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EFFECT OF IMMEDIATE NEGATIVE REINFORCEMENT ON VIGILANCE PERFORMANCE AND ELECTROENCEPHALOGRAM

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The critism is put on that in the majority of vigilance experiments the motivational aspect of the performance was rather neglected, i. e. errors of omission as well as false-alarm responses did not have consequences of any appreciable importance for the subject. In the experiment described in this paper subjects were punished (short horn blast) immediately after either kind of performance error. The results obtained reveal the absence of the common performance decrement under the reinforcement condition. EEG data suggest that subjects remain more awake in the reinforcement condition, while drawsing during the nonreinforcement runs.

From laboratory studies of the performance in situations requiring the detection of relatively rare signals on the background of a similar but irrelevant stimulation it is known that, most typically, such a performance deteriorates with time (1). It is also known that the rate of decline of this performance as well as its overall level may be affected by such variables as the rate of stimulus presentation, intersignal interval, signal magnitude, sudden extraneous stimulation, knowledge of results or of the length of the vigil, physical environmental conditions such as light, heat and humidity, vibration; social situation, drug consumption, etc. (2).

But motivational aspects of a monitoring situation, except for the knowledge-of-results variable, are rather neglected in the literature on vigilance. This is also true for the investigation of physiological concomitants of the observer's behaviour.

In the real life situation of monitoring for the rare critical signals, both the failure to detect them or the act of committing the false alarm are often of considerable importance or emotional value for the human monitor. However, in the laboratory situation usually neither errors of ommitting the critical signal nor false alarm responses have immediate or delayed consequences of appreciable importance for the subject.

Pollack and *Knaff* (3) explored the possibility of affecting the vigilance performance by the manipulation of the subject's motivation. The outcome of their experiment was that moderate monetary incentive in a visual monitoring situation had a slight favorable effect. The immediate negative reinforcement after every error of omission was more effective, particularly for the low performance group of subjects. However, for the negatively reinforced group they found a considerable increase of false alarms which were not penalized.

The relative inefficiency of a delayed or immediate monetary incentive, and a more favorable effect of the immediate negative reinforcement (e. g. a mild shock for every error of ommission) were later on confirmed in several studies (4, 5, 6, 7).

Recently *Lucaccini* et. al. (8) demonstrated that even instructionwise induced positive or negative set toward the task can make a significant difference in detection performance.

The above mentioned studies may be used to raise many questions concerning laboratory studies of vigilance. Particularly, they make questionable the relevance of findings from studies in which the motivation was low or uncontrolled for the field situation.

The literature on physiological variables recorded simultaneously with the performance in the vigilance situation is rather scarce taking into account much advocated activation theory of vigilance.

Davies and *Krković* (9) reported that the amount of EEG alpha activity as well as the skin conductance decreased parallel to a decrement of detection performance in an auditory vigilance task of one and a half hour duration.

Eason et al. (10) reported a similar behaviour of skin conductance for an one hour long visual monitoring task, while *Surwillo* and *Quilter* (11) proved that the detection performance was positively related to the frequency of transient skin potential changes of Tarchanoff's type in an interval immediately preceding the stimulus.

Morell (12) recorded EEG along with the reaction time in the course of a vigil and reported that the short reaction times were associated with continuous alpha waves, while longer reaction times were linked with slow wave activity.

All of the above studies can be used to support the arousal theory of vigilance to a certain extent.

Thorsheim (13) investigated the effect of motor activity on both monitoring efficiency and physiological (EEG) arousal. He found that while motor activity did affect the physiological arousal, it did not influence the monitoring efficiency. Accordingly it was concluded that the arousal theory of vigilance was not supported.

However, in all of the above mentioned studies incorporating physiological measures of arousal no particular importance for the subject was attached to detections, ommissions, or false alarms, neither was it reported that the motivation was controlled more rigorously than in the rest of vigilance studies.

The present investigation was undertaken assuming that the importance of, or the emotional value involved in, consequence of either the failure to detect the signal or of raising the false alarm may have some longer lasting arousing effect which would postpone or lessen the usual performance decrement in a vigilance task.

As a mean to provide for emotional value of either kind of errors an immediate negative reinforcer (the blast of an automobile horn) was chosen, and as the indicant of arousal the EEG alpha rhythm was selected.

EXPERIMENTAL CONDITIONS

Vigilance task. The task employed in this study was an suprathreshold auditory discrimination task lasting for one hour and a half. Critical signals, embeded in a random fashion within a sequence of irrelevant stimuli of equal intensity had an overall frequency of 24 per hour. Intersignal intervals ranged from 42 seconds up to 4 min 37 sec. Stimuli were delivered to the subject by means of the single-side earphone. To report the detection of a signal, the subject was required to depress the key which triggered the response recording system in the adjoining room.

The nature and characteristics of task stimuli and the technique of response recording are described in more detail elsewhere (14).

EEG recording. Standard bipolar leads were employed to obtain an EEG record from subjects performing the vigilance task. Collodion glued silver discs with electrode jelly were located on the parietal and occipital lobes of the dominant hemisphere. Precautions were taken that the electrodes were applied on the same place on all occasions, and that the amplification was strictly held constant all the time. For the sake of noise free recording the subject was comfortably laying in a sound-deadened and electrically shielded room illuminated by a single 100 W incandescent source.

The recording of the EEG was not done continuously but according to the following schedule: (1) one minute long record was taken immediately before the onset of the work, (2) twenty seconds long record was made around each critical signal to be detected (ten seconds before, ten seconds after), and (3) one minute of recording was done immediately upon the termination of the work. Since there were six randomly distributed signals to detect in each of the six fifteen-minute work intervals the total length of the EEG record for the working period was twelve minutes for each subject.

Subjects. Twelve undergraduate psychology students, six of either sex were chosen as subjects. Before the present experiment all of them served as subjects ten times with the same task; the EEG recording being included in the last three sessions of the series. Therefore in the present experiment subjects were thoroughly familiar with the task situation as well as with the routine of EEG recording.

Motivation and reinforcement. In the above mentioned preceding experiments the only outside incentive for our subjects to participate was to earn the required credit-hours. The instruction given to them was essentially of the type »Try to do your best«, but obtained credit hours in no way depended on their performance. The same sort of motivation and instruction was employed in the first of the two runs in the present study (nonreinforcement or NR-condition). But in the second run, which took part on the following day at the same time (9. a. m.) the subject was told in advance that for each error of omission as well as for each false-alarm response he will be immediately punished by the blast of an automobile horn (reinforcement or R-condition). The horn was set half a meter from subject's earphone-free ear. The blast of the horn, which lasted for one second, was demonstrated before the beginning of the second session, and all subjects found it startling and very unpleasant.

Subjects were not told that the second run is a final one. Some more experiments were anticipated but not actualized.

Design. The design of the experiment was one with the same subjects serving as their own control group. The reinforcement was applied in the second session with each subject. On the basis of prior data subjects were selected so that they comprised a group heterogeneous with respect to the average individual performance as well as to the individual amount of alpha rhythm obtained under the standard recording conditions.

RESULTS

The detection performance under the R-condition and NR-condition is illustrated in Fig. 1, which shows a substantially better performance with the reinforcement.

Variance analysis for correlated data (15) revealed a highly significant difference between the two curves (P smaller then 0.001). Furthermore, while the NR-curve has a significant decrement ($P<0,001$) and significantly departs from linearity ($P<0,005$), the R-curve is essentialy parallel to abscissa. It should be noted that the performance curve for the R-condition follows fairly close the initial level of about 82 percent correct detections.

The number of false alarms was generally rather small, averages being 3.5 and 1.5 for the NR- and R-condition respectively. The difference between these averages is insignificant ($0.05<P<0.10$).

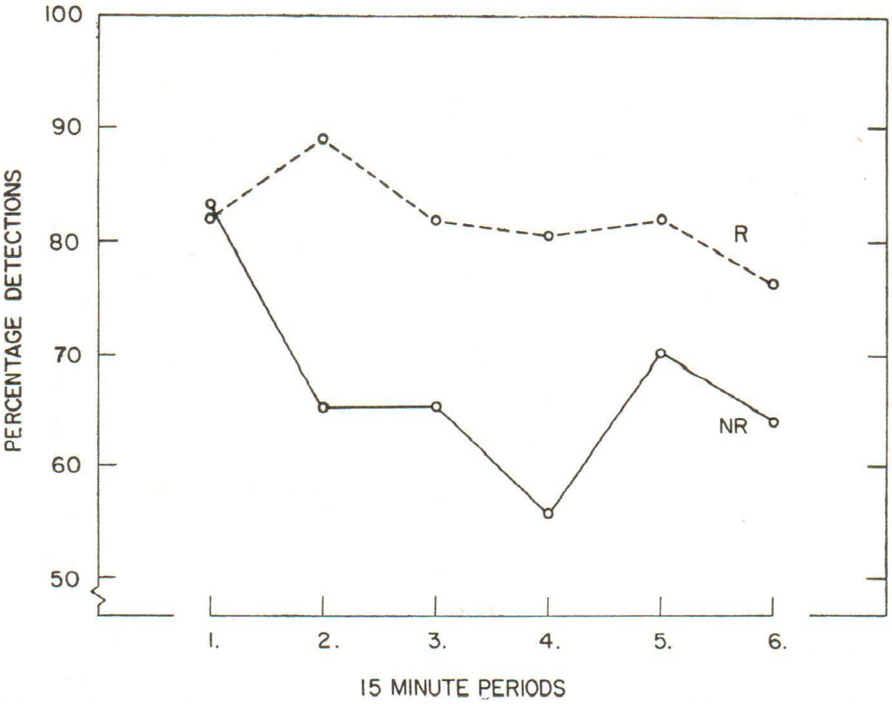

Fig. 1. *Average detection performance under the reinforcement (R) and nonreinforcement (NR) condition during the one and a half hour watch*

Figure 2 ilustrates data obtained from EEG records. Alpha-index was defined as a proportion of time the alpha activity was present on the record, and the alpha was specified as activity with the frequency ranging between 8 and 12 per second and an amplitude of at least five microvolts. Identification and measurement of the presence of alpha activity on the EEG records was done by a trained technician.

As can be seen in Fig. 2 for the NR-condition alpha index drops sharply within the first half hour of work, stays low for another half hour, and then raises to the level close to the resting level.

For the R-condition the behavior of the alpha index is different. All the time during the vigil it stays more or less at the same initial resting level. Analysis of variance revealed a highly significant difference between the curves, with the curve for the R-condition running essentially parallel to abscissa ($F<1$ for the linear slope different than zero), and the curve for the NR-condition containing a significant main effect ($0.05>P>0.025$).

Differences between alpha indexes for resting levels (RG) are insignificant.

The histogram in Fig. 2 represents the amount of slow-wave activity which was, interestingly enough, found only in EEG records from the

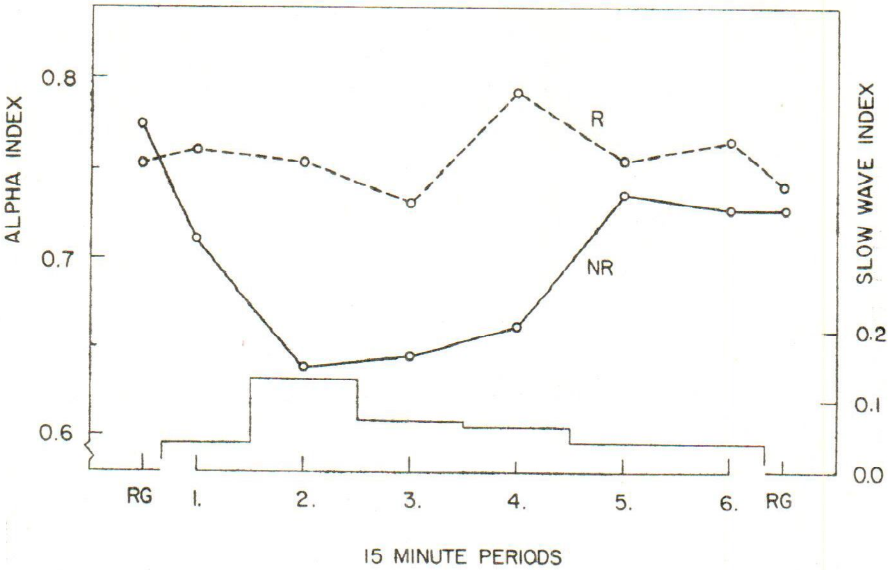

Fig. 2. *Changes in the alpha index during the work for the reinforcement (R) and nonreinforcement (NR) condition. Histogram represents the relative amount of slow-wave activity present in EEG records from the NR-condition. RG = resting*

NR-condition. The right hand ordinata in this figure is for the index of slow-wave activity which is defined as the proportion of time the slow activity was present on a given section of the EEG record. As slow was considered any activity with the frequency of 7 cps or less, and the amplitude of 5 microvolts or greater. The identification of this activity on EEG records was done by the same trained person and in the same way as the identification of alpha activity, though it was done with much less confidence due primarily to the irregularity of the slow-wave activity.

The impression which can be obtained from the NR-curve of alpha index and the histogram for the slow-wave index for the same condition is that, with time on the watch, the amount of slow-wave activity inversely parallels that of alpha activity. In other words when alpha index is low the slow-wave index is high, and vice versa.

Average alpha indexes for before and after detected signals are listed in Table 1. The epoch of observation used here is only two seconds. The shorter epoch was decided upon after it was noticed that the response or reinforcer provoked supressions of alpha activity were rather brief.

Data in Table 1 reveal a small drop of alpha index after the response was made. This drop is more pronounced, although statistically insignificant, for the R-condition, and it reflects genuine but short lasting suppression of the alpha activity which followed the response.

Table 1

Alpha index around detected signals

Condition	2 seconds before	2 seconds after
Nonreinforced (NR)	0.69	0.66
Reinforced (R)	0.71	0.65

The same sort of data for signals which were not detected are presented in Table 2.

Table 2

Alpha index around signals not detected

Condition	2 seconds before	2 seconds after
Nonreinforced (NR)	0.54	0.56
Reinforced (R)	0.65	0.35

Here the alpha index is lower before the signal for the NR-condition than for the R-condition (0.54 vs. 0.65), but relatively much lower after the signal than before it for the R-condition (0.35 vs. 0.65). The last mentioned drop of the alpha index after the missed signal reflects the genuine suppression of alpha activity which followed the horn blast.

Data essentially similar to those listed in Table 2 were obtained for false-alarm responses.

DISCUSSION

The use of immediate negative reinforcer in our experiment had at least three confounded roles. First, it served as an »informational system« providing for the immediate knowledge of results. Second, it very effectively alerted the subject if he chanced to drowse or daydream during the watch. And third, it increased considerably the importance or the emotional value of the critical signal, i. e. it profoundly changed the subject's motivation. In other words, the constant threat of an unpleasant horn blast could have served as a persistent »general arousal« system.

But the relative importance of these attributes of the reinforcer in our experiment probably was not equal.

Preceding the session with the reinforcement every one of our subjects participated in eleven sessions with the same task. That means that they have had plenty of opportunity to become familiar with the frequency and the rate of critical signals, or at least with their own response output which reasonably well reflected the true frequency and the rate of signals. Therefore the knowledge of results supplied by the reinforcer in our experiment is not likely to be the most important attribute of the reinforcement.

Incidentally, the raising of the NR-curve toward the end of the watch in Fig 2, as well as similar but less pronounced tendency of NR-performance curve in Fig. 1 should probably be ascribed to the fairly accurate anticipation of the termination of session due to the accumulated experience.

The alerting effect of the horn probably played a more important part, for from the fact that the detection performance stayed at the initial level of about 82 percent it follows that the subject kept receiving at least one horn blast for the missed signal every fifteen minutes in average.

The presence and effectiveness of the third component, the general arousing effect through the increased motivation, derives support from comments made by subjects that they were »competing against the horn«, or that they were annoyed by the fact that the quality of their performance was immediately socially noticed and sanctioned.

Whatever the relative importance of aforesaid attributes of the immediate negative reinforcement, it remains that their global effect is keeping subjects more awake throughout the watch, what is suggested by our EEG data.

It is well known (e. g. 16) that the decrease of alpha activity may reflect not only an increase in the activation of the organism (as when replaced by the faster, beta, activity), but also the decline of wakefulness, i. e. the somnolence and drowsing, if alpha rhythm is at least partly replaced by the activity of some slower frequency.

The drop of alpha activity and the presence of slower activity on the records from the NR-condition indicate that subjects were drowsing during the watch, and this may at least partly account for their poorer performance in this condition.

On the other side, maintaining the constant initial level of alpha index throughout the watch and the absence of slower activity suggest that subjects were not drowsing while detecting signals under the reinforcement condition.

Such an interpretation of our EEG data conforms to the activation theory of vigilance (17), although it is admitted that the more corroborative evidence would have been obtained had we been able to analyse EEG tracings also in terms of faster activity.

On the basis of our results it can be concluded that:

(a) Increasing the importance or the emotional value of any kind of failure in a vigilance performance by applying the immediate negative reinforcement of sufficient intensity may influence the monitoring efficiency to the point of extinction of the commonly found vigilance decrement, and

(b) Thus increased motivation of subjects apparently owes its beneficial effect to the prevention of drowsing and to keeping the subjects more alert and task-oriented.

The general implication of this conclusion seems to be that in laboratory studies of vigilance the motivation should be very carefully controlled and manipulated over a wide range if the results are expected to have some relevance to the real-life situation.

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Sadržaj

DJELOVANJE NEPOSREDNOG NEGATIVNOG POTKREPLJENJA NA USPJEŠNOST DETEKTIRANJA RIJETKIH SIGNALA I NA ELEKTROENCEFALOGRAM

Polazeći od kritike dosadašnjih ispitivanja detekcije rijetkih signala u kojima je motivacijski aspekt kritičnog signala (važnost posljedice od neotkrivanja signala ili od podizanja lažne uzbune) bio zanemaren, izvršen je pokus u kojem su ispitanici kažnjavani (kratkotrajni jaki zvuk) neposredno nakon svake pogreške učinjene u toku rada. Dobiveni rezultati pokazuju da u takvim uvjetima ne dolazi do uobičajenog progresivnog pada uspješnosti detektiranja, tj. radni učinak kroz cijelo vrijeme ostaje na početnoj razini od oko 82% tačnih detekcija.

Analiza elektroencefalografskih snimaka pokazala je da kod takvog rada, kod kojega stalno prijeti neposredna neugodna posljedica zbog eventualnog propusta ili zbog pogrešne reakcije, izostaju simptomi somnolentnosti (potpuna odsutnost električne aktivnosti sporije od alfa valova), koji se simptomi inače pojavljuju za vrijeme detektiranja rijetkih signala bez neposrednog sankcioniranja uratka.

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