may be maternal and endocrinal whereby a hormone having an effect on arousal varies predictably in quantity toward natural parturition. That the behavioral effect is later seen as a conditioning deficiency is noteworthy; the duration and long-range significance, however, are presently moot questions.

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13 January 1964

Vigilance: The Importance of the Elicited Observing Rate

Abstract. *Observing may be elicited by regularly repeated events that occasionally become signals. Such events were presented at rates of either 5 per minute or 30 per minute, and signals averaged 15 per hour during an 80-minute vigil. Observers missed about 10 percent of the signals with the low event rate and about 70 percent of the signals with the high event rate. The experiment supports a decision-theory approach to observing behavior.*

A major problem in the experimental analysis of human vigilance is to account for the decline in the probability of detection of rare and weak signals during a prolonged vigil. This decrement is certainly due to failures of attention rather than to sensory changes. In the literature on vigilance (*1*) these failures of attention are usually considered as necessary effects of the passage of time. However, it is possible that failures of attention occur only if attending is elicited and then not reinforced, and the main role of the passage of time might be to permit unreinforced observing responses to occur (*2*).

The latter view is part of our present approach to vigilance (*3*), in which we consider attending to be the effect of an observer's decision about whether or not to observe. This approach implies that the demand on a subject's observing behavior is more important than the low rate at which the signals are presented or the mere passage of time as a cause of the decrement. The experiment described here tested this possibility.

Subjects were seated without restraint so that they viewed a recessed display from a distance of about 75 cm. They monitored it continuously for 80 minutes, and signals were presented at the average rate of 15 per hour. With these factors constant, the experimental variable—the elicited observing rate—was manipulated by working with two different rates of regularly recurring events that at rare intervals became the signals. The events were presented at the rate of either 5 or 30 per minute. The event-presentation rate was equivalent to an elicited observing rate because a subject was required to do no more than observe the regularly repeated events in order to detect signals. Observing was, therefore, elicited only when an event was presented.

An event was produced by the apparent movement of a bar of light, 2 mm wide by 18 mm high. The complete event was a pair of movements in which the bar moved 29 mm to the right, snapped back to its zero position, again moved to the right, and again returned to its zero position. The movement was generated by successively lighting small, and appropriately spaced, diffusing screens. The light bar was switched to the deflected position where it remained for 0.41 second, returned to the zero position for 0.38 second, moved again to the deflected position for 0.41 second, and again returned to the zero position where it remained during the ensuing "interevent" interval. The times when no bar was illuminated were negligible and were associated with the rise and decay times of the 6-volt alternating-current (No. 47) tungsten bulbs that were the light sources.

A high event rate of 30 events per minute was produced by making the interval between events 0.8 second, and a low event rate of 5 events per minute was produced by making the interval 10.8 seconds.

The signal was an increase in the length of the second deflection within an event from 29 mm to 35 mm. This was an easy signal for an alert observer to detect. Under a two-alternative, forced-choice psychophysical procedure it was essentially always detected correctly. Subjects operated a switch to indicate that they saw a signal.

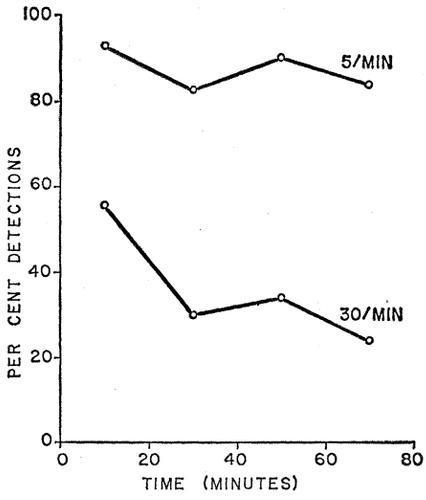

Fig. 1. Effect of event rate on detection of signals during successive 20-minute periods of an uninterrupted 80-minute vigil. Events to be judged as signal or nonsignal were repeated at the rate of either 5 or 30 per minute, and this variable differentiates the two curves. Average signal frequency was constant at 15 per hour. Each point is based on 60 signals.

In the vigilance task, signals appeared at successive intervals of 4.4, 6.0, 5.6, 1.9, and 2.1 minutes during the first 20 minutes. The signal program was repeated four times to provide 20 signals during an uninterrupted 80-minute vigil. The signal schedule was identical for the high and low rates of event presentation. If an observer missed a signal it was repeated until detected in order to insure an equal number of reinforced observing responses for all subjects.

Twenty-four male student volunteers, working individually and alone, were used as subjects, 12 for each event rate. Instructions were presented by tape recording, and a short practice period with three or four signals was part of the procedure. The 80-minute vigil was begun after it was ascertained that the subject could identify the signal readily at its first appearance during the practice period. During both the practice period and the vigil a 73-db white noise was broadcast over a loudspeaker to mask cues from the automatic programming and recording

equipment and to limit distraction by other laboratory sounds.

We found that the rate at which the events were presented dramatically affected the performance of the subjects. The 12 subjects who received 5 events per minute detected 210 out of 240 signals. At the higher event rate of 30 per minute, the other 12 subjects detected only 87 out of 239 signals (the information on one signal for one subject in this group was lost). These results are presented in more detail in Fig. 1 which shows that performance was relatively steady at the low event rate of 5 events per minute.

The familiar decrement in vigilance appeared with the higher event rate of 30 per minute. This decrement, the drop in signal detection from about 60 percent during the first 20 minutes to about 30 percent in the later parts of the vigil, is statistically significant at the .02 level as determined by the Friedman test (*4*). The difference in performance between the two groups was, of course, also statistically significant ($p < .001$).

It is important to keep in mind that the two groups of subjects, differentiated in Fig. 1 by the two rates at which the events were presented, were not systematically differentiated in any other way. The difference, then, had nothing to do with the rarity of signals; signals were equally rare for both groups at least as events embedded in a matrix of time. Nor could the difference be attributed to the length of time that these students had to keep up the dull watch, since the watch was equally long for both groups. Factors such as memory for the signal were controlled by having all of the information that an observer needed to make a "paired-comparison" judgment available within the event. For the sensory task, the observer needed only to compare the two successive deflections of the bar that constituted an event, and the temporal structure of an event was the same for both of the groups.

The large difference between the number of signals detected in the two groups could be due only to the different rates at which the events were presented. We, therefore, have the apparently strange situation in which the "detectability" of a signal is determined by what is going on at times when no signal is being presented (*5*).

In a sense, this experiment was a test of the relative importance of the passive waning of attention in the face of boredom as opposed to the active, though not necessarily conscious, decision to be inattentive. The passive waning of attention might be described as a reduced arousal level (*6*) related to the amount of incoming stimulation. In these terms, low event rates should produce a lower arousal level than high event rates, and in fact, subjectively, there was no question that the situation in which events were presented at the low rate was more dull and monotonous. Therefore, the predictions from an arousal point of view would be that high event rates should produce higher degrees of alertness and more detections than low event rates.

Our results were completely contrary to the arousal position, and fit in very well with the decision-theory approach to vigilance (*7*). We consider that the observer's "decision" about whether or not to observe or be attentive is associated with the average payoff or "expected value" of attending to the regularly recurring events. The observer, then, behaves most economically by being less likely to attend to a given event when few of the events are signals, and more likely to attend to a given event when more of the events are signals. When, as in this experiment, signals are presented at certain fixed times, a change in the event rate produces an inverse change in the probability that an event will be a signal. The "expected value" of observing an event is therefore greater for the lower event-rate.

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5. This result recalls some of the effects found in "signal detectability" studies in which changes in detectability are also associated with nonsensory factors; for example, J. A. Swets, *Science* **134**, 168 (1961). The main difference between such studies and vigilance studies is in the demands made on observing behavior. "Signal detectability" studies are concerned with detection performance when observing occurs, whereas vigilance studies are concerned with factors affecting observing or attending.
6. D. E. Broadbent in (*1*), pp. 184–198, gives a detailed critique of the arousal concept as it has been applied to vigilance studies.
7. Our results can also be described empirically as favoring signal probability as opposed to signal frequency (signals per unit time) as a determinant of vigilance. W. P. Colquhoun, in *Ergonomics* **4**, 41 (1961), used these terms to describe the outcome of an experiment in which the event rate was constant at 30 per minute, and signal probability was associated with the relative frequencies of two types of randomly occurring occasional signals. The results as well as the procedures of Colquhoun's experiment were more complex than ours. For example, signal probability was favored over signal frequency for only certain spatial configurations of Colquhoun's signal. We believe his results involve much more than the making of decisions about whether or not to observe a display. We cite his work now in anticipation of possible confusion due to the applicability to both his work and ours of the distinction between signal frequency and signal probability. Colquhoun's "probability" was the conditional probability of a signal of one type given a signal of either type, with event rate ignored. Our "probability" is the conditional probability of a signal given an event.
8. This work was supported by the U.S. Air Force under contract AF 33(657)-7362, monitored by the Aerospace Medical Laboratories, Aeronautical Systems Division. John F. Wing and Austin W. Kibler gave us helpful criticisms of this manuscript, James M. Campbell served as instrumentation engineer, and Philip H. King was an invaluable research assistant.

21 October 1963

Behavior: Persistence of Shock-Induced Aggression

Abstract. *Previous research has shown that aversive stimulation causes aggression in several lower species of mammals prior to any specific conditioning. Our results show that fighting in response to shock tends to persist in spite of negative reinforcement for other behavior. The frequency of shock-induced fights decreased significantly only when the reinforcement of shock termination was made contingent upon a specific nonaggressive response.*

Electric shocks (*1*), loud sounds (*2*), and strong lights (*3*) all decrease the frequency of the responses which they follow. Conversely, a number of responses have been conditioned entirely on the basis of escape from or reduction of these same aversive stimulus conditions (*2, 4, 5*). Typically, in these experiments, the aversive stimulus has been presented to a single organism rather than to a pair or a group of subjects. One of several exceptions to this single-subject type of experiment is Miller's study (*6*), in which paired