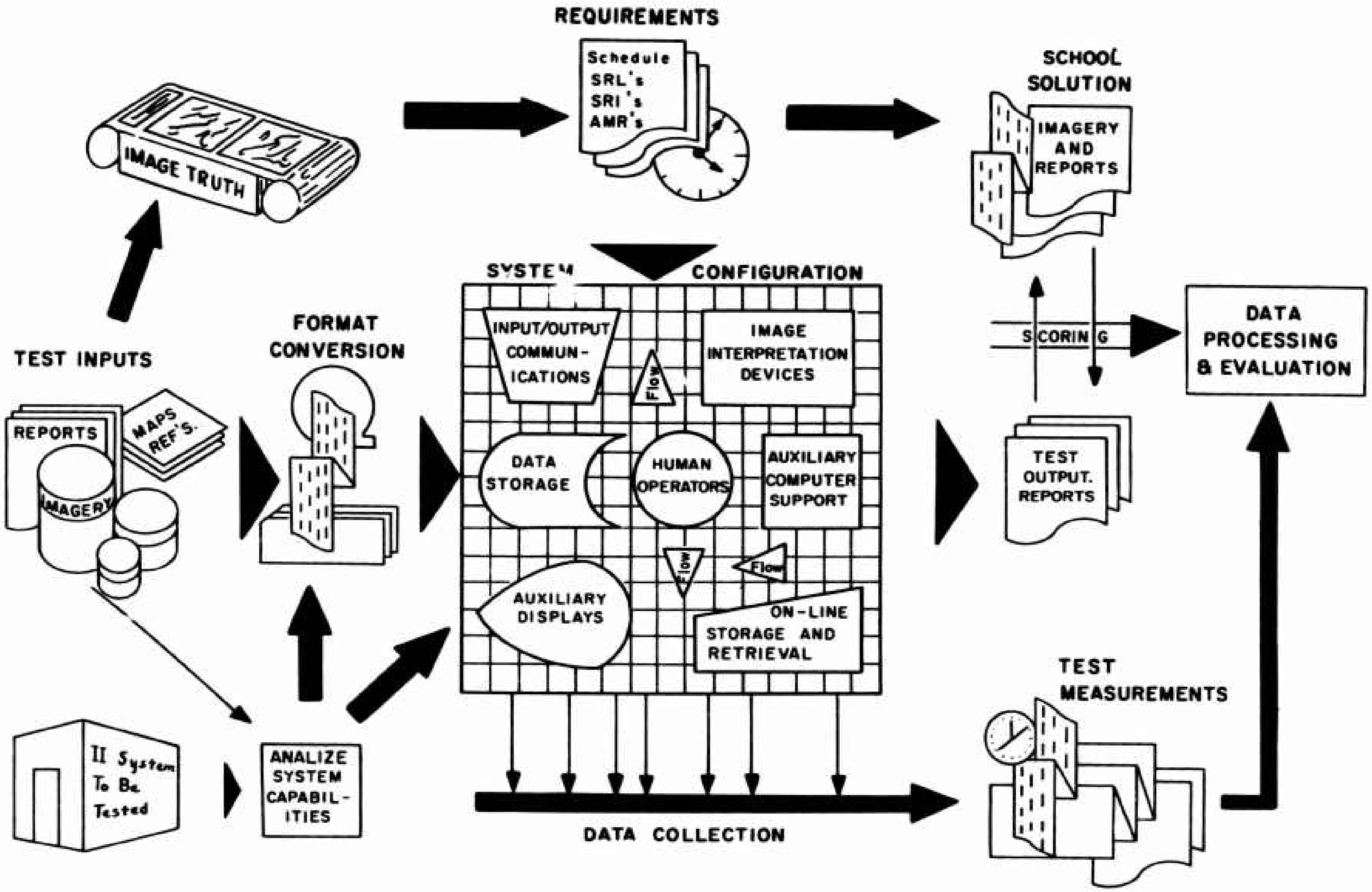


Figure 1. Systems measurement bed for surveillance experimentation. *(From Birnbaum, A. H., R. Sadacca, R. S. Andrews, and M. A. Narva. Summary of BESRL surveillance research. BESRL Technical Research Report 1160. September 1969.*

THE JOB	THE HUMAN FACTORS SYSTEM			AND THEORETICALLY EXPECTED OUTCOMES
Job Demands	Designing for Effectiveness	Selecting for Effectiveness	Training for Effectiveness	
Primarily cognitive involving acceptable objective right or wrong answers. Responses consist of Sensing Perceiving Knowing Doing	Fairly specific, non-controversial, structured goals readily set. Human engineering often effective. Job requirements tend to be consistent when environments are stable.	Mental, perceptual, and special abilities account for a significant portion of productive performance. Principal valid ability predictors are more readily identified, being fairly definitive for many jobs.	School training taps relevant variance and is reasonably related to on-the-job performance as relates to the "right" or "wrong" elements of the job	The greater the proportion of right or wrong elements in the job, the greater the likelihood that we can identify a substantial portion of the criterion variance and relate it to specific predictors for any purposes of the human factors system (selection, training, human engineering, etc.) Validity coefficients will tend to be moderate to high on such jobs. For jobs with high cognitive demand, there is greater opportunity for one part of the human factors system to compensate for inadequacies in other parts. Because of interactions between individual capabilities, training (including experience), and job designing (including human engineering), a great deal of compensation is possible, and trade-offs are more readily measurable.
The Systems Measurement Bed enables the researcher to specify required styles of behavior and goals to yield human factor systems data				
Noncognitive factors relating to style of behavior and performance reflecting specified or implied values and attitudes. Typical responses have styles or behavior such as: Forceful Command of Men Sociable Supervisory Style Cautious Staff Advice for various goals in ad hoc situations. Typical goals include: Emphasis on Quality Output Emphasis on Quantity Output	Environment both physical and psychological seems crucially important, including other employees, organization goals, supervisors, etc. Values are important and may dictate the style of behavior and goals sought	Ability measures for predicting acquisition of knowledge do not relate significantly to acceptable performance on the job after training and experience. Peer ratings and situational testing seem to tap some of the noncognitive variance. Prediction varies with the ad hoc situation. A great many predictors tend to yield same degree of prediction.	School training provides knowledge and cognitive skills to be used in the specific on-the-job environment. The job environment tends to impose the styles, values, and the noncognitive demands. Hence, experience often crucial for the "specific" adequate performance. Effective individuals make maximum use of their own talents and values to achieve goals.	The more noncognitive elements contained in a particular job, the more disagreement arises as to what constitutes judged effectiveness and therefore few stable predictors emerge relative to the various aspects of the human factor system. Since various styles of behavior are "controversial", reliability or consistency of criterion variance is low, except in "forced environments." Validity coefficients tend to be low. For jobs with high noncognitive demand, there is greater variety of styles and ability combinations for achieving goals, and compensations for inadequacies become much more individualized. Value factors and situational conditions are critical for judged effectiveness. Generalized training or generalized job design seems less effective than in cognitive demand jobs.

Schema IV. Cognitive and noncognitive job variance reflected in the systems measurement bed

It is my contention that when we speak of the noncognitive content of a job, we should seriously depart from the cognitive concept of rightness or wrongness. In the noncognitive domain, we are confronted with a host of value judgments--colored by emotionality--which in the abstract are neither right nor wrong, correct nor incorrect. Many of these value judgments tend to be bipolar in concept. For example, a person may use power <u>or</u> conciliation in attempting to achieve certain ends. Quantity may be viewed as preferable to quality or quality preferable to quantity. Daring and risk-taking may be preferred over care and caution, or vice versa. For many of these styles of behavior, there is usually a good or a bad connotation situationally which can easily flip-flop with another step up the scale. Daring and risk-taking may move to recklessness; caution may move to timidity. Moreover, it is felt that it is more useful to replace the general concepts of caution, forcefulness, and other such styles of behavior or traits with greater specificity, such as: forceful command of men in combat or cautious approaches to design of experiments.

Schema IV shows a model relating such concepts to jobs, human factors systems variables, and a systems measurement bed based on such conceptualization.

The relative significance--at various stages of training--of the cognitive and noncognitive content of a job and the resulting interaction accounts for major differences in jobs with respect to predictability. In a highly structured job such as key punch operator, the tasks involved require fairly simple but definite patterns of response to stimuli. Although some noncognitive factors may enter into the level of performance[2] of the job, there is fairly definite agreement as to right and wrong responses. The criterion for such jobs is easily specified and performance is readily predictable.

A second major concept in the systems psychology approach to the measurement of human performance in job settings is specification of the criterion variance which is to be predicted. The concern here is not with the type of criterion measures such as ratings, school grades, product measures, or the like (Uhlaner and Drucker, 1964). The concern is with value differences. Should quality be produced, perhaps at the

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[2] In any job, however simple, a general factor of good work adjustment or poor work adjustment operates. Good work adjustment may be related to a general good adjustment factor translated generally into "playing the game while observing the rules reasonably well." One can think of such an adjustment factor as a general override for almost any work, as is also the variability associated with organizational variables--leadership, incentives, and styles of management. In most jobs of this level of complexity, what is likely to happen is that an individual with a certain set of attitudes, interests, or values will be selected and will or will not accept the job, say, of key punch operator. But once he is in the job, it is his cognitive capability which will tend most of all to determine whether or not his performance is adequate--or that the job is being correctly performed.

expense of quantity or vice versa? Should life be carefully protected and safeguarded at considerable cost? Should the future be emphasized or should the resources be allocated to the here and now? It is evident that different costs may be involved in each of the different criterion choices. The value judgment by the decision maker as to what the criterion variance make-up should be determines much of the rest of the human factors system. Who makes this decision? Who decides to build quality and sacrifice quantity or vice versa? The temptation is to say, the owner of the factory, the executives, the commander. But how much does the individual producer set his own standards, style, and quality controls? Upon a few moments of reflection, it becomes clear that it is a much more complex process, varying with the total cultural-political-economic value complex of a nation. But my thrust here is that, for many applied purposes including systems development, the criterion should be a given rather than the product of a preceding set of given predictors.

In image interpretation, for example, the information output--which can be considered the criterion--can emphasize either accuracy (percent correct information reported by an image interpreter) or completeness (percent correct information extracted from an image in terms of "what is extractable"). Based on empirical data, investigators have shown that, while there is an increase in completeness as a function of increase in time, there is a decrease in cumulative accuracy (Figure 2). In the systems measurement bed, under one set of requirements, the criterion may be set to emphasize accuracy, as in the case of a commander who has to pinpoint critical targets interspersed with noncritical targets. Under another set of requirements, the emphasis may be on completeness, irrespective of criticality. The human factors system variables leading to these different criterion outputs can then be examined in relation to the type of men required, the procedures and work methods required for each of the specified criterion conditions. It is recognized that the applied requirement is often a mix.

If we keep in mind that cognitive elements of performance can be characterized as right or wrong, then schools are indeed effective environments in tapping these elements, and it is appropriate to validate the cognitive predictors for "noncontroversial" tasks in our school training programs.. We must, however, accept for this purpose the "school solutions" in the jobs being taught. Further, prediction of job performance where the cognitive element is crucial has been relatively more substantial because universality of agreement is more readily attainable. The latter works especially well when the noncognitive environment is relatively stable. Prediction of job performance where the noncognitive element is crucial involves value judgments and situational considerations, yielding less agreement on desired outcomes and hence much smaller predictability.

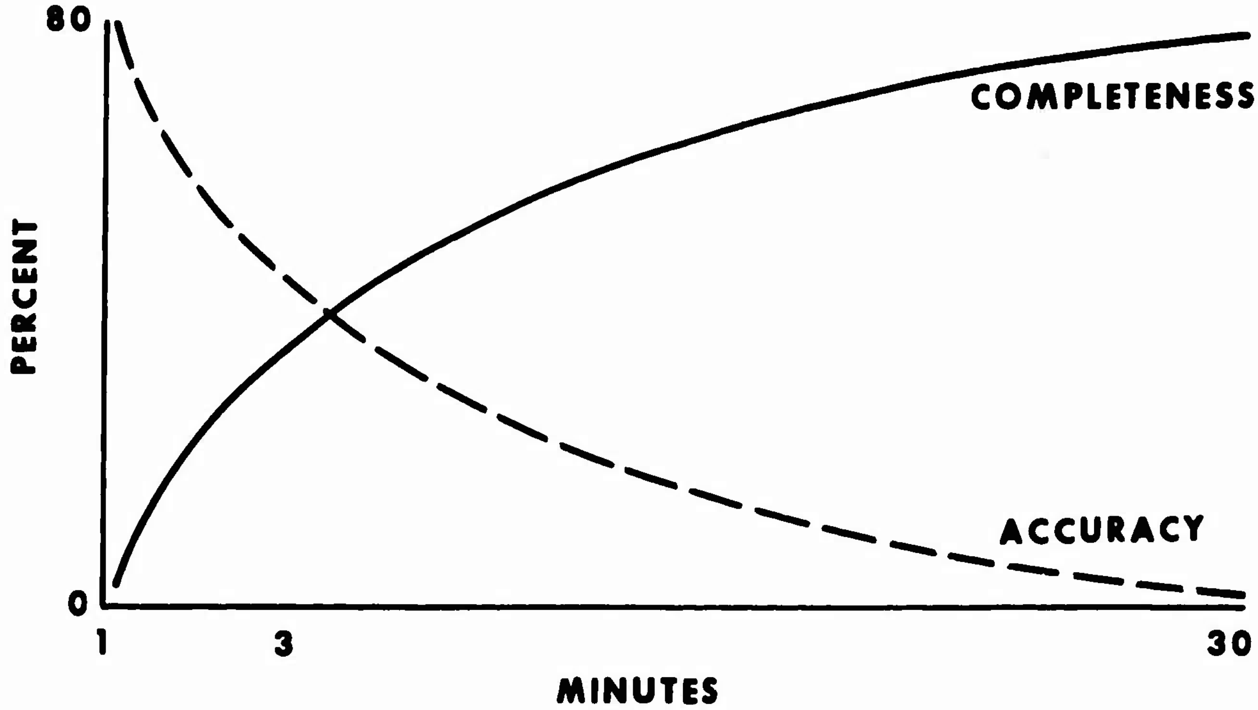

Figure 2. Interpreter performance (accuracy and completeness) as a function of time. *(From Sadacca, R., H. Martinek, and A. I. Schwartz. Image Interpretation Task--Status Report, 30 June 1962. BESRL Technical Research Report 1129. October 1962.)*

The high prediction of school success obtained with cognitive predictors is easily understood in view of the greater ease with which right-wrong concepts--in contrast with attitudinal and value judgments--are structured in school curricula. In general, the cognitive abilities are well measured and yield high validity for school grades--coefficients in the neighborhood of .5 to .7. Even for on-the-job criteria, the cognitive variance is more easily tapped. Research studies show that raters can assess with considerable agreement the cognitive elements of performance.

An analysis of over 100 studies of criteria and predictors reported in Dorcus and Jones' Handbook of Employee Selection, plus a collection of more recent validation studies, led Gaylord, Severin, and Johnson (1952) to the general conclusion that cognitive tests predict job performance--whether evaluated by ratings or by production records--better than do noncognitive measures (median correlation of .33 versus .15). Thus, even when both predictor and criterion emphasize the noncognitive, much of the cognitive enters into the relationship.

Peer ratings, and indeed ratings of most kinds including school grades, yield a heterogeneous variance. They are complex measures and quite meaningless when independent of the job situation or specific environment. In a forced environment, in which specific values and styles of behavior are taught as preferred and in which these values are continually reinforced, the rater makes his judgments in relation to the subtleties of the job demands he has been taught. He has absorbed the total systems setting and what is or is not considered desirable in that setting. The USMA is a good example of such a forced environment. The cadet learns what is considered a desirable stance and gives this emphasis in his rating; he does not, I believe, rate a trait in the abstract. He judges in terms of qualities the job demands as he was taught and how well the rated individual, in his judgment, adjusts to these demands, and whether the ratee utilizes "desirable" styles of behavior in given settings. Predicted validity is generally high when the rater has known the ratee in such job situations. The longer the period of association, the more able the rater is to make such judgments. For example, performance of officer trainees was better predicted for the West Point-trained officers in combat in Korea than for OCS-trained officers, a difference attributable to the factors discussed above (Table 2).

The crux of why we get high or relatively high covariance with the aptitude for the service rating (a combination of tactical officer and peer ratings) (Drucker, 1957) is that in a forced environment such as the service academies the other cadets have learned the desired noncognitive elements such as forcefulness in the specific settings. "Obnoxious" forcefulness is rated down. Just the right amount of forcefulness appropriate to the situation tends to be rated high. In other words, ratings in a forced environment get at the essence of job demands specified in that environment.

How does all this differ from traditional research approaches? It seems to me that what we have been doing in traditional personnel research is to abstract certain traits, bits of cognitive and noncognitive behavior, and relate them, singly or in linear combination, to part of a job criterion. We relate measures of reasoning ability, summations of self-descriptors said to describe the trait ascendency, to criterion measures of opportunity, whether it be performance in a job specialty or a job generality, e.g., leadership. In a way, we have been like the three blind men touching different parts of the elephant and describing it variously as a wall, a snake, and a piece of rope. To have a better understanding of job performance, we <u>have to have</u> the more complete ad hoc aspects of the noncognitive demands along with the cognitive demands in the appropriate combination.

The appropriate combination becomes crucial if it can be shown that there is a residue of criterion variance which is significantly different from the prediction arising from the linear combination of valid predictors.

Let us focus on the simple problem of predicting end-of-training success with empirically determined predictors. If we restrict ourselves to the case where we examine a pair of predictors, some of the principles

Table 2

PEER RATINGS AS PREDICTORS OF OFFICER TRAINING AND JOB PERFORMANCE[a]

Sample	Predictor	Criterion	Validity Coefficient
163 Leaders' Course Graduates (1948)	Bd. Rating and Report Form	Superiors' and Associates' Ratings	.18 to .40
	Stud. Lead. Eval. Report	Superiors' and Associates' Ratings	.34
	Composite of above two	Superiors' and Associates' Ratings	.34
3000 Reserve Officers (1945)	Biog. Info. Blank	Superiors' and Associates' Ratings	.35
	Evaluation Report		.60
	Board Interview		.30
	Composite of above three		.67
90 OCS Graduates (1951)	OCS Final Peer Rankings	Officer Efficiency Report for Combat Period	.41
	OCS Final Tac. Off. Rankings		.34
	OCS Final Peer and Tac. Off. Rankings		.41
353 USMA Graduates (1951)	ASR (Sr. Year)	8-Step Combat Effectiveness Scale	.50
	Phys. Educ. Grades (Sr.)		.21 to .27
	Tactics (Sr. Year)		.20 to .24
	Conduct		.24 to .28
	Summary of Acad. Grades		.02 to .13
64 to 464 USMA Graduates in Technical Services and Combat Arms (1950)	ASR (Sr. Year)	Officer Efficiency Rating (67-1)	.27 to .50
	Phys. Educ. Grades		.09 to .28
	Tactics		-.11 to .33
	Conduct		.21 to .30
	Mathematics Grades		.06 to .23
	Class Standing at Graduation		-.12 to .18

[a] Drucker, A. J. Predicting leadership ratings in the U. S. Army. Journal of Educational and Psychological Measurement. Volume 17, No. 2, 240-263, Summer 1957.

are more readily apparent. Further, one predictor of the pair is drawn from the broader mental ability domain--mathematical aptitude--and the other from the more specific aptitudes--mechanical aptitude. Further, we contrast the phenomenon between more complex jobs (electronics) and less complex jobs (electrical).

I should now like to introduce the principle of substitutability with intensification or dilution (nonlinear), adding it to the existing principle of substitutability with compensation (linear) (Guilford, 1954).

The principle of substitutability operates in several ways. In one case, a relatively high level of ability in one area makes up for a low level in another so that observed performance equals that predicted from a linear combination of two predictor measures. This phenomenon has been defined as substitutability with compensation. The data base gives some indications that a further interaction is operating under certain circumstances.

From an Army sample of over 20,000 cases, studied with respect to a variety of predictors in approximately 100 jobs (MOS) providing criterion measures in an end-of-school setting, two groups of samples were identified: the first in a variety of electrical jobs and the second in a variety of electronics jobs. The demands of the electrical jobs were less complex than those of the electronics jobs. A concept of substitutability between two predictors, mechanical aptitude and mathematical aptitude, was hypothesized. If the observed criterion score is greater than the score predicted from the linear model (with appropriate beta weights, etc.), then the difference can be considered substitutability with intensification. In other words, the observed measures of performance are higher than that predicted by a linear combination of mechanical aptitude and mathematical aptitude. If the observed criterion score is smaller than the score predicted from the linear model (with appropriate beta weights, etc.), then the difference can be considered substitutability with dilution. If predicted and observed performance means are equal, then substitutability can be considered compensation in the linear sense: that is, a certain amount of mathematics aptitude is substituting in linear fashion for lesser mechanical aptitude. Further, it was reasoned that intensification is more likely to occur in the more complex jobs. Table 3 substantiates the hypothesis that for more complex jobs (electronics, in this case), substitutability with intensification does operate. For this analysis, the criterion performance of men relatively high in mathematics (minimum standard score 110) but appreciably lower in mechanical aptitude (at least 20 points--about one standard deviation) was examined. If, for example, a man had a score of 130 in mathematics aptitude, his mechanical aptitude score had to be no higher than 110. In this case, the linear model fails to account for the higher criterion scores of this select group. In less complex jobs (electrical), with a similarly select sample, the linear model explains the variance. Hence, only compensation seems to operate here.

Table 3

DIFFERENCES BETWEEN OBSERVED AND PREDICTED CRITERION SCORES WHEN THE MATHEMATICS PREDICTOR SCORE IS SUBSTANTIALLY (AT LEAST ONE S.D.) GREATER OR SMALLER THAN THE MECHANICS PREDICTOR SCORE (Large Differences Reflect Non-Linearity)

Electronics Jobs	MECH > MATH				MECH < MATH			
	Pred	Obs	N	T	Pred	Obs	N	T
BASIC ELECT	83.70	83.40	47	-.25	81.50	87.50	6	1.50
HAWK E. W. RADAR MECH	80.85	82.77	13	.83	80.92	84.77	13	1.37
HAWK MISS REP	88.00	87.69	29	-.27	80.40	85.20	5	.84
HAWK FIRE CNT	84.65	84.55	20	-.08	81.00	83.67	6	.79
ELECT REP APPRENT	75.69	76.23	13	.51	83.60	84.56	25	.95
NIKE LAUNCHER SYS REP	80.92	80.54	13	-.28	81.00	91.00	1	-
HAWK RADAR REPAIR	81.65	83.54	20	1.12	81.38	83.38	13	1.28
MICRO WAVE REPAIR	94.20	96.80	5	.50	101.49	103.58	43	1.12
FIELD STA RADIO REPAIR	101.05	101.23	22	.08	89.00	95.75	4	2.74
FIXED PLANT COMM REPAIR	98.00	104.64	14	2.12	101.24	101.14	37	-.05
RADIO RELAY ATT	83.94	84.10	51	.17	85.05	85.00	37	-.04
FIELD RADIO RELAY EQUP REP	78.63	78.11	19	-.24	77.88	78.38	16	.31
FIELD RADIO REPAIR	81.87	82.77	39	.74	79.20	83.40	5	.94

Electrical Jobs	MECH > MATH				MECH < MATH			
	Pred	Obs	N	T	Pred	Obs	N	T
BALLISTIC MISSILE REPAIR	80.00	81.00	5	.26	79.69	81.69	13	.80
WIREMAN	83.64	81.00	11	-1.50	82.00	84.33	3	1.32
WIREMAN	84.50	88.75	8	2.07	83.00	85.00	5	1.75
WIREMAN	85.38	85.23	13	-.11	84.75	81.00	4	-2.51
LINEMAN	86.46	86.56	48	.14	88.86	89.50	28	.74
MAN CEN OFF REPAIR	83.00	83.90	10	.46	83.78	83.67	18	-.06
DIAL CEN OFF REPAIR	96.40	85.20	5	-2.70	101.50	95.50	2	-1.20
TELETYP REPAIR	84.00	84.71	2	.46	83.50	75.50	2	-.89
FIXED CARTOGRAPH REPAIR	105.94	105.00	16	-.45			0	

SUBSTITUTABILITY/INTENSIFICATION IN ELECTRONICS JOBS BUT NOT IN ELECTRICAL JOBS

	Substitutability with Compensation	Substitutability with Intensification	Substitutability with Compensation	
	(Electronics)		(Electrical)	
	Mech. > Math.	Math. > Mech.	Mech. > Math.	Math. > Mech.
No. Samples	13	13	9	9
Total N	305	211	118	75
Total $\bar{d}$	.60	1.55	-.40	.31
Crit Ratio	.12	2.58	-.34	.62
P	-	<.01	-	-

d = Y - Y' = observed crit - predicted crit.

No data are offered in this paper for the substitutability with dilution model. It seems likely, however, that the combination of different domain variables--cognitive, noncognitive--may yield even greater substitutability/intensification and substitutability/dilution.

To the degree the linear model operates effectively, prediction from one time frame to another--from school to job, for example--is appropriate using present variables and regression techniques. To the degree the linear model does not sufficiently explain what is going on, the systems measurement bed gives one the opportunity to embed appropriate subjects (often after extensive training) for appropriate data points.

In summary, if we accept that cognitive elements of tasks and jobs have a reasonably objective right or wrong specification but that noncognitive elements deal with styles of behavior and values not readily identified as right or wrong except on an ad hoc basis, then criterion measures containing such noncognitive components may have to be specified arbitrarily by the policy maker, the decision maker, the "man with authority" and/or the scientist in order to reach scientific conclusions as to what is really taking place under a specified variety of criteria or specified outcomes. It is recognized that the specified desired outcomes can have strong plus or minus preference loadings.

In the case of complex jobs (electronics), the combination of mathematics aptitude of higher level with mechanical aptitude of lesser level has been shown to be nonlinear and in the direction of intensification. Individuals who possess this combination of predictors, then, will better represent the group of people for whom such criterion performance is characteristic than will individuals identified by scores linearly derived (with beta weights) from a large random sample of individuals possessing varying amounts of such predictors.

The research framework suggested is the system measurement bed. The focus of inquiry concerns itself with the human factors system variables shown in Schemata I through IV. These deal with designing, selecting, and training for effective behavior.

Once the framework and the focus of inquiry are decided upon, we must build into the systems measurement bed job elements in an interacting context to enable us to study operations and outcomes so as to gain insights and data for predicting and managing desired behavior--in our case, effective military behavior.

For such studies, it becomes crucial, in the opinion of this writer, that the performers in systems measurement beds be experienced and even "expert" performers in whom the nonlinear combinations of abilities have already taken place by virtue of a host of factors including training, experience, and systems variance. By examining the behavior of such appropriately trained and experienced performers in such scientifically unique settings, the human factors system variables can be more meaningfully interrelated.

Such studies involve the performers as dependent variables in an experimental design conducted in a specified situation. The results of such experimentation are measured in terms of the amount of variance predicted in the systems measurement bed, variance which may be accounted for to only a slight extent, and perhaps not at all, by the individual differences in the performers. The objective: to gain a better understanding of human performance in a specified realistic setting. The systems measurement bed is a means of focusing step by step on the human performance aspects of the system to be enhanced and identifying the interrelationships of the human factor system variables in order to determine, for a given cost, productivity under varying conditions.

What is proposed is a vehicle for looking at what really happens on a job in a more systematic way. We must move from preoccupation with the covariance of abstract measures--which often yields little in the way of scientific knowledge--to a means of bringing into the laboratory a better and more meaningful representation of the jobs and systems to be studied. Our psychometric heritage of measurement techniques has provided us with such concepts as construct validity and predictive validation. The last 50 years have given us a rich methodology of empirical methods and more recently a sophisticated base of computer techniques which together make simulation a more mature technology. With the systems measurement bed and system psychology principles, we can now vary men, training and experience, management styles in relation to specified outcomes and thus apply the more rigorous methodology of experimental psychology to the study of jobs and human performance in systems settings.

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13. ABSTRACT - Continued

relatively high level of one aptitude to compensate for a lesser level of another aptitude. This major hypothesis, tested and supported in appropriate samples, highlights the complex of performance as a function of abilities. Crucial to productive experimentation in the framework of the systems measurement bed is the participation of performers who are experienced and even "expert" in the job situation under scrutiny.

The theoretical discussion, the hypothesis developed and tested, and the resultant research considerations strongly affirm that the generation of principles for the understanding of pertinent human behavior in certain jobs (e.g., electronics specialists, high level jobs in complex information systems, military commanders and leaders) seems to demand a special research framework. The research framework which meets such a requirement is the systems measurement bed.

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13. ABSTRACT

The major hypothesis concerns the way aptitudes, job demands, and surrounding conditions coalesce to yield varying levels of performance.

The conceptual background for the hypothesis includes: 1) a taxonomy of jobs containing cognitive variance (responses more objectively characterized as right or wrong) and noncognitive variance (responses less objectively characterized as desirable or undesirable); 2) the ad hoc nature of values and goals (quality output, safety of operation, quantity output, etc.); 3) the great variety of styles of behavior (authoritarian, forceful, democratic, permissive, cautious, risk-taking, etc.) by which individuals and organizations seek to achieve and do achieve goals.

Styles of behavior and values and goals are considered ad hoc by the investigator. To the extent that <u>such</u> variance enters into criterion determination, it is proposed that for many applied purposes including systems development, the criterion should be a <u>given</u> rather than the yield of preceding predictors, and the criterion should be explicitly specified with respect to both cognitive and noncognitive variance. The systems measurement bed--constructed for research purposes to contain situational tests and exercises--can be designed to yield such criterion measures and measures related to the human factors variables.

And most importantly, in certain jobs (probably more complex or less structured jobs) as performed by groups of individuals whose effectiveness is greater than would be expected based on the usual linear combination of empirically validated aptitude measures, there occurs an intensification of capability that goes beyond the use of a

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	ROLE	WT	ROLE	WT	ROLE	WT
Personnel psychology *Systems research *Systems psychology *Systems measurement bed Human factor variables *Military Manpower management *Prediction research Military research psychology *Human performance prediction Cognitive - noncognitive dimensionality Leadership behavior Behavioral interactions Value judgments Value differences Measurement techniques Methodology - experimental psychology *Behavior and systems research theory						

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