A MEASUREMENT OF ALERTNESS BASED ON ELECTROENCEPHALOGRAPHIC TIME SERIES ANALYSIS

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Introduction

Can the electrical activity of the brain under given conditions of stress be an indication of the resistance of an individual, or of his capability to function, or remain alert and perform a pre-established routine of commands?

To test the viability of this premise a group of scientists within Advanced Product Planning, RCA, in joint participation with the noted neurosurgeon, Dr. J. Negrin, Jr., established a clinical methodology and multistage, probability sample design to collect raw data amenable to measurements of sample reliability. In this initial stage of the project, a series of statistical analyses were programmed for an RCA 301 Electronic Computer to identify discriminant parameters of eeg waveforms through the systematic characterization and classification of empirical data. In terms of these discriminant empirical characteristics, the objectives of our research were to classify a given set of waveforms as arising from a specified time period on an eeg time series extending over 72 hours of experimental insomnia. The specific time periods were in turn correlated with binary scores reflecting alertness in the human being as designed in the experiment. In this way, we wish to predict the alertness of an individual by a description of sample eeg waveforms.

Clinical Methodology and Sample Design

This study was conducted within the controlled environment of a hospital where adequate supervision of physical activity, diet, and other sampling requirements could be carried out. The volunteers selected for this experiment are medically normal with normal spontaneous electroencephalograms, are of average normal intelligence, of good physical conditions, and are between the ages of 20 and 40 years. Sex and race were not considered. In establishing the sample design, and investigation of the pertinent literature and discussions with authorities in the field served as a basis for deciding what factors should be included as strata in the sample.

Variation in the electroencephalogram parallels changes occurring in fundamental elements controlling brain potentials such as metabolic cellular activities, the composition of surrounding fluid media, etc. Significant relationships are known to exist between electroencephalographic data and blood pressure, rectal temperature, respiration, calorie intake, pulse rates, oxygen deprivation, pharmacologic and photic stimuli. A longer list of general factors such as general intelligence, sex, race, ect. have as yet eluded analysis and their influence of eeg data is unknown or only suspected. The advantages in establishing strata which are homogeneous with regard to the characteristics being measured amply compensated

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for the time and energy devoted to establishing criteria for possible stratification. In an effort to equate the cost of the sample with optimal stratification and to assure that the initial analyses of the eeg data would be unencumbered by undue complexity, it was decided that a minimum of strata should be incorporated in the sample design. This decision was translated into the selection of only those factors possessing known a priori associative relationships to electroencephalograms and which are of major relevance to the project objectives. This reduced the list to experimental insomnia and changes in room temperature.

Each patient is subjected to five consecutive periods of sleeplessness. An initial recording of the eeg is made when the patient awakes from eight hours of normal sleep and at subsequent random eight hour periods of accumulated sleeplessness during the ensuing 24 hours. An additional recording is made after 48 hours of sleeplessness. During the sample periods of one hour monitored electroencephalograms, three kinds of photic stimuli are presented to the patient. On the basis of prior instructions the patient then performs a simple function appropriate to the specific stimulus. Specific procedures have been designed to assure rendomness in the presentation of photic stimuli and to prevent unknown biases from entering the data and reducing the precision of the sample estimates. The three kinds of photic stimulus conditions were used to test (1) the electrical and automatic responses of the fatigued brain to the struboscope; (2) the mental response of the patient, through the identification by number of a series of patterns displayed in front of the volunteers; and (3) the physical and mental coordination ellicited from the volunteer by dots and dashes requiring activation of a series of buttons and levers to the left and right of the volunteer. Correct and incorrect responses were weighted by the time lag as indicated by electromyograph recording of the inter-carpal muscular movements.

The Stress Run

Electrode placements premitted the recording of electromyographic and stroboscope pulses on the electroencephalographic data sheet. Although this limited placements to 6 channels, the electromyograph indicated the moment at which the patient was activated while the photic pulses indicated the moment at which the stimulus was applied. The following electrode placements were used for the study:

Right frontal	- Right central
Left frontal	- Left central
Right anterior temporal	- Left posterior temporal
Left anterior temporal	- Left posterior temporal
Right parietal	- Right occipital
Left parietal	- Left occipital
Electromyograph	
Photic Stimulus	

Statistical Analysis

The hour-long samples of electroencephalograms were divided into equal intervals of 4 seconds. A computer program was required to identify consecutive maxima and minima within each interval for amplitude calculations. This operation required two passes to identify both local as well as global cyclical phenomena. The average amplitude of the interval was computed and a curve constructed of the accumulated sum of the individual waveform differences from the average interval amplitude. To those points contributing successively to the subtraction from, or addition to, the accumulated sum, and which consequently possessed a common sign, was fitted a line of regression. A test of significance for successive coefficients of regression was performed and where no significant difference between coefficients was noted, points were combined into a single group within the interval. This group was then characterized by the mean, variance, and third and fourth semi-variances. This procedure performed over the entire interval resulted in a series of admissible groups into which waveforms could be classified. Based on the examination of the third and fourth semi-invariances, assumptions as to normality were made and groups between intervals were compared and when possible, combined on the basis of tests of significance for the differences of means. For those groups not possessing a normal distribution, a test of the difference of mediums was performed. The result of this procedure was a series of admissible groups into which waveforms could be classified. Groups appearing in pairs over the time series were identified and characterized in terms of their relative duration. The paired groups and their relative durations represented the vector number of measurements by which a given waveform was classified into a finite number of categories representing intervals on the eeg time series which extended over 72 hours. It should be noted that the categories in this analysis are not specified a priori, in the sense that the probability distribution of measurements is not known. Only the form of distribution is known as well as an estimate of population parameters which has been made from a sample of statistics. A detailed explanation of the statistical programs and results of this experiment will be presented.

In brief, experimental results indicated that long periods of sleeplessness produced deleterious effects on the monitored activity and general alertness of human beings. Characteristic electroencephalographic reading taken under lengthening periods of insomnia showed such irregularities as increases in wave amplitudes, discontinuous alpha rhythm and significant frequency distribution changes over time. An increase in mental activity has been observed to result in a corresponding increase in electrical activity. A general reduction in this electrical activity can be induced, however, by continuous periods of experimental insomnia indicating the reduced response of a fatigued brain to mental stimulus conditions. It was also recorded that mental effort, superimposed on experimental insomnia, results in characteristic irregular changes indicating the fatigued brain possesses a reduced capacity to further increase the rate of electrical activity in response to such stimulus. The details of a computer program permitting the characterization of these eeg phenomena will be described in the presentation.