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Alpha Blocking to Auditory Stimulation in Simple and Discrimination Reaction Time Tasks

Lynn Riette Cooper

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ALPHA BLOCKING TO AUDITORY STIMULATION IN SIMPLE AND DISCRIMINATION REACTION TIME TASKS

A THESIS

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ABSTRACT

The effects of selective and anticipatory attention on alpha blocking were examined by presenting an .8 sec. warning tone followed .4 sec. later by a second tone which alternately commenced 1) a control series of passive listening, 2) a simple reaction time task, or 3) a discrimination reaction time task. No differences in alpha activity were noted in the period of auditory anticipation following the onset of the warning signal or during the process of selection after the reaction signal. Significant differences in conditions were noted only in the period after the response had been made. It was suggested that the presence of an overt response, combined with a complexity factor, may explain the reduction in amount of alpha activity after the response occurs.

CHAPTER I

INTRODUCTION

When Hans Berger (1929) discovered the alpha rhythm, he postulated that alpha blockade resulted from the attentional value of the stimulus rather than its other attributes. Following his example a number of subsequent investigators concluded that attenuation of the alpha rhythm was related in one way or another to attending (Adrian and Mathews, 1934; Bagchi, 1937; Jasper and Cruickshank, 1937; Jasper, Cruickshank, and Howard, 1935; and Williams, 1940). More recent authors have also stated that alpha blocking was a concommittant of attention (Eberlin and Yeager, 1968; Lynch and Paskewitz, 1971; Mundy-Castle, 1957; and Oswald, 1957).

The existence of a relationship between alpha attenuation and attention received formal sanction in a definition proposed by the terminology committee of the International Federation for Electroencephalography and Clinical Neurophysiology. The committee stated that alpha is "a rhythm, usually with a frequency of 8-13 cycles per second in adults, most prominent in the posterior areas, present most markedly with the eyes closed and attenuated during attention, especially visual" (Storm van Leeuwan, *et al*., 1966).

However, the value of incorporating the concept of attention as being either wholly or partly responsible for alpha activity is subject to question. One criticism of evoking attention as an explanation of alpha activation is the ambiguity inherent in the term itself (Hebb, 1949). Despite the diversity of connotations and meanings attached to the term, attention when cited in the literature as an explanatory concept is seldom limited to a single meaning nor is clear reason given as to why attention is determined to be the relevant variable in any particular instance (Mulholland and Evans, 1966). Thus, a specific physiological phenomenon, alpha blockade, has been frequently explained by a loosely defined psychological construct.

An alternative way of approaching the concept of attention in experimentation is to define the term within the framework of the experimental design, in conjunction with a critical appraisal of definitions of attention set forth by the more theoretically-oriented literature. Berlyne (1970) divides the meanings of attention into the two basic categories of intensive and selective aspects. Selection determines which stimuli will be responded to and maximizes sensory input from these stimuli while minimizing input from conflicting stimuli. In contrast, the intensive aspects of attention are concerned with the arousal level of the organism. Moray (1970) also considers these two aspects of

attention valid but he expands the intensive aspects to include activation, set, and vigilance, which have been traditionally associated with the foreperiod in reaction time experiments in which _S_ is waiting in anticipation.

A second criticism of much of the literature supporting a relationship between attention and alpha blockade is that in almost every instance, vision was the main sensory modality studied. It has been tacitly assumed that the effect of visual attention on alpha activity is duplicated in the other senses as well. That the alpha blocking response is not identical in all senses can, however, be clearly demonstrated by the fact that vision is the only known mode of stimulation producing alpha blockade continually with repeated stimulation.

Moreover, with the use of visual stimuli, oculomotor functions may become involved in explaining the reduction of alpha amplitude. The existence of a positive relationship between alpha blockade and specific oculomotor components of the orienting response has received substantial support (Mulholland, 1971; Mulholland and Evans, 1966; Mulholland and Peper, 1971; and Peper, 1970) and the potentially confounding effect of these functions should not be ignored when generalizing the reaction of alpha activity from visual stimulation to the other senses.

Bakes (1939) is the only experimenter who has examined alpha blocking during selective attention to non visual stimulation. Bakes found that when passively listening to a series of tonal stimuli, his Ss initially showed alpha blockade in response to the tones in 34% of the cases; repetition of this same condition at the conclusion of the experiment showed blocking only 27% of the time. However, when Ss were asked to respond manually to the tones, alpha blockade was noted 44% of the time. Finally, when asked to respond only to one of two tones in a disjunctive reaction time test blocking increased to 62% when a manual response occurred to the positive stimulus, but dropped to 40% to the negative stimulus when no overt response occurred. Thus, Bakes (1939) found support for the idea that a factor involved in discrimination also seemed to be connected to the occurrance of greater alpha blockade when the reactive requirements on the S were more complex. However, in the simple reaction time task, the onset of blockade occurred .10 sec. after the response, while in the discrimination condition alpha blockade was reported .13 sec. before the response, suggesting that the role of selectivity is not a simple one. The differences in the sequence of blocking and response might have been accounted for by task complexity had not the mean latency of onset of blockade been longer in the two control conditions than in

either the reaction time or discrimination tasks. Because of the foregoing incongruity it is difficult to determine the relationship of selective attention to alpha blockade.

Bake's (1939) use of a binary criterion of alpha blocking or persistence rather than a measure of degree of alpha reduction further limits the usefullness of his results. When alpha activity diminished but did not disappear entirely, no decrease was recorded. Moreover, alpha activity could quite possibly have begun to decrease much earlier than the latency of total blocking would indicate. Utilizing measures sensitive to smaller fluctuations in alpha amplitude would eliminate some of the restrictions imposed by the method of quantification used by Bakes.

In a study primarily concerned with the vertex evoked potential Larson (1960) provides some evidence that anticipation of an auditory stimulus is not necessarily accompanied by absence of alpha activity. In fact, alpha waves were more abundant in 20 sec. periods prior to a reaction stimulus which was highly significant to Ss than a stimulus which was passively listened to. However, since the stimuli were presented on a random schedule, Ss had no way of actually anticipating the onset of the stimulus as could be done with a warning signal. Larson's results were further complicated by the fact that Ss had their eyes open

in a lighted room during the entire experiment, reducing the likelihood of alpha production.

Niether Bakes (1939) nor Larson (1960) demonstrate a clear relationship between selective and/or anticipatory attention and alpha blocking. It was therefore the purpose of the present study to incorporate both the anticipatory and selective aspects of auditory attention in a single investigation by monitoring EEG activity from a warning stimulus through the onset and duration of a reaction stimulus. The addition of a warning stimulus alerted Ss prior to the onset of the response tone, in order to determine the possible effect of anticipation. The experimental conditions paralleled those of Bakes and involved passive listening to the stimulus sequence as well as two response tasks of varying difficulty, a simple reaction time task and a discrimination task. A sophistocated method of data acquisition and reduction enabled the evaluation of changing trends in alpha amplitude in order to assess the differences in experimental conditions more carefully than could Bakes (1939) with the binary criterion of alpha presence or absence.

CHAPTER II

METHOD

Subjects

Ss were volunteer undergraduate students from introductory psychology classes at Georgia State University. Sixteen Ss, five females and eleven males, with moderate to persistent alpha, participated. Four additional Ss were eliminated because they lacked sufficient alpha to produce stimuli in the manner to be described below.

Apparatus

A Grass silver cup electrode filled with EKG Sol were placed on the right occipital area (O), one inch above and one inch to the right of the occiput and was secured by a Velcro head harness. A monopolar recording from O referenced to the left earlobe was the source of the data presented below. A ground electrode was attached to the right ear. The EEG was recorded by a Grass model 78 polygraph. The occipital recording was filtered through a Kron-Hite model 1335 filter with the 3-Db points set to pass 7.5-12.5 Hz. The filtered record was rectified through a Grass 7P3 preamplifier and was integrated by a Grass 7P10 Ramp Integrator. Finally, the slope of the Ramp

Integrator was sampled by an IBM 1800 Data Acquisition and Control System at the rate of 100 times per sec. averaged into .1 sec. blocks as described below.

Digibit 300 series Logic Circuitry was programmed to present stimuli only when Ss had achieved a pre-established criterion of alpha abundance as determined from the output of the filter. The alpha criterion consisted of seven consecutive waves in an .8 sec. interval, each wave being above a voltage level determined by an adjustable Schmitt trigger. Data sampling was begun by the computer with the onset of each stimulus. Readings by the Ramp occurred at intervals of .01 sec. Every ten of these readings were averaged to yield a mean value of the Ramp slope in .1 sec. intervals. Each mean value was subtracted from the preceeding mean value. A large difference corresponded to substantial alpha activity whereas a small difference reflected relatively little activity in the alpha band. Computer monitoring began with the onset of the stimulus and continued for 2,2 seconds. yielding 22 differences.

Procedure

During the experiment Ss were seated in a reclining chair in an Industrial Acoustics room, without illumination. Ss were told that they would hear a series of tones and that they would eventually receive

instructions to respond to these tones by depressing a response key. Ss were then reminded to make no response at present, but to relax with eyes closed, keeping movements to a minimum. A blindfold was used on all Ss to prevent visual input. After a brief period of relaxation and adjustment of the equipment, lasting about 3 min., the experiment commenced.

Each S received 80 trials of sequences of two tones. Each tone sequence consisted of a warning stimulus lasting .8 sec. followed .4 sec. later by a 1.0 sec. reaction tone. Two clearly audible tones of distinct frequencies (400 c/s and 600 c/s). were used. The warning tone was always the low tone, but the response tone was randomly distributed between the high and the low tones. The intertrial interval was 5, 10, or 15 sec., plus whatever time Ss required to achieve the alpha-present criterion described above.

Trials were divided into four experimental conditions of 20 trials each. Each set of 20 trials consisted of ten trials each of the two stimulus sequences (low-low and low-high) presented in random order. The first and last blocks of 20 trials were the control conditions in which S made no response to the stimuli. The second condition consisted of a simple reaction time task in which S was asked to depress the response key as soon as

he heard the second tone, whether it was high or low. The final condition consisted of a discrimination task in which S responded to only one of the two combinations of tone pairs. Half of the Ss were instructed to depress the response key only when the second tone was the same as the first and the other half were told to respond only when the two tones were different. Taped instructions were presented over a speaker before starting each condition.

In addition to counterbalancing response to high and low tone in the discrimination condition, the order of presentation of the reaction time and discrimination tasks was also counterbalanced. Half of the Ss received the reaction time condition first while half received the discrimination task first.

CHAPTER III
RESULTS

In order to compare results from different parts of the session as well as to allow cross-subject comparisons the 22 differences corresponding to the alpha amplitude in successive .1 sec. intervals were converted to proportions. This procedure was performed by conditions in blocks consisting of all trials of the same type of stimulus combination, low-low or low-high. A total of eight ten-trial blocks was obtained for each S, each two blocks corresponding to the two stimulus sequences for each of the four experimental conditions. The mean value for all ten values in the block occurring at .2 sec after the onset of the warning stimulus was calculated and divided into each of the values for the 20 successive .1 sec. intervals of the trial. The reading at .2 sec. was chosen because, due to a switching artefact, it was the first valid reading after the onset of the stimulus sequence and was prior to any pronounced effect of the stimulus in the electroencephalogram.

A comparison of the two control series using a Wilcoxan matched-pairs signed-ranks test showed that the overall decrease in alpha activity from .1 to 2.2 sec. was less in the second control series than in the first (T=12,

$p<.01$). To achieve a representative response for passive listening, the two control series were pooled for comparison with the reaction time and discrimination conditions. The discrimination trials were also separated into those trials in which *S*s made a manual response to the stimulus (discrimination with response) and those trials in which no manual response occurred (discrimination without response). The mean values for all 16 *S*s in the pooled control conditions, the reaction time condition, and the discrimination condition, with trends of alpha amplitude to positive and negative stimuli shown separately, appear in Figure 1. The horizontal axis indicates time passage beginning with the onset of the warning signal and extending through the termination of the reaction stimulus 2.2 sec. later. Readings for the points at .1, .9, and 1.3 sec. were eliminated due to contamination by the switching artefact. The mean reaction times for the reaction time and discrimination tasks were .217 sec. and .337 sec. respectively and are indicated by the letters *a* and *b* in Figure 1.

The left section of Figure 1 is composed of the seven values occurring between .2 and .7 sec. after the onset of the warning stimulus. A Friedman two-way analysis of variance showed no significant differences between experimental conditions ($X = .975$, $p<.90$). There was an

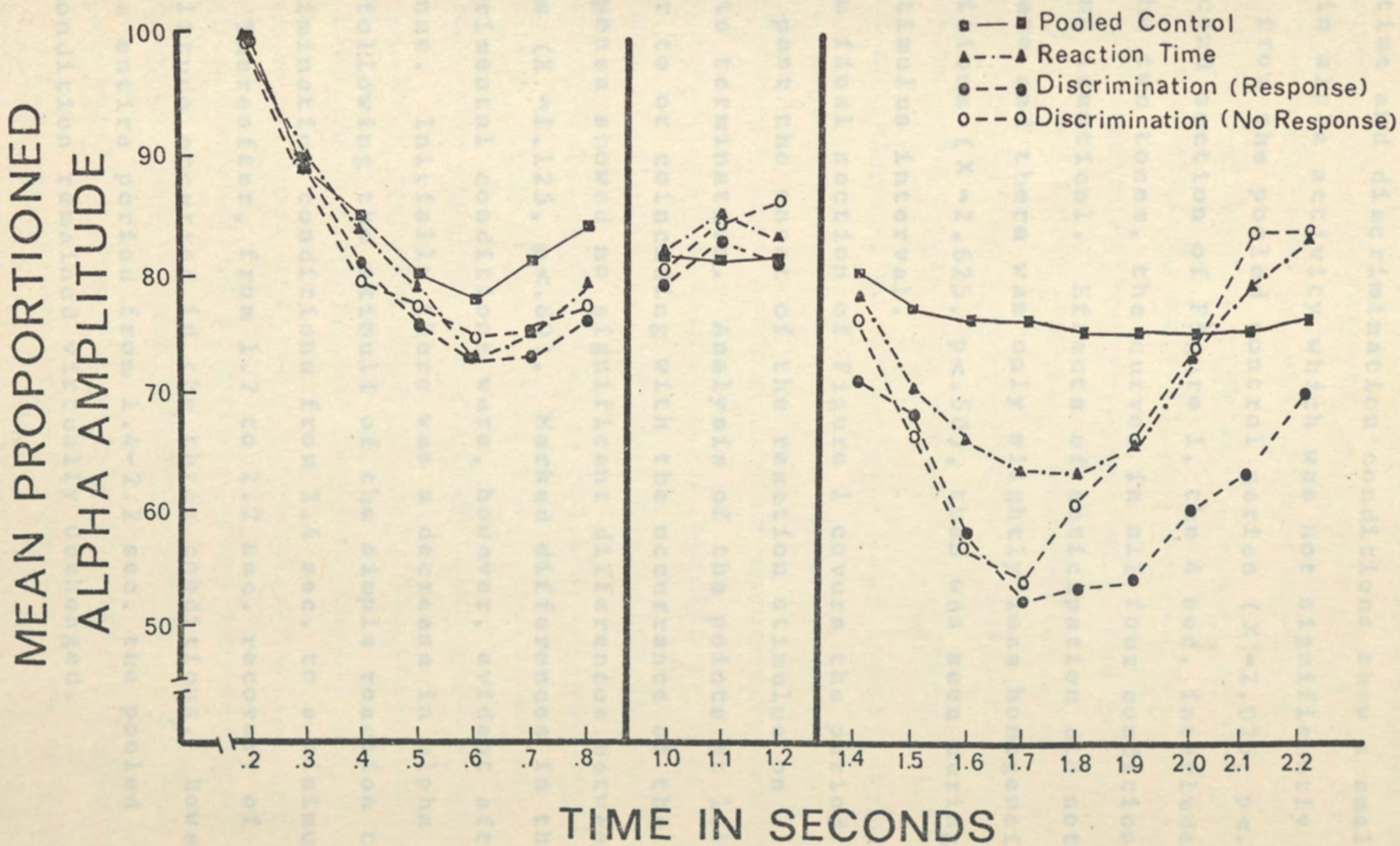

Figure 1. Alpha amplitude in the four experimental conditions.

initial decrease in alpha activity which was uniform for all conditions through .5 sec. From .6 to .8 sec. the reaction time and discrimination conditions show a small decrease in alpha activity which was not significantly different from the pooled control series (X =2.025, p<.70). In the second section of Figure 1, the 4 sec. interlude between the two tones, the curves in all four conditions were almost identical. Effects of anticipation did not show up here and there was only slightly less homogeneity over conditions (X =2.625, p<.50), than was seen during the warning stimulus interval.

The final section of Figure 1 covers the period from just past the onset of the reaction stimulus on through its termination. Analysis of the points at 1.4-1.5 sec. prior to or coinciding with the occurrance of the overt response showed no significant differences between conditions (X =1.125, p<.80). Marked differences in the four experimental conditions were, however, evident after the response. Initially there was a decrease in alpha activity following the stimuli of the simple reaction time and discrimination conditions from 1.4 sec. to a minimum at 1.7 sec. Thereafter, from 1.7 to 2.2 sec. recovery of alpha amplitude occurred in the three conditions. However, during the entire period from 1.4-2.2 sec. the pooled control condition remained virtually unchanged.

Page's L test of monotonic trend (Page, 1963) was used to test the significance of the trends mentioned above and to contrast the differences in trends among the four experimental conditions. A significant downward trend was demonstrated in the period from 1.4-1.7 sec. in the reaction time condition (L=445.0, p<.001), in the discrimination condition with response (L=449.0, p<.001), and in the discrimination condition without response (L=457.4, p<.001), but not in the pooled control condition (L=412.5, p<.15). Using a variation of the L test (Putney, 1972) significant differences in trend were also found between the control condition and the other three conditions. The procedure involved subtracting in turn successive points of the reaction time and discrimination conditions from corresponding points of the control condition for each S and then computing the value of L for the difference scores. By this method, significant increasing separation was found between the control and reaction time conditions (L=437.0, p<.001), between control and discrimination with response (L=442.0, p<.001), and between control and discrimination without response (L=441.0, p<.001). No significant difference in trend was noted between reaction time and discrimination with response (L=406.0, p<.35), between reaction time and discriminatin without response (L=414.0, p<.15), or between discrimination with or without

a response (L=406.0, p<.35).

Analysis of the recovery period from 1.7-2.2 sec. showed significant upward trend for reaction time (L=1328.0, p<.001), discrimination with response (L=1307.5, p<.001), and discrimination without response (L= 1346.0, p<.001), but not for the pooled control condition (L=1152.0, p<.25). Moreover, analysis of the difference scores showed significant difference in trend between control and reaction time (L=1352.0, p<.001), between control and discrimination with response (L=1279.0, p<.001), and between control and discrimination without response (L=1370.0, p<.001). A significant difference in trend also occurred between the two discrimination conditions (L=1257.0, p<.001) and between reaction time and discrimination without response (L=1239.0, p<.025), but not between the reaction time and discrimination with response (L=1146.0, p<.25).

The trends over the trials during each experimental condition were also analysed. As noted previously, alpha activity was greater during the second control series than the first (T=12, p<.01). In addition to this overall habituation from the beginning to the end of the experiment, habituation was also found within two of the four experimental conditions. The trends were demonstrated by obtaining the mean for all <u>S</u>s by trials at the 1.7, 1.8,

and 1.9 sec. points where the largest alpha reduction was obtained. A graph of mean values by pairs of trials appears in Figure 2. Alpha activity increased significantly over trials in the discrimination condition without response (L=5158.5, p<.01) and in the second control series (L=36659.5, p<.05). Moreover, there was a significant difference in trend between the discrimination conditions with and without a response (L=5079.0, p<.05). No significant trends of increased alpha activity were found in the first control series (L=3592.5, p<.70), the reaction time condition (L=36047.0, p<.30), or the discrimination condition with response (L=4813.0, p<.90).

Subjects were also compared on the basis of whether they responded to the low-low or low-high sequence in the discrimination condition. Mean levels of alpha activity for the ten discrimination trials in which a response occurred were obtained for each S for values from 1.7 to 2.2 sec. The values from 1.7 on were selected because they comprised the greatest differences between the discrimination conditions with and without response. Using a Mann-Whitney U-Test it was found that when Ss responded to the low tone in the discrimination condition that their alpha activity was significantly less than that of the Ss responding to the high tone (U=52, p<.025).

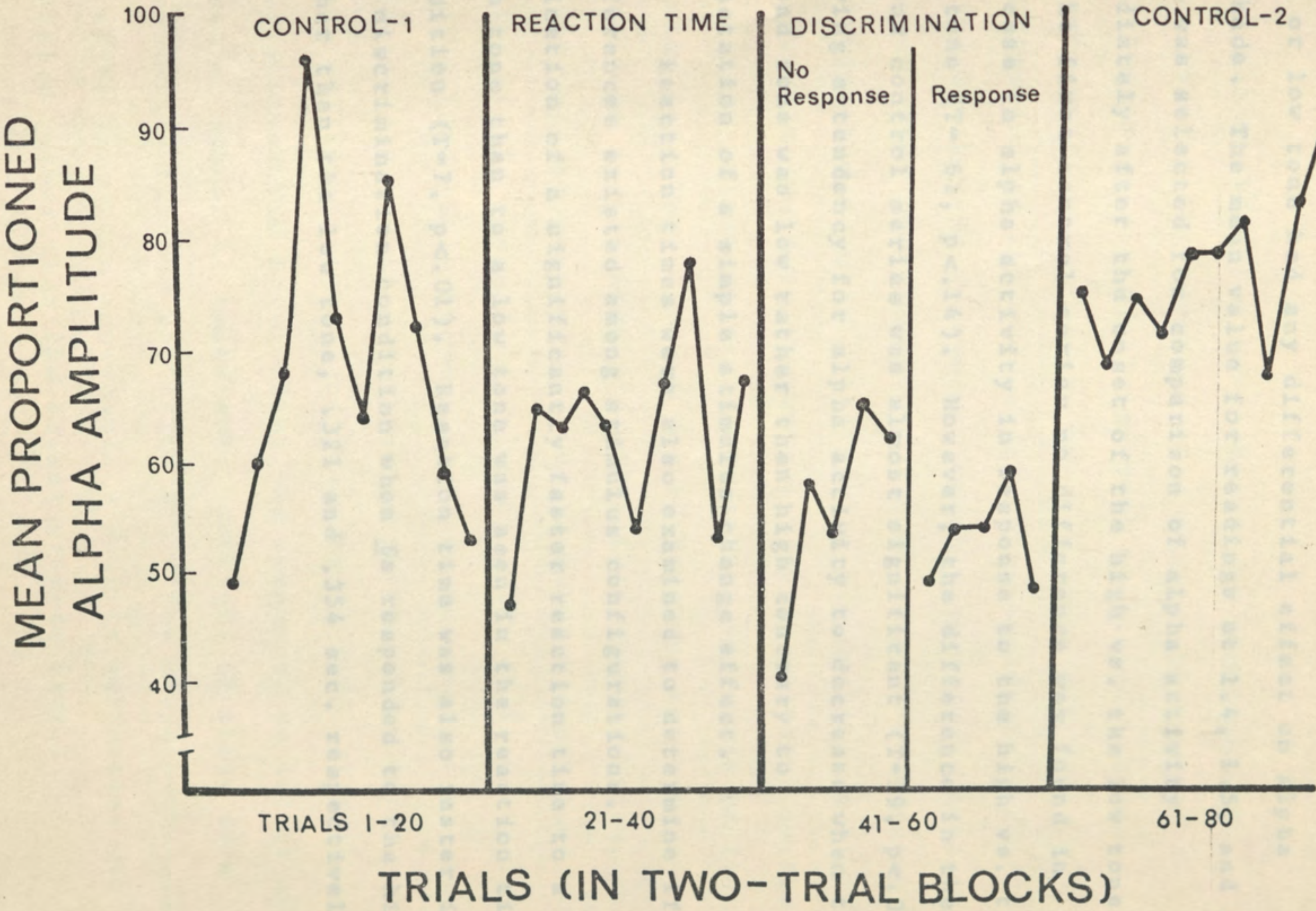

Figure 2. Habituation in the four experimental conditions in blocks of two trials.

The effect of the two tone frequencies was also evaluated in the two control series to determine if the high or low tone had any differential effect on alpha blockade. The mean value for readings at 1.4, 1.5, and 1.6 sec. was selected for comparison of alpha activity immediately after the onset of the high vs. the low tone. In the first control series no difference was found in decrease in alpha activity in response to the high vs. the low tone ($T= 61$, $p<.14$). However, the difference in the second control series was almost significant ($T=39$, $p<.08$) showing a tendency for alpha activity to decrease when the second tone was low rather than high contrary to expectation of a simple stimulus change effect.

Reaction times were also examined to determine if differences existed among stimulus configurations. Indication of a significantly faster reaction time to a high tone than to a low tone was seen in the reaction time condition ($T=7$, $p<.01$). Reaction time was also faster in the discrimination condition when _S_s responded to the high rather then the low tone, .321 and .354 sec. respectively.

CHAPTER IV

DISCUSSION

Alpha reduction was found to be significantly greater during the reaction time and discrimination conditions than during the control condition. However, the salient contribution of the present study was the specification of the sequential patterns of alpha blockade and the subsequent determination that the greatest blocking occurred after the response had been made. No evidence of a relationship between anticipation and decline in alpha activity was found in either the warning stimulus period or the .4 sec. silent interval preceeding the onset of the reaction stimulus. In the period from the onset of the second tone to the mean discriminatory response time, no significant differences were found between conditions. The results of the present study, then, seem to argue against a direct relationship between alpha desynchronization and attention defined in selective or anticipatory terms, as far as auditory stimuli are concerned. Since differences in conditions did occur after the response, an effect of selection cannot be ruled out. However, if there is a relationship between selection and alpha desynchronization the alpha reduction represents a delayed reflection of selection rather than the actual process itself.

In comparing the results of the present study to both Bake's (1939) and Larson's (1960) results, some important differences become apparent. Larson, it will be remembered, found that alpha activity was more abundant during an anticipatory period in which _S_s were alerted for a simple reaction than when they were relaxed. This trend was not found in the present study, as alpha activity during the warning tone and silence was equally or more abundant in the control condition than in the other three experimental conditions. Secondly, Larson's findings tend to convey the idea that alpha activity is abundant during anticipation. With the addition of a warning signal and the use of a shorter anticipatory period (.4 sec. rather than 20 sec., plus a longer randomly varied interval) the present study demonstrated no substantial persistence of alpha activity during anticipation. However, both Larson's results and those of the present study are in agreement that there was no discernable decrease in or absence of alpha activity which could be linked to anticipation of a reaction stimulus.

Bakes (1939) results can be clarified as well as expanded by the temporal pattern of alpha activity in response to the varied auditory stimulus conditions. Bakes found that blockade occurred .10 sec. before the overt response in the simple reaction time condition, but

occurred .13 sec. after the overt response in the discrimination condition. Inspection of the sequential alpha patterns in panel three of Figure 1 shows that in both the reaction time and discrimination conditions the bulk of the alpha reduction occurred after the response. Rather than suggesting a selection effect in the discrimination condition as might be concluded from Bake's results, the present study clearly showed that alpha blockade was not a temporal concommitant of selection. Secondly, Bakes, in his discussion, gives the factors of making a decision and a simple muscular response equal weight in their contribution to alpha blockade. This is misleading in that the post discrimination effect occurs equally from 1.5-1.7 sec. regardless of the presence or absence of an overt response. It is only in the second phase from 1.8-2.0 sec. that the effect Bakes describes is directly reflected. However, during the period from 1.8 to 2.0 sec., the amount of alpha amplitude shown in Figure 1 is close to Bake's findings, with the least reduction in alpha activity occurring in the control series, and the most reduction occurring in the discrimination condition accompanied by an overt response. Finally, the alpha activity is almost equal in the simple reaction time and discrimination condition without overt response, this amount of alpha being more abundant than the discrimination

condition with response but less abundant than the control condition. Therefore, it seems that Bake's conclusions based upon the binary criterion reflected only an after effect of the reaction conditions and not the similarity of their initial alpha reduction.

On the basis of the work of Mulholland (1971) and others, which has strongly implicated a connection between oculomotor function and alpha decrease, the possibility of an effect of eye movement cannot be overlooked as a potential determinant of the differences in amount of alpha activity in experimental conditions. Mulholland accounts for alpha blockade in response to auditory stimuli by an oculomotor response which automatically accompanies the auditory stimulus. According to Mulholland, it is the looking response which blocks alpha activity to auditory stimuli. There is little reason, however, to expect ocular orientation to occur in blindfolded Ss when the stimulus source is directly in front of them. Moreover, even if ocular orientation did occur, there is no reason why it should cease in the control conditions, but persist in the reaction time and discrimination conditions where alpha decreases are noted. There is also a possibility that the overt response was accompanied by a startle blink and that it is the blink which either directly affected the alpha activity or indirectly maintained the oculomotor looking

function. This explanation can also be ruled out as alpha activity showed almost identical initial decrease in all discrimination trials regardless of whether an overt response occurred or not.

An alternative explanation of the observed alpha decrease in the reaction time and two discrimination conditions is that the decrease represents increased effort involved in the making of a response or the possibility of doing so. Moreover, the presence of an overt response seems to be important in lengthening the recovery time required. The separation between the response and non-response discrimination conditions in the ascending portion of Figure 1 demonstrates the longer recovery period when an overt response is present. Some of the separation can be accounted for by habituation which occurred in the discrimination condition when the response was absent but not when the response was present (see Figure 2). Moreover, habituation is not seen in the simple reaction time condition. Possibly, the presence of an overt response counteracts the tendency toward habituation and prolongs alpha reduction.

In addition to the differences accounted for by the presence of an overt response, the difficulty of the task is also a possible factor affecting alpha decrease. Difference in difficulty would explain the greater

initial attenuation of alpha activity in both discrimination conditions than was noted in the simple reaction time task. Additional evidence of a complexity factor is seen in the differential effect of the tones themselves. The results indicate that when the second tone is high rather than low, the response time is significantly faster which may indicate that it is easier to respond to a tone change rather than when the tone remains the same. Moreover, Ss tend to show more overall decrease in alpha activity when responding to the low tone than when responding to the high one, again suggesting that the difficulty of the task involves increased effort when responding to the same tone as the warning signal.

In summary, the findings of the present study indicate that attention, when defined in terms of anticipation, does not significantly decrease alpha activity. In addition, the actual process of selection is accomplished prior to any differential effect on the alpha rhythm, indicating that alpha activity is not altered by the process of selection as it is going on, although desynchronization might reflect this process in a delayed fashion. The pronounced differences in conditions which occurred after the response was made can tentatively be accounted for in part by the complexity of the task, those tasks of the greater complexity showing the greater degree

of initial post response alpha reduction. Secondly, the presence of an overt response seems to be important in lengthening the recovery period, possibly by preventing or reducing habituation to the reaction stimulus.

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