Alpha blocking to the omission of a stimulus

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The study sought to demonstrate an increase in duration of alpha blocking to the omission of a scheduled stimulus and to examine the role of attentive state in producing the effect. Twenty male and 20 female subjects selected on the basis of consistent alpha rhythm were employed in a 2 by 2 by 2 design, the factors being presence or absence of the stimulus on the test trials, instructional set, and whether or not the subject was required to make a motor response to offset of the stimulus. EEG was recorded from the right and left hemispheres in response to a series of 5-sec pure tones of 100 dB presented at regular intervals of 20 sec. The stimulus was omitted on Trials 11, 22, and 33, and duration of alpha blocking was measured on the trials preceding and following the test trials and for an interval immediately prior to the test trials. Analysis indicated a significant increase in alpha blocking on the test trials for groups in which the stimulus was omitted, $F(1,38) = 8.85$, $p < .01$, but no other significant effects. It was concluded that omission of a stimulus results in increased alpha blocking, at least for some subjects, but that this does not depend on a conscious or accurate anticipation of the stimulus. Theoretically, the results support E. N. Sokolov's model of the mechanism of the orienting reaction.

Voronin and Sokolov (1960) reported that if an auditory stimulus that evokes blocking of the alpha rhythm in the human electroencephalogram is repeatedly presented at strictly regular intervals, the alpha blocking response diminishes in amplitude but can be reinstated by omitting the stimulus at a time it is scheduled to occur. A similar effect was reported by Davis (1939). In her study, some subjects showed alpha blocking "if a series of regular sound sequences were cut short" (p. 496). Neither report provides much information on the conditions under which the omission effect was obtained. More recently, a series of studies with the evoked potential response demonstrated an effect due to the omission of a stimulus and indicated that the state of attention of the subject was an important parameter for its occurrence (Picton, Hillyard, & Galambos, 1974). Subjects instructed to attend to or to count a train of clicks presented at the rate of 1.1/sec showed a complex of waves when a click was omitted from the train. Although the work of Picton et al. implicates an active decision process in producing the effect, it cannot be assumed that the conditions governing the evoked potential response to clicks presented in train are the same as those governing spontaneous electrocortical responses such as alpha blocking to discrete stimuli. Accordingly, the present study investigated the role of attentional factors in the omission effect reported by Voronin and Sokolov (1960).

Attention to the stimulus was manipulated by instructions and by making a motor response contingent

on the stimulus. Independent groups of subjects were required to pay attention to the stimulus or to press a button at offset of the stimulus. Control groups were given no specific instructions to attend to the stimulus and were not required to buttonpress. For half the subjects in each of these groups, the stimulus was omitted on three test trials in a series of stimulus presentations, while for the other half it was not. Alpha blocking was studied on the test trials and on the trials immediately prior to the test trials. We expected that there would be no difference in amplitude of alpha blocking on the trials preceding the test trials among groups, but that there would be reliably greater alpha blocking on the test trials for groups in which the stimulus was omitted. We further expected that amplitude of alpha blocking on the test trials would be a function of anticipatory set and the requirement to respond to the stimulus.

In addition to measuring alpha blocking on the test and pretest trials, measures were taken during a period immediately prior to the test trials and on the posttest trials. Each subject also completed a time estimation task at the completion of the test session to study the relationship between accuracy of judgment of the temporal interval between stimuli and magnitude of the omission effect.

METHOD

Subjects

Since not all persons show alpha rhythm, selection of subjects was necessary. The subject pool comprised undergraduate and postgraduate students and clerical and technical staff of the university willing to participate in the study when asked. Volunteers were rejected who did not show a persistent 10-12-Hz wave form of amplitude greater than $30 \mu\text{V}$ during a 10-min recording session prior to the experiment proper. A total of 22

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subjects were rejected on these grounds in selecting the 20 males and 20 females finally studied. Five subjects were assigned to each cell of a 2 by 2 by 2 design, with the constraint that the ratio of sexes in any cell should not be less than 2:3.

Apparatus

Two channels of a Both eight-channel EEG unit were used to record spontaneous electrical activity from the right and left hemispheres. The unit was calibrated to give a signal of $10 \mu\text{V/mm}$, and recording was conducted with a paper speed of 3 cm/sec, a time constant of 0.3 sec, and a high-frequency loss setting of 75. Electrodes were silver-silver chloride, 10 mm in diameter, and were employed in conjunction with a commercial EEG paste.

The stimulus was a pure tone of 1,000 Hz produced by a Madsen clinical audiometer, Model TBN-60, and presented to the subject through TDH 39 headphones. Intensity was set on the basis of pilot studies at a level which produced substantial alpha blocking and was rated at 100 dB SPL using a Dawe sound level meter, Type 1419c. The duration of the stimulus was 5 sec and the interval between presentations was 20 sec, both of which were controlled by a punched-tape programmer. Stimulus onset was automatically recorded on a third channel of the Both EEG unit.

A buttonpress was attached to the arm of the subject's chair, and its activation was recorded on a fourth channel of the EEG.

Procedure

On arriving at the laboratory, the subject was reassured about the purpose of the experiment, asked to remove his watch, and prepared for EEG recording. Electrodes were attached bilaterally on the vertex and occipital region of the skull at sites C3 and O1, and C4 and O2 of the ten-twenty system (Cooper, Osselson, & Shaw, 1974). The subject was then conducted to an electrostatically shielded room adjacent to the EEG unit, and asked to relax in a comfortable chair. A 10-min test recording with eyes closed followed, at the end of which a decision was made on whether to retain the subject.

If the subject was retained, specific instructions about the requirements of the experiment were then administered. All subjects were informed that a tone would be presented through headphones every 20 sec. Subjects in the appropriate groups were further told, "I want you to anticipate when the tone will come on," and/or, "When the tone goes off, I want you to press this button (indicating the buttonpress attached to the arm of the chair)." All subjects were asked to keep their eyes closed throughout the experiment.

Thirty-four trials were run with each subject, with the stimulus being omitted for the appropriate groups on Trials 11, 22, and 33. The tape program for groups under the omission condition was prepared so that interspersing of a test trial resulted in a total of 45 sec between stimuli.

The session concluded for the subject with completion of a questionnaire about the experiment and a time-estimation task. The purpose of the questionnaire was to determine if instructions to anticipate the stimulus had been followed and if such active anticipation occurred only in the case of subjects so requested. Two subjects who had misunderstood the instructions and one who reported sleeping during the experiment were replaced from the subject pool. The time-estimation task involved five attempts by the subject to indicate when, following a cue from the experimenter, 20 sec had elapsed. The mean of the actual time elapsed, measured by stopwatch over the five attempts, was taken as an index of the subject's accuracy of perception of a 20-sec interval.

Scoring

Records were scored manually, with group membership of the subject concealed. First, each subject's record was scanned to determine whether alpha rhythm was more pronounced from the right or left hemisphere, and further scoring was then con-

finied to the more abundant channel. A 2.5-sec interval following stimulus onset (or scheduled onset in the case of test trials on which the stimulus was omitted) on Trials 10, 11, 12, 21, 22, 23, 32, 33, and 34 was marked on each subject's record. In addition, the 2.5-sec intervals immediately preceding Trials 11, 22, and 33 were marked on the record. The total duration of alpha blocking, in milliseconds, within each of these intervals was measured. The definition of alpha blocking was a decrease in the amplitude of any 10- to 12-Hz wave form present in the interval. To provide a reliable index of alpha blocking to stimulus omission, scores were averaged over the three test trials, Trials 11, 22, and 33. Average scores were obtained as well for the pretest trials, Trials 10, 21, and 32, for the posttest trials, Trials 12, 23, and 34, and for the anticipatory intervals on Trials 11, 22, and 33. Thus, for each subject, an index of alpha blocking was obtained for pretest, anticipatory, test, and posttest periods.

RESULTS

To establish that omission of the stimulus actually evoked increased alpha blocking, mean response levels in each of the four observation periods were compared between groups in which the stimulus was omitted on the test trials and groups in which it was not. These data are presented in Figure 1. A repeated-measures analysis of variance (Winer, 1962) indicated a significant main effect for periods, $F(3,114) = 3.79$, $p < .05$, and a significant Periods by Groups interaction, $F(3,114) = 31.62$, $p < .01$. Tests of simple main effects indicated that duration of alpha blocking for the test period was significantly greater for the groups in which the stimulus was omitted than for the groups in which it was not, $F(1,38) = 8.85$, $p < .01$. No other tests of simple effects proved statistically significant, though the F value was greater than unity in the case of the comparison of duration of alpha blocking between groups on the posttest trial, $F = 1.09$. Thus, while groups did not differ in duration of alpha blocking during pretest, posttest, or anticipatory periods, a reliable increase in alpha blocking was produced by omitting the stimulus at the test period. This conclusion is not altered if the more conservative decision rule of Greenhouse and

Figure 1. Mean duration of alpha blocking in observation periods for groups in which the stimulus was (omission) and was not (stimulus) omitted.

Geiser (1959) is applied to the outcome of the repeated-measures analysis.

In examining the influence of experimental conditions on duration of alpha blocking during the test period, a 2 by 2 by 2 analysis of variance was performed in which the factors were presence or absence of the stimulus during the test period, instructional set, and buttonpressing in response to the stimulus. Only the factor of presence or absence of the stimulus proved statistically significant, $F(1,32) = 5.79$, $p < .01$, which is a repetition of the effect observed in the repeated measures analysis. All other F values were less than unity, with the exception of that for the interaction between presence or absence of the stimulus and buttonpressing, $F(1,32) = 3.67$, $p > .05$. The origin of the interaction was a greater response during the test period for subjects required to buttonpress. The conservative conclusion, however, in the light of the statistical test is that neither buttonpressing nor instructions influenced duration of alpha blocking to stimulus omission.

An individual subject analysis of the data for the groups in which the stimulus was omitted in the test period indicated that, for 12 of the 20 subjects, duration of alpha blocking during the test period was greater than that during the pretest period. Thus, not all subjects responded to stimulus omission with increased alpha blocking. Correlational analysis indicated that duration of alpha blocking to omission of the stimulus was unrelated to accuracy of time estimation ($r = 0.07$, $N = 20$, $p > .05$) and was unrelated to duration of alpha blocking during the anticipatory period ($r = 0.26$, $N = 20$, $p > .05$).

DISCUSSION

The finding of the present study that increased alpha blocking can be elicited by the omission of a previously presented stimulus is consistent with the observations of Voronin and Sokolov (1960) and Davis (1939). Unlike the previous studies, which employed within-subject designs, the present study employed a between-subject design to test for the effect. Demonstration of increased responsiveness to omission under these conditions indicates that it is a robust effect, though, as the intra-individual analysis indicated, one not manifest in all subjects.

The conditions under which the omission effect occurs are clarified to some extent by the results of the present study. Subjects given an active anticipatory set did not show larger magnitude responses to stimulus omission than subjects not actively anticipating the stimulus, nor did a physiological index of anticipation, duration of alpha blocking in the interval immediately prior to the test period, correlate with duration of response during the test period. Moreover, accuracy of estimation of the interval between stimuli was unrelated to magnitude of the effect. This pattern of results points

to the conclusion that a conscious and accurate anticipation of the stimulus is not a necessary condition for its omission to elicit an increase in alpha blocking.

Results with the buttonpressing manipulation were more equivocal. Although not statistically reliable, there was a tendency for subjects who were required to make a motor response to the stimulus to show larger magnitude responses on the omission trial. Further examination of this factor is required before its influence on omission is dismissed. In any such further studies, variation in stimulus intensity is indicated. In the present study, intensity was selected on the basis of pilot studies to ensure substantial alpha blocking and thus optimal conditions for demonstrating the omission effect. The intensity level thus selected was quite high, and this may have resulted in a stimulus of "significance" irrespective of its role in signaling a motor response.

Theoretically, the omission effect provides strong support for Sokolov's (1969) model of the orienting response (cf. O'Gorman, 1973). The model postulates that the nervous system stores the parameters of a stimulus such as intensity and frequency of presentation, and extrapolates on the basis of this information the likely future occurrence of the stimulus. If the predicted stimulus does not occur, an orienting response is elicited, one of the components of which is alpha blocking. The essence of the model is that the discrepancy of a stimulus from previous experience, and not the physical properties of the stimulus, determines whether an orienting response is elicited. In the case of omission of a stimulus, its physical properties are removed completely, and hence any effect which this event has seems attributable to its discrepancy from previous experience.

An alternative interpretation of the omission effect was proposed by Groves and Thompson (1970). According to their view, the effect of stimulus omission is the result of temporal conditioning of central state of arousal. Presentation of the stimulus at regular intervals provides a conditioned stimulus for the change in state induced by stimulation. The omission trial in these terms is a test trial on which the unconditioned stimulus is not presented. The present data are at variance with the conditioning interpretation in that amplitude of response on the omission trial was not influenced by anticipatory set and was unrelated to responding in the anticipatory period prior to the omission period. Both observations are contrary to expectations based on studies of temporal conditioning (cf. Harley, 1973), and as such fail to support a temporal conditioning interpretation of the omission effect. The literature on temporal conditioning is, however, meager and is based largely on autonomic response data. Further studies of the omission effect within the context of attempts to temporally condition electrocortical activity may indicate the convergence of these two operations.

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