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A PROPOSAL FOR THE EVALUATION OF BIOLOGICAL INFLUENCES UPON COG--ETC(U)

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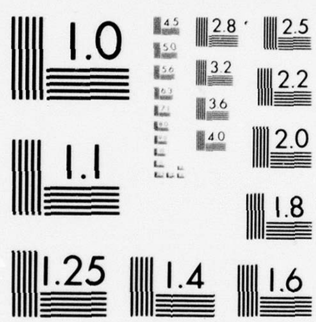
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A PROPOSAL FOR THE EVALUATION OF BIOLOGICAL INFLUENCES UPON COGNITION

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Cognitive behavior depends upon both educational and medical factors; i.e. what a person knows and how well the person is. A complete examination of a person's functioning would include both physical and mental functioning, insofar as the latter could be viewed as a concomitant of physical condition. Tests of cognitive behavior that have developed for educational and personnel selection settings, however, may not be appropriate or feasible in medical settings. The appropriate criteria

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) for mental testing allied with both medical maintenance and biologically oriented research are considered. Some examples are given of the sort of mental functions that should be tested. Illustrative performance tests are provided in the appendix.

A Proposal for the Evaluation of Biological Influences upon Cognition.[1]

Earl Hunt[2]

The University of Washington

I. Introduction

One of my sons has the challenging, if unnerving, habit of prefacing his questions by the words "What, exactly, does..." I dread the day when he wants to know about the effect of marijuana upon thinking. I would feel the same sense of humility if he asked about alcohol, valium, or the amphetamines. My worry is not just limited to drug effects. Aging, hypertension, inadequate nutrition, fever, and even continued lack of sleep are all biological events that we are sure affect our thinking. It is not clear how or why.

Psychologists should not let this situation continue. Major advances are being made in our understanding of human physiology, neurology, and biochemistry. If we can simultaneously develop precise descriptions of the effects of various biological agents upon cognition, then we are likely to make a major advance in our understanding of the physiology of thought. Such advances could have incalculable scientific and practical consequences. Consider the case in pharmacology, which is particularly acute. There are now in use a number of therapeutic drugs that have cognitive side effects. Indeed, in some cases the primary reason for giving a drug may be to obtain a particular psychological effect, although the desired effect is seldom on the reasoning processes themselves. A total picture of the efficacy of drug therapy can only be obtained if one monitors the components of rational thought. The use of prescription drugs is only part of the problem. Recreational drugs are a fact of life. We need to be able to monitor their effects upon cognition for diagnosis and therapy in cases of drug abuse, and in order to provide advice to policy makers who are charged with developing policies concerning the regulation of drug use.

We do not need to consider only those biological agents that we introduce. Natural biological processes also affect cognition. Aging, for instance, is associated with marked changes in cognition. Shifts in cognitive capacity from age 20 to age 60 are well documented. We have little idea when and how such changes occur. Which cognitive functions change gradually, and which change suddenly? Are changes the natural concomitant of aging or are they associated with either critical problems, such as febrile infections, or chronic problems such as hypertension or intemperate (but socially acceptable) levels of alcohol use? The answers to such questions will become increasingly important to those who are charged with maintaining the health of an aging population. The questions will be similarly important to those who wish to utilize the talents of an older work force.

Saying that a biological event "affects thinking" is inadequate. What we require is a way of dissecting such a general statement into statements tying specific events to quantifiable influences on specific aspects of thought, memory, perception, etc. Furthermore, we must be able to measure such influences at the level of the individual, because there are marked individual differences both in thinking and in physiological reactions to almost every event. The gist of this paper is that it is time to begin development of a standard set of assessment procedures that were developed specifically to measure biological and cognitive interactions, and are not simply procedures borrowed from the methods used in other assessment procedures in education and medicine. There will certainly be analogies between the methods proposed here and methods used in other cognitive areas. Perhaps the closest analogy is to the use of behavioral measures to assess neurological damage through the procedures developed by Halstead, Reitan, and their collaborators (Russell, Neuringer, and Goldstein 1970). As was the case in the development of cognitive measures in neurology, the special characteristics of different assessment problems requires careful evaluation of the appropriateness of the procedures to be used. The proposition that there is ever going to be a general, all purpose method of measuring cognition seems dubious.

The immediately following section discusses the problem of psychological measurement in a "public health - preventive medicine" setting in somewhat more detail. For convenience, the study of drug effects will often be used as an illustration. I believe that the seme general concerns are applicable to any combining of medical and physical examination procedures. I will discuss the restrictions that must be placed upon cognitive assessment, and questions whether many "standard, clinical" tests of intellectual functioning cannot satisfy these restrictions. The third section of the paper provides a plan for choosing tests of cognitive functioning. The fourth section describes some illustrative procedures that might find their way into a test battery. The fifth section outlines the steps that must be executed before such a battery becomes a reality.

II. THE REQUIREMENTS TO BE MET

Cognition can be evaluated in a number of ways. Day to day cognitive capacity is defined by how smart we seem to be to ourselves and to our associates. Indeed, peer ratings could be used to evaluate a person's mental state. These would be face-valid assessments of a person's global functioning in both the cognitive and social realm, and might, indeed, be useful predictors of subsequent performance. At the other extreme, Jensen (1978) has proposed the use of a specific technique for measuring choice reaction time as an index of general intelligence. If we regard these two proposals as extremes along a continuum of possible test procedures, we will find some procedure at almost every point in between. Following a useful technique in mathematical problem solving, let us consider what restrictions on measurement are inherent in most medical settings. These restrictions may limit our possible sets of measurements to some manageable set of candidate procedures. The restrictions that are to be imposed fall into two broad categories; conceptual restrictions forced upon us by the nature of biomedical research, and practical restrictions that are dictated by the logistics of health care delivery. Each category will be considered separately.

What is it that we are trying to measure? Cognitive competence is a blend of what a person knows and how well she or he is able to manipulate that knowledge. In only slightly more formal terms, we can distinguish between the information a person has in their memory and the capacity that the same person has for processing information in general. Physical agents, such as drugs, hypertension, or fever, must act upon information processing capacity rather than upon information per se. Thus any test of the effects of a biological agent should be a test of cognitive processing, and not a test of knowledge possession. Note that there is a quite different situation in education, where testing for knowledge is appropriate.

It is probably impossible to construct a test that is completely knowledge free. It is possible, however, to construct a test such that, in appropriate populations, variations in individual performance are not due to variations in the possession of knowledge. Some examples are given in the appendices. The criterion that test performance should not be a function of knowledge is far from a vacuous one. Most "intelligence tests" developed for use in an educational setting do test knowledge, and for perfectly appropriate reasons. If we wish to predict performance at an absolute level, then global assessments of overall competence are our best ways of doing so (Wechsler, 1975). This is a different goal from the goal of evaluating changes in cognitive competence due to changes in physical status.

"Information processing capacity" is a global concept. There is substantial argument that it is an appropriate one, because there may be a general "facility in information processing" factor that underlies cognition (Jensen, 1978). Without going into any detail, I simply state that this is not my view. I regard cognition as being composed of a set of rather specific skills; short term memory, control of attention, ability to manipulate visual images, etc. I shall go into more detail concerning the nature of these skills subsequently. A specific skills approach appears to me to be more compatible with our theories of psychopharmacology than does a theory of general intelligence. We do not think of drugs as "influencing the brain", we think of them as influencing particular chemical systems that are differentially important in different structures of the brain. Admittedly, the interaction between the various systems and structures can be bewildering. Nevertheless, I believe that it will be more profitable to examine biological effects upon specific information processing capacities than it will be to examine effects upon measures of general intellectual capacity, even when these measures are relatively unaffected by knowledge.

Ruling out tests of general intellectual functioning is no more vacuous than ruling out tests of knowledge. There are a variety of "culture free" or "culture fair" tests, such as the Raven Matrix test, that might conceivably be used as evaluation devices. I do not believe that these tests are very useful as direct tests of biological effects, but I shall describe an indirect use of such tests subsequently.

Now let us move from conceptual to practical issues. From the viewpoint of a health care practitioner, a measure of cognitive behavior should be rapid, repeatable without concern for practice effects, and should be administerable in a highly objective way by minimally trained people. The more that the cognitive test looks like the measurement of blood pressure, the better. No such cognitive measurement procedure exists. There are some cognitive functions that cannot, in principle, ever be tested in a way that will meet these requirements. Thus we want to consider when and to what extent issues of speed, repeatability, and objectivity are important.

Rapid measurement is essential in any situation in which the phenomenon to be studied is restricted to a relatively brief period of time, such as a particular stage of drug intoxication. Speed of administration is also a requirement if the available subject time is limited either for administrative reasons, which can be a major problem when dealing with non-institutionalized individuals, or because the patient can only stand so much testing before becoming "mentally exhausted." The latter problem is serious with the elderly. Speed of administration is less of a factor in studies of chronic effects. It should be noted, though, that very long batteries, such as the Halstead-Reitan procedure, which requires hours to administer, are probably going to be of only restricted use in most health care settings, simply because the patients cannot spare the time. In generalthe approach that I advocate is to have an "armory" of tests from which a small number of tests are to be selected in each study, rather than committing oneself to the computation of indices that can only be calculated if an entire battery of tests is given to each individual.

Repeatability of the measurement procedure is essential whenever a within subjects design is used. There are three separate aspects of repeatability. Some tests are inherently unrepeatable, in the sense that they lose their validity on second administration. Measurements of academic achievement are examples; asking the question sensitizes the person to a second query. This problem can be handled, in part, by the construction of parallel tests, but there are practical limits to the number of parallel tests that one can have. A more interesting issue in repeatability is the problem of practice effects. The most obvious, and least interesting, issue is that reactions to a medical event may be masked by the change of performance level with practice. A somewhat more interesting issue is the fact that some events may be dependent upon the subject being at a particular level of skill. This is not just a nuisance, it is a phenomenon worth of study. There is considerable evidence arguing that highly overlearned, "automatic" skills are much less susceptible to drug effects than are tasks that require some allocation of the subject's attention. Such observations suggest that many drug effects can be understood in terms of an effect upon attentional resources and attention allocation, rather than by an effect upon specific cognitive systems. This thought has considerably influenced the selection of tests that is proposed below. Finally, the practice effect is a form of learning, and learning is a cognitive process of considerable importance in itself. If a drug influences the learning process, this is an extremely important finding.

Repeatability effects, thus, touch on both theoretical and practical concerns. Objectivity and economy of administration are strictly logistical concerns. In educational measurement objectivity and economy are achieved by restricting the test format. This usually means paper and pencil, machine scored tests. While this is a useful format that should always be considered, it is restricted in an important way. Item by item measures of response speed are virtually impossible to obtain. This can become important if one wishes to test a subject's ability to allocate attention to one or more tasks, on a concurrent basis. Recent developments in microcomputer technology have offered us ways to expand the format of objective testing and, in particular, to measure response times much more accurately than we can using paper and pencil tests. Here, however, we again encounter a learning problem. Most people are not proficient in the operation of computer controlled equipment. It may be advisable to train subjects in the use of equipment before beginning the experiment itself, in order to have better control over the problem as the subject sees it.

Objective measures of intellectual performance implicitly assume subject motivation. This assumption may not always be valid in medical settings, especially when dealing with ill persons or psychiatric cases. No general guidelines can be given; in part because there is little integration between theories of motivation and of cognition. Indeed, the need to have such an integration in order to do research on the physiological basis of cognition highlights a serious deficiency in cognitive psychology. There is little that we can do to "control" for motivational effects. It is highly desirable to obtain some measure of motivation and mood at the same time that one obtains a measure of cognition.

III. A THEORETICAL PLAN FOR GENERATING TESTS OF COGNITION

The constraints described in the preceeding section are serious but not insurmountable. Indeed, the statement of constraints may dictate the solution. This section presents a framework for generating procedures for cognitive measurement. A few remarks concerning its theoretical basis are in order.

The basic approach has been to draw an analogy between human thinking and the information processing that occurs in digital computer systems. Both humans and computer systems are seen as specific examples of problem solvers who operate on the information available to them in order to create new information. This view forces a sharp distinction between problem solving capacities that are due to the possession of specific information and problem solving capacities that are due to a capability for manipulating information in general. The latter will be referred to as mechanistic processes. Biologically derived effects, being due to a manipulation of the physical state of the information processor, must exert their action directly upon mechanistic processes. We do, however, have to realize that any particular problem solving activity depends on the interaction between mechanistic and information-specific capacity. Alterations of mechanistic processes may change the relative efficiency with which a person can deal with different types of information content, and thus bias cognition toward the use of content that can be handled best, given the state of the mechanics at the time. Thus it will be appropriate to consider measurements both of the efficiency of various mechanistic processes under different physical states and of the probability of their use in problem solving. The existence of qualitative changes in problem solving style during different physical states would not be evidence to cause us to reject the information processing view in dealing with psychology in medicine. Such findings would demand an explanation within the information processing framework.

The computer analogy has to be supplemented by two concepts that do not have clear analogs in physical information processing systems. One of these is the concept of attentional resources. This is a "power" concept; we assume that cognitive machinery draws upon a pool of rather poorly defined attentional resources, and that the machinery works only to the extent that an appropriate amount of attention can be supplied. Attention, itself, is looked upon as a finite resource. Both the amount of attention available and a person's flexibility in allocating it are important processes in the mechanics of cognition.

"Mood" is a concept that certainly has no analog in computer processing of information, but it is important in human processing.

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The concept of mood is difficulty to fit into a mechanistic approach to thought. As a first approximation, I think of mood in two different ways. One is as a biasing factor. Most of the information with which we deal is ambiguous. It may be incomplete, or even when complete, it may permit several different interpretations. In addition, virtually all interpretations of information have some affective load. One of the effects of mood may be to bias the individual toward interpretations that have a particular affect. (Isn't this the basis of our many optimist-pessimist jokes?) Since there is a powerful drive toward consistent interpretation of thoughts over time, a person's mood could cause the interpretation of a key piece of information in a way that could exert considerable influence over subsequent thoughts.

The second role of mood is as a stimulus in itself. Mood is part of the information stored during a learning experience, and hence a part of the scheme for retrieval of this information. At the Belmont conference on drug abuse, H. Weingartner offered this as a plausible explanation for much of the state-dependent learning phenomena. In addition, mood, as a stimulus, may have the capacity to capture a substantial amount of a person's attentional resources. This could make it virtually impossible to execute cognitive acts that themselves require attentional resources. A recent article by Hasher and Zacks (1978) discusses this point in more detail, with special reference to depression.

We are well short of the goal of having an information processing theory that integrates attention and mood. We do know that they have to be integrated into the theory, and that any measurement of cognition must, at a minimum, consider attentional effects. Mood effects probably ought to be considered as well.

IV. GENERATION OF A TEST BATTERY

In order to generate specific tests within this theoretical approach, some consideration has to be given to a classification scheme for the possible cognitive functions. This classification scheme should be considered as a way of describing cognitive functions from different points of view. To be specific, we shall consider cognitive tasks that differ in the type of stimuli used, the degree of involvement of memory, the demand for attentional resources, and the extent to which "strategic choice" can be executed by a person faced with solving a task. Although the term "dimension" will be used, for clarity, it is important to remember that a cross classification scheme is not intended. Our approach is that there are a number of different ways of looking at cognitive behavior, and that an armory of tests of cognitive functioning must be wide enough to allow us to take the appropriate view under the particular circumstances. Commitment to a monolithic theory of "what intelligence is" would put us far beyond the current state of psychological knowledge.

Stimulus class: This dimension describes processes by the type of information with which they deal. Within this dimension there are two psychologically relevant schemes of subclassification. Physically, information may be presented through different sensory modalities... visual, auditory, tactile, etc. We need consider only visual and auditory stimuli. Logically, stimuli should be classified as being linguistic or non-linguistic, as this clearly makes a difference in our behavior and, further, this has resulted in the evolution of different physical structures for dealing with language stimuli.

At a more psychological level, Garner (1976) has proposed that we distinguish between stimuli whose features are separable, integral, or configural. Loosely, separable dimensions are attributes that are clearly seen as distinct, independent characteristics, such as color and size of geometric figures. Integral attributes are attributes that fuse together, to form a global impression, even though the dimensions themselves can be distinguished with an effort. An example is the fusing of temperature and wind to produce an impression of a cold day. Finally, configural stimuli are stimuli where the overall impression is not predictable from knowledge of the parts. Our impressions of physical attractiveness, for instance, are not predictable from knowledge of the size of a person's nose, shape of ear, etc. These intuitive notions have been formalized by Garner and his associates, and they have developed precise methods of measuring separability, integrality, and configurality. The extent to which this is an important dimension of stimulus classification in medical research is simply not drug known. It may be quite important when we deal with psychoactive drugs. Informal reports of the effects of the hallucinogens (and marijuana, in particular) suggest that one of the effects of these drugs may be an alteration in our tendency to treat stimuli as being separable, integral or configural. There are similar, almost anecdotal, reports of changes in stimulus assessment associated with age and sex.

Involvement of memory: Memory has played a central role in theories of cognition since Aristotle. A number of ways of classifying memory types and functions have been proposed. There are four logical classes of memory functions; speed of access to information in store, given that it can be accessed, the probability that one can obtain access to a particular piece of information at all, the storage process, and a rather more vaguely defined process that I shall call transformation. In terms of structure, the distinction between sensory buffer memories, short term memory for information presented within a minute, and long term memory seems to be well established. I suggest reserving the concept "long term memory" for records of events that have occurred at least a day before, rather than for events that have occurred within an hour. Each of the different memory functions may have to be studied separately for each type of memory, as it is at least plausible that we are dealing with physically different storage systems.

Some theoretical treatments of memory make a distinction between episodic and semantic memory (Tulving, 1972). Episodic memory is our memory for specific, time bound events, whereas semantic memory is our memory for general, timeless knowledge. Note that this is a logical distinction, rather than a psychological one, since any information that is part of semantic memory must be obtained in a particular episode. In this note I will not consider the implications of the episodic-semantic distinction, but it may be appropriate to amplify upon this at a later time.

Now let us look somewhat more closely at the different memory functions.

Speed of access to information is of interest as a test of the level of ultimate efficiency of our memory system. Highly automated access to overlearned material, such as recognizing the letters of the alphabet or the meaning of common words, or just that a particular configuration of letters is a common word, can be thought of as an exercise of our memory functions at their peak efficiency.

Speed of access to information in short term memory seems to involve quite different processes, which are attention demanding rather than automated. Rapid access to information in short term memory is an important cognitive function because it provides a m mechanism for integrating information presented in discrete units over time. This should be particularly important in speech comprehension.

Probability of recall. Our ability to recall information that we have acquired is an important part of our cognitive functioning. It is useful to look upon recall as the construction of a retrieval scheme, analogically similar to the scheme one uses to search for information in a library. The amount of cueing provided by the situation determines the extent to which the person must be responsible for developing the retrieval scheme. The effects of prior and subsequent learning can also influence the need for an elaborate scheme. Reports of an interaction between the drug state and amount of cueing needed to produce recall suggest that this will be a particularly useful area of research. Similar effects have been noted in research on the aging, for aged people also seem to have problems in constructing retrieval schemes. This may be due to general deficits in attentional resources, as discussed below.

Storage. By this term I mean the consolidation of information from one stage of memory to another. The transfer of information from sensory buffer memory to some form of short term memory involves a merging of stimulus-driven information with information aroused from long term memory. In the final stage information from short term memory must be consolidated into long term memory. Norman and Bobrow (in press) have made the important point that the consolidation of information must include consolidation of information on which a retrieval scheme can act. In essence, we store both a piece of information and some directions about the contexts with which that information is to be associated.

The various stages of memory transfer very probably involve different physical processes, and thus may be affected differentially by different chemical agents and/or biological processes, such as aging or brain injury. In addition, any physical agent, such as a drug, which has important cue properties of its own will become part of the context within which the information is consolidated.

Transformation: "Transformation" will be used to refer to the process by which we change a memory image into some more manageable form. Since the term is vaguely defined, I will proceed by examples. Shepard and his collaborators have developed techniques for studying the rotation of visual images "inside the head." Two figures are presented at different orientations, and the subject is asked to determine whether they are actually views of different physical objects, or of the same object viewed from a different perspective. This would be an example of short term memory transformation of a visual, non-linguistic stimuli. In sentence comprehension studies the person being tested must determine the meaning of sentences that vary in surface form. An example would be the realization that the sentences "A to the right of B" and "B to the left of A" mean the same thing. In speech comprehension studies the subject may have to extract the gist of meaning from long passages, or even from books.

From the examples it is clear that transformations are varied, and may depend upon different physical structures and processes. The function of being able to transform stimuli is a crucial one for cognition, as we seldom, if ever, have to react to exactly the same stimuli that was presented before.

The involvement of attention: The simplest view of attention allocation is that there exists a pool of "attentional resources" which is drawn upon in order to fuel cognitive processes. Routine, highly practiced processes ("automatic processes") can be executed with little attentional resources, while more complex, novel tasks require allocation of a substantial amount of attention. Since the attention resource pool is limited, there will be a limit upon the number of tasks that we can do at once. The extent of the limitation depends upon two things; the extent to which two tasks must use the same physical structure (which is not very interesting) and the extent to which the tasks, separately, draw upon the attentional resource pool. Because of the pervasive need for attentional resources, anything that affects the amount of such resources will have a profound effect upon cognition.

Simplistic as this idea is, it proves to be a surprisingly accurate summary of many facts about thinking (Kahneman, 1973). A technology for measuring attentional resource allocation has been developed. This is based upon the secondary task methodology. In a secondary task paradigm the subject is asked to do two things at once. The primary task is typically a difficult, attention demanding one, such as mental arithmetic. The secondary task is a simple one whose performance is believed to vary continuously as a function of the amount of attention devoted to it. A frequently used task is response to a simple probe stimulus, either a light or a tone. Speed of responding is assumed to be an ordinal measure of the amount of attention available for the secondary task. A reward schedule is established such that the person should always perform as well as possible on the primary task, and only then devote attentional resources to the secondary task. Thus performance on the secondary task can be used to compare the attentional demands of different types of primary tasks. For instance, this technique can be used to show that mental arithmetic is more demanding than simple counting.

The distinction between tasks that make large or small demands upon attention is assuming increasing importance in our theories of cognition. Some processes, such as the recognition of word meaning, seem to be highly automated and apparently require almost no attention. Other tasks, such as the phrasing of sentences or text comprehension, are highly attention demanding. There are similar examples of attention free and attention demanding tasks dealing with non-verbal stimuli. Since attentional resources availability may be a function of biological status, cognitive functions that depend upon attention resources should be highly responsive to changes in age, physical condition, and drug state.

Just measuring "total attention" is not enough, we are often interested in a person's ability to control the allocation of attention to different tasks. This includes both the ability to shift attention from one task to another in serial fashion and the ability to perform one task while monitoring signals relevant to a second task. A great deal of work on these problems has been done in the

Human Engineering field, especially in studies of the selection and evaluation of aviators. Some of the human engineering techniques may well be adaptable for biomedical research. The biggest drawback to the measurement of split attention, however, is that the procedures used typically require manipulation of fairly complex equipment. Therefore it will often be necessary to pretrain experimental subjects prior to beginning the experiment itself. This could be a substantial logistical problem.

In addition to measuring people's ability to react to signals, we must also measure their ability to withhold reaction, since this is the essence of ignoring distractors. Measurement of susceptibility to distractors is generally accomplished using computer-controlled stimulus presentations or other rather formidable laboratory procedures. An example would be the use of the Brown-Peterson paradigm for studying the effects of distractors during a short term memory task. There are some paper and pencil procedures, such as the Stroop test, that are worth investigating.

Strategy use In closing the section on general considerations, I shall introduce a concept that stands somewhat apart from the three dimensional classification system shown in Figure 1. There is a pervasive, though vaguely stated, belief that people differ in the extent to which they use "verbal-analytic" or "visual-wholistic" strategies in problem solving. Other dichotomies of style have also been proposed (Goldstein & Blackman, 1978). The whole issue of style cannot be ignored, because there is good evidence that cognitive style does change with age (Horn and Donaldson, 1978), and the very considerable anecdotal evidence of dramatic changes in cognitive style with drug state. The extent to which cognitive style is transitory, however, is of considerable debate. Some theorists regard style as pervading virtually everything the individual does, others feel that different styles can be adopted, easily, in different situations. In the remaining sections little will be said about the measurement of strategy choice, but eventually this problem will have to be considered.

V. SOME SAMPLE TASKS

This section describes procedures that seem to be worth exploring as candidates for inclusion in a set of standard measurement techniques. The choice has been strongly biased toward procedures that I and my colleagues have used, simply because these are procedures with which I am familiar. Three examples are offered of paper and pencil tests, and three of computer-presented tasks.

Paper and Pencil Format Tests

Identification of linguistic stimuli. Building upon experimental studies by Posner and his associates, we colleagues have developed a "paper and pencil" test that measures the speed with which people can identify the meaning of highly overlearned symbols. Most of our work has centered on letter identification, although the technique could be extended to word identification. Each test item consists of a pair of letters. The task is to identify letter pairs as naming the same or a different letter. For example, the letter pair A-A is a "same pair." So is the pair A-a, although in this case the physical symbols are not identical. Both pairs contrast with the pair A-b, in which the figures are associated with different names. There is considerable experimental support for the proposition that rapid identification of letter identities (and similarly, of identities in word-name associations) is associated with a facility in dealing with verbal material. Presumably this is because good performance in this task indicates rapid access to the highly overlearned association between the visual figure and its associated name (Hunt, 1978). The mechanism by which this access occurs is not clear (Posner, 1978). Appendix A provides an example of the procedure we use.

Sentence verification The purpose of this test is to measure the speed with which people can determine whether or not a simple sentence is an accurate description of a picture. Such a determination is clearly a basic step in the use of language. In the test situation people are presented with sentences of the form PLUS ABOVE STAR, STAR NOT ABOVE PLUS, etc. Each sentence is followed by an appropriate picture; either $\overset{+}{*}$ or $\overset{*}{+}$. The test is thus a test of the speed of linguistic processing in short term memory. It is an attention demanding task that does not depend upon knowledge about words, providing that the person being tested has only a minimal reading competency. Thus while the test would not be appropriate in work with the retarded, or in work with very young children, it is an appropriate test for virtually all literate adults. Appendix B is an example of the test that we have used.

There is a considerable literature on sentence verification and on sentence verification tests. Several models for the task have been proposed. Baddeley (1969) and Lansman (1978) have found substantial correlations between sentence verification speed and performance on various measures of verbal aptitude. Interestingly, if the task is changed only slightly, it is possible to change a person's strategy from a linguistic to a non-linguistic one (MacLeod, Hunt, and Mathews, 1978). This does not appear to be a problem when we use the form of presentation illustrated in appendix B.

Visual rotation of images. This test has been derived from the previously mentioned work of R. Shepard and his colleagues on the mental manipulation of visual stimuli. The test items consist of pairs of figures presented in different orientations. The task is to determine whether the pairs represent the same figure seen from different perspectives, or two different figures. Appendix C shows an example test. The test is thought of as a test of the ability to make a transformation of non-linguistic information in short term memory. Thus it somewhat parallels the sentence verification task, which requires a transformation of linguistic material into its deep structure representation.

Computer controlled procedures

Most of the computer-controlled procedures to be illustrated involve the secondary task methodology, as they center on the evaluation of attention and attention allocation. An exception is the first task, which is intended to measure access to information in short term memory. Although computer controlled display equipment is required for all these tasks, it appears that the cost of such equipment can be kept under $5000 for a single testing station.

Memory scanning. This procedure was originally developed by S. Sternberg to test certain theoretical ideas about short term memory function, and has been the subject of a very large amount of investigation since then. The person is shown a small number of stimuli (usually 2 to 5), followed by a probe stimulus. The task is to indicate whether or not the probe stimulus was contained in the original set of stimuli. Numerous studies have shown that the time to make this identification is a linear function of the number of stimuli being held in memory. The slope of this function can be interpreted as a measure of the speed of accessing and comparing one item in short term memory. (Note the analogy to the linguistic stimulus identification task, where the access and comparison had to be made on the basis of long term memory information.)

This task is typically done with linguistic stimuli; usually letters or words. We are currently conducting a series of experiments in which the procedure is executed with tones and visual figures to determine whether one can think of a general "access to short term memory" or whether one should consider tests of access to different short term memories that are modality specific. The task has been shown to be sensitive to aging, brain damage, and barbiturate dose, and thus is a reasonable candidate for inclusion in our measures. Its principal drawback is that several training sessions may be required before reliable data can be obtained.

Effort and comprehension: The purpose of this test is to measure the attentional resources required during the comprehension of passages. The task itself is an example of the secondary task methodology.

The subject listens to prerecorded passages of varying complexity, knowing that questions will be asked about these passages. This is the primary task. The secondary task is a psychomotor tracking task, in which a lever must be kept positioned between two poles. A visual display indicates when the lever is out of position. This task was chosen because it provides a continuous measure of attention allocation on the secondary task.

We have experimented with two other varieties of this task. In one the secondary task remains the same (except that the feedback is auditory), but the primary task is solution of Raven Matrices problems. These problems were chosen because they have well established norms for difficulty. We can thus measure the amount of attentional resources required to solve problems at varying levels of difficulty.

In the other variety of the paradigm the primary task is again listening for comprehension, but the secondary task is a more demanding psychomotor task, somewhat similar to a "shooting gallery" game. S must move a sight onto a target and then "shoot" the target within a brief time period. While the sight is being moved the subject also has to listen to spoken passages, which can then be tested for comprehension. The analysis of this task is somewhat more complex, and is mentioned here largely to illustrate the potential for design of tasks requiring simultaneous allocation of attention but not competing for particular structures, such as the visual or manual systems.

Split attention: The impact task The purpose of this procedure is to measure a person's ability to shift attention from one task to another. Again, two tasks are to be performed. One is a visual tracking task, while the other is a short term memory task involving verbal material, similar to the continuous paired associates task analyzed by Atkinson and Schiffrin (1968). The sequence of trials is divided into blocks, and within each block the payoffs are shifted for reward of one task or another. Our interest centers on the ability of the subject to shift attention with the reward structure.

This task is a modification of a procedure that has been studied extensively in the Human Engineering field. For ideal results, the test should utilize a computer system capable of limited speech recognition.

Attention switching: The purpose of this procedure is to measure how quickly a person can switch attention from one set of signals to another. The procedure is based upon a dichotic listening technique. Stimuli are presented, synchronously, to each ear, in two separate streams. Thus the right ear might receive the sequence A, R, Q, T while the left ear received K, Z, H, L. The listener is instructed to repeat the sequence in one ear ("shadow" is the jargon of this line of research".) Aperiodically a tone is sounded. If the tone is high, the listener is to switch to shadowing the other ear. If the tone is low, the listener is to continue shadowing in the same ear. Thus we have a measure of how quickly shadowing can be changed from ear to ear. Similar procedures can be developed to investigate switches from auditory to visual stimulus monitoring.

Again, tasks such as this have attracted considerable attention in Human Engineering as predictors of performance in the operation of complex machinery.

V. PROSPECTUS

The basic assumption of this note is that the development of a standardized set of measures for assessing biological influences on cognition is both possible and desirable. Such an effort, if successful, could greatly aid in systematizing what promises to be an explosive area of research. There are three steps that must be taken before such a battery can be offered as a recommended set of procedures.

First, a systematic coverage of the present literature is required. There needs to be a more thorough consideration of the procedures that have been used already in this field, and of those experimental procedures that have been developed within cognitive psychology, but have not been used. It would also be advisable to make a more systematic survey of theoretical positions that might lead to a markedly different series of tests. Some co-ordination with the psychometric traditions based on the Horn-Cattell distinction between fluid and crystallized intelligence seems particularly appropriate. The literature survey should result in a formal report, assessing the literature for evidence of candidate tests, and to point out research that may be required before candidate tests can be developed in certain areas. Such a literature survey would be a useful contribution to knowledge in itself.

In parallel with the literature search, it will be possible to begin evaluation of some test procedures that are virtually certain to be candidates for the final set of measurements. The seven procedures described in this report are examples; we already know enough about these procedures to know that they may be appropriate standard tasks. In order to evaluate the tasks, experiments should be run that include in their design tests for effects that are already known to exist..eg. the effect of alcohol upon memory consolidation or the effect of marijuana upon time perception. An attempt should be made to see if particular biological effects, such as drugs, aging, or specific types of illness have a characteristic pattern across tests. This provides a test of the entire approach, since one of the uses of the measurement set is to be to differentiate one effect from another in behavioral terms.

This phase of the research would probably best be carried out in a collaborative arrangement with several laboratories, since the experiments require familiarity with the study of a number of different drugs, and other biological effects. It will probably be easier to ensure common procedure across laboratories than to attempt to assemble a great deal of expertise (and ensure access to appropriate populations) within a single laboratory. As a practical matter, if the test procedures described here are to be useful, a final phase of the research will be the establishment of appropriate reference data for each of the procedures to be used in the set of measures.

Where possible, common response scales should be established for different tests designed to measure the same conceptual variable. There are a number of interesting measurement theory questions involved. I shall make no attempt to answer them, as each could be the topic of a separate paper. The problems are difficult, but there is no reason to believe that they cannot be solved.

Statistical norms can always be established for different reference groups. Such norms are useful, providing that the reference groups on which the norms are obtained can be related to the groups on which the measurements will be made in later practice. A more challenging problem is to obtain data on the practical significance of scores on the different measurement procedures. In effect, this moves one from "norm referenced" to "criterion referenced" testing. This would be highly advisable if clinical use of the measurement procedures is proposed, as it should be. If such research is to be attempted, the difficult problem of obtaining "real world" measures of performance must be faced. One approach to this question is to use as a unit the mean difference between two groups known to have significant practical differences on some cognitive ability. Examples of such units might be the <u>average</u> difference between a 30 year old and a 60 year old person on a spatial rotation task, or the average amount of decrement in a recall task that would be associated with some level of alcohol intoxication. The utility of self reports as criterion measures should not be overlooked, as people are quite sophisticated monitors of changes in their own cognitive capacities.

A research activity of this type can only be carried forward by a team approach, as expertise in behavioral psychiatry, gerontology, pharmacology, experimental psychology, and psychometrics are all required. Several laboratories will have to be involved, as no one group could possibly have the expertise needed to do all the necessary studies. The next step is to assemble a group of investigators, in different laboratories, who will conduct trial research on the procedures used here, in a variety of medical settings.

REFERENCES

Atkinson, R. C. & Shiffrin, R. Human memory: A proposed system and its control processes. In Spence, K. & Spence, J. (Eds.) The Psychology of Learning and Motivation (Vol. II). New York: Academic Press, 1968.

Baddeley, A. D. A three-minute reasoning test based on grammatical transformation. Psychonomic Science, 1968, 10, 341-342.

Garner, W. R. Interaction of stimulus dimensions in concept and choice processes. Cognitive Psychology, 1976, 8, 98-123.

Goldstein, A. K. & Blackman, S. Cognitive Style . New York: Wiley, 1978.

Hasher, L. & Zacks, R. Automatic and effortful processes in memory. Journal of Experimental Psychology: General. (in press) 1978.

Horn, J. L. & Davidson, G. Cognitive development II: Adulthood development of human abilities. In Brim, O.G., Jr. & Kagan, J. (Eds.) Constancy and Change in Human Development: A volume of Review Essays. (in press), 1978.

Hunt, E. B. The mechanics of verbal ability. Psychological Review, 1978, 85, 109-130.

Jensen, A. Invited address to American Psychological Association, Toronto, August, 1978.

Kahneman, D. Attention and Effort. New York: Academic Press, 1973.

Lansman, M. An attentional approach to individual differences in immediate memory. University of Washington Technical Report, 1978.

MacLeod, C., Hunt. E., & Mathews, N. Individual differences in the verification of sentence-picture relationships. Journal of Verbal Learning and Verbal Behavior, 1978, 17, 493-507.

Norman, D., & Bobrow, D. On data limited and resource limited processes. Cognitive Psychology, 1975, 7, 44-64.

Russell, E., Neuringer, C., & Goldstein, G. *Assessment of Brain Damage. A Neuropsychological Approach*. New York: Wiley, 1970.

Tulving, E. Episodic and semantic memory. In Tulving, E. & Donaldson, W. (Eds.) *Organization of Memory*. New York: Academic Press, 1972.

Wechsler, D. Intelligence defined and redefined: A relativistic appraisal. *American Psychologist*, 1975, *30*, 135-139.

NOTES

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Appendix A

LETTER MATCHING TEST

Instructions

On this test, you will see pairs of letters. If the two letters have the same name, put a mark through S (for same). If the two letters have different names, put a mark through D (for different). The following pairs are marked correctly:

Ab	S Đ
Rr	$ D
BB	$ D
NA	S Đ

Here are some sample pairs for you to mark:

1.	AA	S D
2.	Br	S D
3.	nN	S D
4.	ER	S D

You should have marked S for the first and third pairs, and D for the second and fourth pairs.

Work as fast as you can without making mistakes. But if you should make a mistake and mark the wrong letter, do not waste time by erasing. Simply put a horizontal mark through your mistake and mark the correct letter in the usual way. For example:

Mistake		Correction	
AA	S Đ	AA	$ ~~Đ~~

This test has five sections. Each section is printed on two adjoining pages. You will have 1½ minutes to work on each section. Your score for each section will be the number of pairs you mark correctly in 1½ minutes.

When the experimenter says, "Begin," turn the page and start work. When the experimenter says, "Stop," turn the page again and relax.

Appendix A

LETTER MATCHING TEST

Section 1

1.	aB	S D	21.	Nn	S D	41.	Rr	S D
2.	Re	S D	22.	rr	S D	42.	nr	S D
3.	bB	S D	23.	rA	S D	43.	rr	S D
4.	bB	S D	24.	ba	S D	44.	Be	S D
5.	ad	S D	25.	ER	S D	45.	rR	S D
6.	aa	S D	26.	Bn	S D	46.	BE	S D
7.	BA	S D	27.	AA	S D	47.	RR	S D
8.	AA	S D	28.	Nn	S D	48.	bR	S D
9.	aA	S D	29.	rb	S D	49.	Ae	S D
10.	AE	S D	30.	nB	S D	50.	RR	S D
11.	rN	S D	31.	aA	S D	51.	bB	S D
12.	Ar	S D	32.	nn	S D	52.	RA	S D
13.	RR	S D	33.	nN	S D	53.	ee	S D
14.	rr	S D	34.	Ne	S D	54.	Ee	S D
15.	nb	S D	35.	aa	S D	55.	Ee	S D
16.	Aa	S D	36.	EE	S D	56.	nr	S D
17.	RE	S D	37.	ar	S D	57.	BR	S D
18.	EE	S D	38.	Nn	S D	58.	bb	S D
19.	Rb	S D	39.	RA	S D	59.	nr	S D
20.	nN	S D	40.	nB	S D	60.	nB	S D

Appendix B

SENTENCE VERIFICATION TEST

Instructions

In this test you will read a list of sentences. Each sentence has a plus and a star following it.

<u>Example</u>: Star below plus. $\overset{\star}{+}$ T F

You must read the sentence, then decide if the sentence is a true description of the plus and the star.

If the sentence is true, mark out the T. If it is false, mark out the F. Here are some practice items for you to try:

1. Plus above star. $\overset{+}{\star}$ T F

---

2. Star below plus. $\overset{\star}{+}$ T F

---

3. Plus isn't above star. $\overset{\star}{+}$ T F

You should have marked T for Item 1, F for Item 2, and T for Item 3.

This test has five sections. Each section is printed on two adjoining pages. You will have 2 ½ minutes to work on each section. There will be short breaks between sections. Your score for each section will be the number of items you mark correctly in 2 ½ minutes, so work as fast as you can without making mistakes.

When the experimenter says, "Begin," turn the page and start work. When the experimenter says, "Stop," turn the page again and relax.

Appendix B

SENTENCE VERIFICATION TEST

Section 1

1. Plus below star.	+ ★	T F	17. Star isn't above plus.	+ ★	T F
2. Plus isn't below star.	★ +	T F	18. Plus isn't below star.	+ ★	T F
3. Star above plus.	+ ★	T F	19. Star below plus.	★ +	T F
4. Plus isn't above star.	+ ★	T F	20. Plus above star.	★ +	T F
5. Star below plus.	+ ★	T F	21. Plus above star.	+ ★	T F
6. Plus above star.	+ ★	T F	22. Star isn't above plus.	★ +	T F
7. Plus isn't below star.	+ ★	T F	23. Star isn't below plus.	+ ★	T F
8. Plus isn't above star.	★ +	T F	24. Plus below star.	★ +	T F
9. Plus isn't above star.	★ +	T F	25. Plus isn't below star.	+ ★	T F
10. Plus above star.	+ ★	T F	26. Star above plus.	★ +	T F
11. Star isn't above plus.	★ +	T F	27. Star below plus.	+ ★	T F
12. Star below plus.	+ ★	T F	28. Plus isn't above star.	★ +	T F
13. Star isn't below plus.	+ ★	T F	29. Plus isn't above star.	+ ★	T F
14. Plus above star.	★ +	T F	30. Star below plus.	★ +	T F
15. Plus isn't below star.	+ ★	T F	31. Plus above star.	★ +	T F
16. Star below plus.	★ +	T F	32. Plus isn't below star.	★ +	T F

Appendix C

MENTAL ROTATIONS TEST

Instructions

Figures A and B are two pictures of the same object seen from different angles. Observe that you could rotate the object in Figure B so that it would be exactly the same as the object in Figure A.

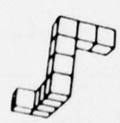
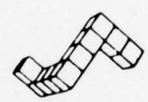


Figure A



S D

Figure B

Figures C and D are pictures of two different objects. No matter how you rotated the object in Figure D, it would never match the object in Figure C.

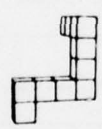
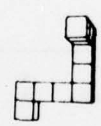


Figure C



S D

Figure D

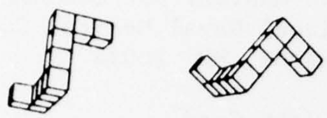
This test is made up of pairs of figures similar to those above. For each pair you must decide if the two pictures are both of the same object, or if they are pictures of different objects. If the pictures are of the same object, mark the S next to the pair. If they are of different objects, mark the D.

Turn the page for some practice problems.

MENTAL ROTATIONS TEST

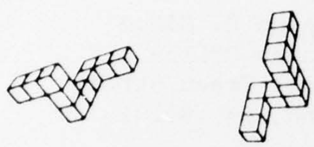
Section 1

1.



S D

2.

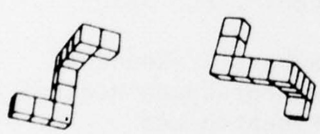


S D

3.

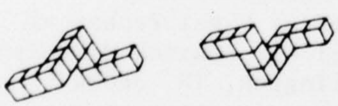
S D

4.



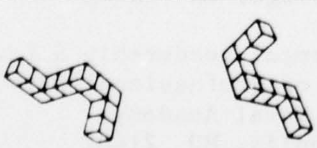
S D

5.



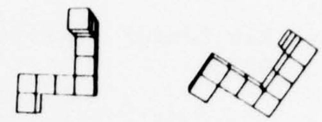
S D

6.



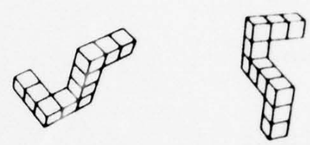
S D

7.



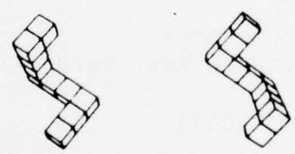
S D

8.



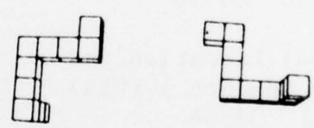
S D

9.



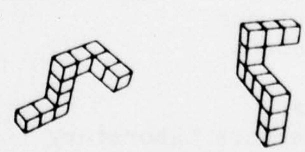
S D

10.



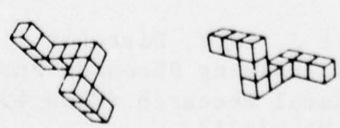
S D

11.



S D

12.



S D

Go on to the next page.

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