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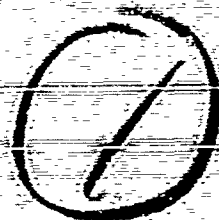
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SOME PRACTICAL PROBLEMS OF THE
ALERTNESS INDICATOR

John L. Kennedy

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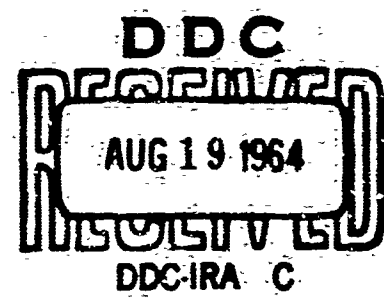
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SOME PRACTICAL PROBLEMS OF THE ALERTNESS INDICATOR

During the closing phases of World War II, it was reported that German scientists had been working on an automatic device for alerting personnel, such as pilots, when they were in a dangerous condition of drowsiness or fatigue. The physiologist Kornmüller, it was further stated, had developed a portable, lightweight device for using brain-waves as a physiological indicator of the alertness condition of the subject, particularly the slowing of alpha frequency which occurs when the subject is drowsy. The practical device was so constructed that an alarm or alerting signal would be turned on by the change in frequency of alpha and, I presume, would be turned off when the alpha rhythm returned to its normal frequency of around 10 cycles/sec.

This report was of sufficient interest to the Special Devices Center, Office of Naval Research, that a contract was established with the Department of Psychology, Tufts College to investigate the feasibility of this idea. Several years were devoted to the study of ways of warning personnel of impending unalertness. This paper will attempt to evaluate the accomplishments of the project and will deal with the problem of personnel alertness from a practical point of view.

The first phase of the project was a laboratory study using a 4-channel EEG apparatus, in which recordings of the alpha

rhythm were obtained from an unselected sample of people in a monotonous vigilance situation. Two facts emerged from these observations: (1) the range of individual differences in the amount and frequency of the eyes-open alpha rhythm in a group of normal people was quite remarkable and seemed to be relatively independent of alertness. Some evidence of slowing of frequency was found in some people but the conditions favorable for this phenomenon to occur appeared to be well beyond the initial phases of drowsiness in which we were interested; (2) some normal people do not exhibit an alpha rhythm.

Our troubles with the alpha rhythm, indicated above, were responsible for a shift of physiological indicator. We next explored the possibility of using muscle action potentials, according to the method of Jacobson and others.

Our first observations were made using the biceps and triceps for electrode placements. Here again we drew a blank because we were unable to record "tonus" of the muscle with surface electrodes. (One of the characteristics, we thought, of a practical device was that it should not require needle electrodes!) Various other placements on the large anti-gravity muscles of the body were tried, again without success. The large muscles of the body appear to be "silent" to surface electrodes unless they are involved in an active contraction.

In exploring other possible electrode placements, our first success came in placing two electrodes on the pinna. From this spot we obtained a set of muscle spikes that exhibited

continuous variation in activity and, when the amount of activity was related to periods of unalertness on the monotonous vigilance task, there seemed to be some correlation between fluctuations of muscle spikes (primarily in amplitude) and fluctuations in readiness to respond to an unexpected signal as measured by reaction time. We later found that we could obtain a similar continuous physiological indicator by placing electrodes of sponge rubber on the forehead just above the supraorbital ridges. The electrodes were held in place by an elastic head-band and could be worn comfortably by the subject for several hours. Low resistance contact was maintained with the skin by soaking the sponge rubber electrodes in saline solution.

From this point, experimentation on the usefulness of the muscle spike indicator of alertness became possible. Since we were interested in obtaining a continuous DC measure of the subjects' level of electrical activity, the Electrodynic Co. of Boston, Massachusetts developed for us an integrator, which translated muscle spike activity electronically into a moving average DC level over the past second. Thus it became possible to measure the activity in terms of average integrated microvolts. This is a kind of statistical smoothing circuit. This same device also contained a sensitive relay circuit, with an adjustable threshold, such that an alarm or a stimulus could be activated when the subjects' activity dropped below a given level. Thus, it was possible to present a stimulus automatically for the measurement

of reaction time at any desired level of tension of the subject.

If the subjects' tension level dropped below the threshold, the stimulus would come on and stay on until the relay was opened again by increase in tension level of the subject. We had then, the possibility of an automatic electronic monitor. Slide I shows some of the equipment involved, which, I should emphasize, was laboratory equipment and hence bulky and heavy. Slide II shows the kind of results obtained in an experiment in which the task was a continuous steering task on a target which was being driven off center by a cam. The primary job of the subject was to keep the target centered with a joy stick. Subjects were required to operate for periods of 2-3 hours. The data in Slide II were collected from an auxiliary task in the experimental situation. A red jewel warning light was placed in the periphery. It came on whenever the subjects' tension level dropped to the threshold of the Alertness Indicator. Slide II, then, contains distributions of reaction times to the appearance of the red jewel light. The subject was instructed to respond as rapidly as he could with a foot-key as soon as he noticed the red light. This was not an elegant experiment on reaction time, but it served our purpose in providing a criterion measure and an operational definition of alertness in that situation. If the subject was slow in responding to the unexpected peripheral stimulus, we could argue that his general level of awareness was not as high as when he gave short reaction times to the same stimulus. Actually, these data do not provide us with an unequivocal answer to the question, "Does muscle spike activity provide a useful measure of alertness"? As usual,

it depends. If your goal is to warn the subject when his condition is such as to make his reaction times only slightly delayed, then the Alertness Indicator will "warn" the subject many times when he is perfectly all right. This is due to the fact that there is a great deal of second-to-second variability in the muscle spike output. If, however, you only want to warn the subject when his condition is such as to produce very slow reaction times, then the picture is considerably better. A particular threshold level on the Alertness Indicator will predict the long reaction-times and no responses fairly well.

The individual polygraph records of each subject tell this story rather better than any statistical analysis. We ran one subject on Sunday mornings for several months just before he went to bed after working all day Saturday and all Saturday night at the airport as a meteorologist. These records provide an interesting summary of the temporal fluctuation of alertness during a monotonous job under conditions of sleep deprivation. For a few minutes after starting the job, his tension level would be steady and work would be accurate, reaction time short. Then the tension level would start to fluctuate, initially for very brief periods like a second, the tension level would drop and return to normal or go higher than normal. Gradually, a slow oscillation of tension level would start and eventually the red light would go on. For awhile after the alerting stimulus, the tension level would be maintained and then the oscillation would start again. During the later stages of the session, it was quite usual for this subject to require an additional alerting stimulus. We had to introduce a

raucous buzzer into the situation, as indicated in Slide III. Occasionally, none of these stimuli would bring him out of the arms of Morpheus and the experimenter had to enter the room and shake him. These same slow oscillations are present in the output of subjects without sleep deficit but they occur less regularly and the amplitude of the oscillation is smaller. Some subjects would go through a 2-3 hour session without a serious drop in tension level. Others would start oscillating almost immediately after the start. The phenomenon of oscillation, incidentally, is probably responsible for the fact that decrement in performance is hard to find if the testing is done by sampling a continuous performance. The subject can muster his resources for a test period quite well, as other studies have shown, but he may "coast" between the test periods unless he is monitored continuously. In order to get the oscillation described above, the test situation must be monotonous, as Mackworth has demonstrated. Anything that happens to break the monotony will result in a maintained output for a while thereafter.

With the foregoing as an introduction, let me now proceed to the title of this talk, namely, some practical problems of the Alertness Indicator. There are a great many, but I shall not burden you with all of them.

We touched on the first problem earlier in describing the previous work as a laboratory investigation. Alertness is a problem in the laboratory certainly but our interest and the interest of the Special Devices Center was in the prediction and control of alertness status out in real life -- in aircraft, vehicles and on board ship where alertness may mean the difference between life and death. The first practical problem, then, was to obtain a

device which would duplicate the functioning of the laboratory equipment but would be small, light, easy to adjust, simple to operate and, finally, would require the minimum of maintenance. We have been working on this problem off and on since 1948. The Electrodyne Co. has produced two different models, which satisfy many of the requirements, but not all. Robert Hennessey, in the Tufts Laboratory has constructed an improved version which is currently under test.

The first problem encountered outside the laboratory is pick-up from AC lines and other sources. The use of a balanced input, which amplifies only out-of-phase signals, will cut down on this limitation considerably. Residual AC may be balanced out in any particular location by putting a scope on the input. The second problem is the noise level of the amplification system itself. A noisy tube will make it difficult to discriminate the levels of the subjects' output, since the output is near the noise level of many amplification systems, particularly those on which there are restrictions as to size and weight.

Another set of problems arise when the requirement for wearing head-band electrodes is considered. People don't like to wear head bands. They don't care for electrodes on their skin, even our comfortable sponge-rubber electrodes. They don't like to be attached to any electrical device, even though you assure them that the electrodes are fused at .05 amp.

We have conducted some field tests with the Portable Alertness Indicator. These, in general, have indicated that, if you send a specially-trained technician out with the equipment,

it will perform with about the same characteristics as the laboratory model. But it would be impossible, at the present stage of development, to just turn the device over to an untrained person to operate, such as is possible, for example, with an automobile radio.

Slide IV shows the present model currently under test. It is roughly 24" x 8" x 9" and weighs 15 pounds including wet cell batteries. The power supply is obtained from small wet-cells, with an estimated life of around 6 hours. It has a built-in CRO for balancing out AC noise. I hope that it will be rugged, reliable, easy to operate and easy to maintain.

The last practical problem I wish to raise has to do with alternative ways of handling the alertness problem practically. There are other available physiological indicators of the condition of the body, such as the Cximeter, which uses a photo-electric pickup based on transmission of light through the lobe of the ear and measures the amount of oxygen in the blood by the change in color of the blood, the electrocardiogram, the galvanic skin response et cetera. One of these, or a combination of these might provide a more positive indication. There is an old patent on simple alertness monitor, namely, a harness for positioning a spike under the subjects' jaw. When his head falls down, his chin is impaled on the spike and he is alerted very positively!

Drugs, such as Benzedrine, have been proposed and there are good reasons for adopting this technique, rather than any method requiring expensive apparatus and special training.

But the most serious practical problem of all seems to be, "Is protection against lapses in alertness a serious enough

problem for anyone to worry about?" I confess to having mixed feelings on this issue. I suppose that this problem is similar to the life insurance problem. How much are you going to be willing to pay for protection against something that may never happen, for which we have only the support of accident statistics. Most of the time, accident statistics only tell us that accidents happen and not where to pin the blame. Is alertness a problem cut in the real world of human affairs?