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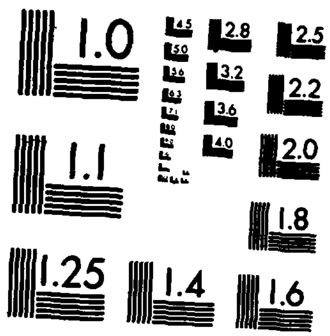
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A NEUROMETRIC APPROACH TO PERSONNEL SELECTION IN THE MILITARY

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SUMMARY

Event related potentials (ERPs) are recognized as measures of brain function that might increase the validity of personnel selection test batteries. Although not a replacement for the usual paper-and-pencil type tests, ERPs have the advantage of being objective and readily obtained in just a few minutes. In Navy-related research, visual ERPs have been reported to differentiate highly skilled from unskilled workers.

The current neurometric program, which is being developed at four Naval laboratories, uses ERPs to generate prediction equations for personnel placement. Sonar operators and aviators are the key personnel being studied at present. The process consists of having the subject view screens of visual information and to make judgements regarding some aspect of the display (e.g. which part of the field is different from the rest?). Each time the stimulus changes, the electrical activity of the brain at several points on the scalp is sampled and processed by a computer. The computer program, which carries out signal averaging on a sequence of the stimulus changes, provides an ERP that can be measured and used to identify those brain electrical events associated with high level cognitive performance.

As instrumentation for modern military applications becomes increasingly complex, it becomes necessary to improve the validity of tests that will select the right personnel for critical jobs. It is hoped that the neurometric test battery approach will provide that increased validity.

The selection of personnel for various military jobs has traditionally been based on the results of paper and pencil testing (1). The initial post-World War II pilot selection batteries heavily emphasized simple mental abilities and perceptual-motor coordination skills (4,14). The reliability and validity of the tests are well documented. In some cases the validity of the tests, that is, the degree to which the placement of personnel results in a satisfactory job accomplishment, is not considered good enough. Objective measures, based on some other attributes of the applicants, have been sought in various areas (1,7,8,10). One such area, which has recently come to the attention of military administrators, measures brain function directly. These brain functions, called "Event Related Potentials" (ERPs), grew out of advances in computer technology and electroencephalography, the measurement of electrical brain activity (11). The rationale for this approach is based on recent studies of human information processing which have identified components of ERPs from the brain that are associated with good versus poor performance on complex cognitive tasks. What this means is that the ERP might be considered an adjunctive measurement of ability that could improve the validity of selection processes for certain military jobs. The objectivity is due to the fact that the cooperation of the subject is not required (5). However, this objectivity is not one hundred percent since the presence or absence of the various parts of the ERP has to be judged (5). If the ERP does show unique characteristics that are associated with very successful individuals, then conceivably a test could be constructed around it. For those kinds of complex jobs that require extensive and expensive training, and where high attrition rates occur, an improvement in selection validity is desirable. But even more important is the consideration of the impact that an improperly placed individual would have on the success of a mission. Most would agree that the quality of being able to perform at a high level under stress is an individual difference that lies on a continuum having a very large range. Some individuals cope well, while others make serious errors in judgement. How do we predict who will be able to cope with the intense stress of combat and who will not? As test administrators, can we identify the relevant psychological or perceptual attributes that would give a probability of a particular individual being too impulsive or of making incorrect decisions under pressure? Our level of technological development is booming and it has become increasingly important to take heed of human limitations. The integration of sensory inputs that is necessary to control complex instruments must be realized. Add to these considerations the fact that it costs upward of half a million dollars to train some specialists, and it becomes clear that more information is needed than that provided by paper and pencil tests.

Enter neurometrics. Although not considered a replacement for standard measures of intellectual and perceptual variables, there are high hopes that a neurometric approach will facilitate selection accuracy for certain jobs that require sustained attention and high level cognitive functioning. Neurometrics is defined as "...A methodology...to provide quantitative information about brain activity related to anatomical integrity, developmental maturation, and mediation of sensory, perceptual, and cognitive processes." (6). This definition of neurometrics is based on the particular environment in which it developed, namely a large brain research laboratory at a major medical center. The purpose of the neurometric test battery in that setting is to identify subtle abnormalities in the electrical activity in the brains of children. The ERP is one of the measurements comprising the test. Once the abnormalities have been identified, decisions regarding the course of remedial therapy or medical treatments can be made. The principles by which the test results are used to help physicians make decisions is the same as that used in other settings where people are categorized or selected for positions based on test results. In college entrance exams, for example, a prospective student's test scores are compared to the norms for college students, and if the scores are above a set criterion, then the student is admitted. The only difference with using neurometric test scores in selection procedures is that the measurements are of the electrical events in the brain associated with sensory, perceptual, and cognitive functioning rather than of these attributes directly, as in the standard type tests. It is still the case that norms for the test parameters must be developed, and that test reliability and validity must be established. Once the norms for a particular occupation or task are determined, then the results of the neurometric test can be compared to the norms and a decision regarding the likelihood that a particular individual will be a success in that occupation can be made.

Although neurometrics is fairly well developed in clinical settings where the goal is to identify subtle abnormalities in brain function, it is not well developed in other settings where the goal would be to identify individuals who are likely to succeed or fail, based on subtle characteristics of brain electrical activity. This new application of neurometrics actually started several years ago at the Naval Personnel Research and Development Center, San Diego, where reports of a relationship between ERP components and success on one's job first appeared (7,8). In these studies visual stimuli were presented to subjects sitting in front of monitoring scopes similar to those used to train sonar operators. The visual stimuli consisted of sequences of light flashes or matrices that contained information to which the subject was to respond. Attached to the subject's scalp were one or more recording electrodes of the type used to obtain electroencephalograms. Each time a visual stimulus occurred, a response from the brain, consisting of a transient change in voltage, also occurred. This response, which is of the order of only a few microvolts, and lasts approximately half a second, was then amplified, digitized and stored in a computer's memory. The sequence of digital values, which represents the brain's response to the stimulus is not in itself very useful because it is highly variable from trial to trial. However, when a technique known as signal averaging is then applied, the result is a highly reliable measure. Signal averaging simply adds the responses from several stimulus presentations together and displays the resulting composite on a screen or X-Y plotter (or alternatively, stores the digital values for on-line data reduction and statistical analysis). The effect of adding several responses in sequence is two-fold, both of which serve to make the response observable and reliable. First, when several responses are added together, the effect of the stimulus on the brain's electrical activity, which for a single stimulus is normally not observable because of its minute size, is now observable because of the additive effect. Second, because of the random nature of the background rhythms relative to the stimulus, the digitized values of this random activity add up to zero (actually they approach zero as the number of stimuli in the sequence becomes large). By averaging over several responses, the signal to noise ratio is enhanced. The result of applying the signal averaging technique to the electrical activity evoked by the stimulus is the ERP. These basic ideas of what the ERP consists of are represented schematically in Figure 1. Note first, in Part A, that individual stimuli (S1, S2, etc.) do not evoke responses of sufficient size relative to the background brain activity to be seen with any clarity. Reliable measures of ERP components would not be possible under these conditions. This is because the background rhythms represent a lot of ongoing activity--activity that is unrelated to the occurrence of the stimulus. In effect, the brain's response to the stimulus is lost in a way similar to the way a particular conversation at a cocktail party might be lost in the background chatter. Now think of what would happen to one's ability to extract the particular conversation from the chatter by repeating it in segments, many times over. Eventually almost any amount of outside distraction could be overcome simply by repeating, over and over, "relevant" portions of the total auditory environment. This concept, as it applies to the study of ERPs, is represented in Part B of the Figure. Here it can

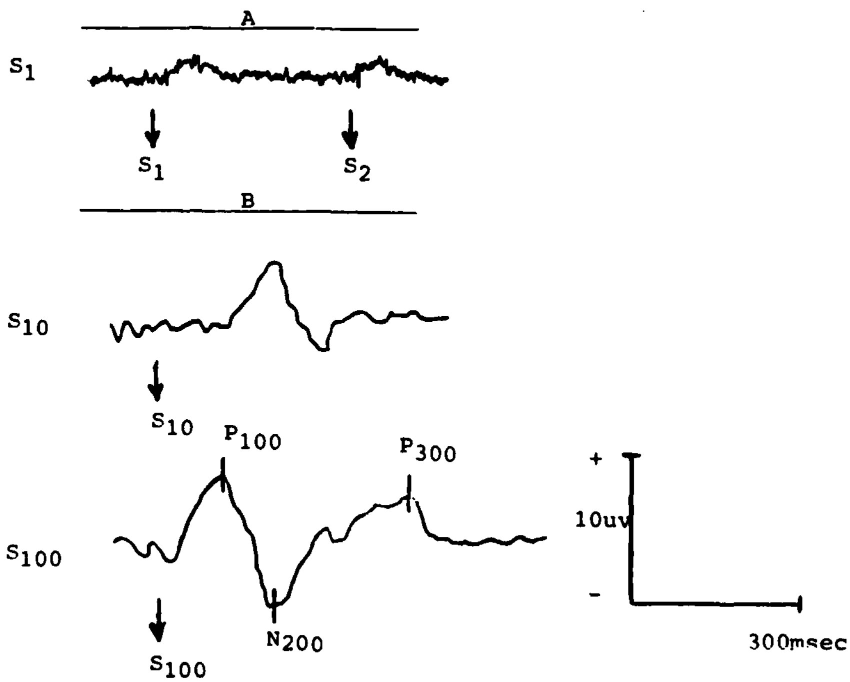

FIGURE 1. A schematic presentation of the extraction of a visual evoked response from an EEG recording through signal averaging.

be seen that repeating the stimulus several times, for example 10, causes the relevant response in the brain to begin to emerge from the background rhythms, so that some kind of measurement can be made. As the number of repetitions increases, as represented in the bottom part of B, the ERP becomes increasingly clear and reliable. The three basic components of the ERP that will be subject to study in the neurometric program are represented here. They are labeled P100, N200, and P300, which refers to their polarity (positive or negative) and their approximate latency (100, 200, or 300 milliseconds). These components are not the only ones that could be studied (there are several more occurring before and after these), but they are the ones of interest because they are associated with the cognitive processes that are thought to be important in doing the kinds of things that sonar operators and pilots do.

Outside of the clinical laboratory, ERPs are used to study the nature of complex human behaviors such as making decisions, processing information, or employing selective attention (3). The techniques used to study these higher level functions involve a wide range of independent variables, such as anticipation, surprise, identifying objects or sounds, or listening to whole sentences. The primary dependent variable in these cases also becomes complex: Instead of looking at single components of the response, several aspects are analyzed, including negative and positive waves, amplitude and latency, and the relationships between various components. A given experimental session might involve the task of identifying a word in a sentence or phrase that is out of place. For example, the sentence "He usually had sugar with his book," leads to an expectation that is not fulfilled. The unexpected word "book" causes a state of surprise that is accompanied by a unique component in the ERP. This component occurs after approximately 300 milliseconds have passed, and is usually referred to as the P300 wave because it consists of a shift in the voltage on the scalp in the positive direction. Another type of so-called "endogenous" component of the ERP is the N200, so named for the fact that it is a negative wave that occurs approximately 200 milliseconds after the stimulus. Also referred to as "processing negativity," the N200 wave varies in amplitude according to how a subject allocates his attention among several different channels.

In the original Navy studies referred to above, the tasks were simple and the ERPs were measured in terms of their variance rather than their sums or averages.

But the hypotheses that were being tested were clear: Measurements of ERPs will yield a metric that identifies electrophysiological correlates of highly efficient or highly inefficient behavior. If the measurement of the brain's electrical activity is related to how well a person can carry out his or her job, then the inference can be made that the measurement of ERPs in prospective pilots, sonar operators, or air traffic controllers might improve selection for these kinds of jobs.

There are currently four Navy laboratories developing ERP technologies to facilitate selection of sonar operators and pilots. They include the Navy Personnel Research and Development Center, San Diego; the Naval Submarine Medical Research Laboratory at New London; the Naval Air Medical Research Laboratory, Pensacola, and the Naval Health Research Center, San Diego. Each laboratory addresses unique, but related problems. The bottom line is to develop and validate prediction equations based on the measurement of ERPs. The equation will probably differ for different kinds of jobs. Thus, for example, in San Diego the Naval Health Research Center is examining the ERP components that are related to the kind of job that a sonar operator must perform. A similar effort is underway at the New London laboratory, where visual discrimination tasks are already being used. The results from their experiments, together with the work getting underway at the Naval Health Research Center, will provide a basis for determining what parts of the brain's response to visual and auditory information displays are uniquely related to highly successful and highly unsuccessful sonar operators. Meanwhile, a similar coordinated effort is underway at the Naval Personnel Research and Development Center, San Diego, and the laboratory at Pensacola. At these two Naval laboratories the components that are associated with highly successful and unsuccessful pilots and aviators is being studied. They are also using an extensive test battery based on measurements other than ERPs that tap perceptual and sensory-motor abilities thought to be associated with successful pilot performance.

Modern information display systems are becoming increasingly complex and greater attention must be given to the "man-machine" interface. The human operator has limits in terms of his ability to process information and make judicious and rapid decisions, and if those limits are exceeded, chaos could result. As we move toward a future of unknown sensory complexity, it will certainly be to our advantage to have a greater understanding of the brain's response to the changing visual and auditory information that confronts it. It is hoped that the field of neurometrics will, by clarifying the functional relationships between brain events and behavior, facilitate that understanding.

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The Navy is developing a neurometric test program, based partly on event related potentials (ERPs) from the brain, that hopefully will increase the validity of testing procedures currently being used. The rationale for the neurometric approach is derived from several years of basic research on the relationships between cognitive performance abilities, such as complex information processing, and the correlated changes in the electrical activity of the brain. These minute changes are made usable by the process of signal

20. Abstract (continued)

averaging, which increases the signal-to-noise ratio of the minute voltage changes measured at the surface of the scalp. The tedhnique, if found to be valid, would greatly decrease the number of mismatches in assigning individuals to jobs that require complex cognitive behaviors and would reduce attrition rates in such jobs as sonar operators, pilots, or air traffic controllers.

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