EEG DESYNCHRONIZATION AND SERIAL LEARNING

by

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THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Arts for acceptance, a thesis entitled "EEG Desynchronization and Serial Learning," submitted by Ihor Kozyra in partial fulfilment of the requirements for the degree of Master of Arts.

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ABSTRACT

EEG correlates of serial learning were studied by examining two characteristics of EEG activation (mean or general level and peak level) in two groups of subjects, one of which was presented with a serial list for learning through the anticipation method (E group). The other was a resting control group which did not hear the serial items (C group).

The E group was found to have a significantly higher overall activation level than the C group. Also, a significant F ratio was found for the E group, but not the C group, for mean activation levels associated with Serial Position. The serial position activation levels were found to be negatively correlated with the number of anticipation errors. This suggests that earlier learned serial items were associated with higher mean activation levels. In addition, a significant Trial X Serial Position effect was found which indicates that the EEG response to specific list positions changed across trials.

The nature of the Trial X Serial Position interaction was further examined through an investigation of the peak activation level for each serial item. The peak activation levels revealed, as did the mean levels, a significant negative correlation with anticipation errors. In addition, the peak levels had a significant negative correlation with the trial of peak occurrence (i.e., 1 to 10) while trial of peak occurrence and anticipation errors were positively correlated. This indicates that earlier learned serial items had higher and earlier activation peaks in addition to having higher overall activation levels. This suggests that both mean and peak activation levels for specific serial items are related to the order in which the items are considered for learning.

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INTRODUCTION

The responsiveness of the human EEG to sensory stimulation and a variety of behavioural states has been investigated for nearly half a century. The demonstration by Adrian and Matthews (1934) that oscillating electrical potentials could be recorded from the intact human scalp effectively dispelled the skeptical reception accorded Berger's original claims to the same effect in 1928 (Cobb, 1963). Berger discovered what came to be known as the alpha rhythm and the early EEG studies dealt primarily with this rhythm. The normal adult EEG, however, is comprised of a number of rhythms. These rhythms have become classified primarily according to frequency and assigned a Greek signature letter. A detailed discussion of the various EEG rhythms and their characteristics is presented by Cobb (1963).

The alpha rhythm is probably best understood in terms of its relationship to other rhythms which reflect differing states of alertness. As noted by Lindsley (1952), an alert, aroused, or excited organism produces low voltage fast EEG activity whereas relaxed states of wakefulness are characterized by predominant alpha activity (high voltage synchronized activity in the 8 to 12.5 c/s frequency range). As the individual becomes progressively drowsy, the alpha waves gradually disappear and during sleep the EEG picture becomes one of low voltage slow EEG in the 4 to 5 per second frequency range. Duffy (1957) suggests that this EEG pattern represents an EEG activation continuum, with the alpha pattern appearing between the two extremes of arousal or activation. Lindsley (1952) similarly indicates that alpha blocking or EEG desynchronization (increase in wave frequency and a reduction in wave amplitude) represents an increment in activation.

The finding of a peripheral measure of supposed central activity made the establishment of correlates between mental activity and the EEG one of the principle objectives of EEG researchers. The findings of the early studies, however, were primarily limited to a demonstration of blocking or desynchronization of the alpha rhythm in response to various forms of stimulation and behavioral states. As noted by Shagass (1972) the discovered relatiohships were for the most part disappointing. Adrian and Matthews (1934) observed that the alpha rhythm characteristically appeared when the subject had his eyes shut or was staring into a uniform visual field. Eye opening and perception of pattern or even the attempt to perceive pattern typically resulted in partial or complete disruption of the alpha rhythm. Loomis, Harvey, and Hobart (1936) found alpha disruption to occur even during the expectation of visual stimuli while Mundy-Castle (1957) demonstrated the same effect in response to visual imagery.

Bagchi (1937) attempted to determine the differential effectiveness of a variety of situations in effecting alpha desynchronization. Measuring the time taken for the alpha rhythm to reappear following the presentation of a stimulus (adaptation) he made the following findings:

(a) adaptation was quicker to a continuous tone than to a repetitive one,

(b) sound was not as effective as light in blocking the rhythm,

(c) a 500 cycle decrease in pitch produced no change in the adaptation time,

(d) subjects' reactions to common words were varied and alpha blocking did not always occur,

(e) adaptation was slower to an abstract word such as "how" than to nouns,

(f) calling out of the subject's name produced alpha blocking in every instance.

Mundy-Castle (1957) conducted a more systematic investigation to determine the relative effectiveness of various activities in causing disruption of the alpha rhythm. He presented his subjects with five different activities and measured the degree of activity-related alpha rhythm disruption on a four-point scale ranging from no effect on the alpha rhythm to complete alpha rhythm blocking. His results may be summarized to provide the following order of effectiveness: eye-opening>visual imagery>mental arithmetic>auditory imagery> kinesthetic imagery. From his findings, Mundy-Castle (1957) concluded that the alpha rhythm was principally related to visual processes in that eye opening and visual imagery were the most effective alpha rhythm disruptors. However, he did establish that conscious involvement of the visual process was not a necessary condition for complete blocking of the alpha rhythm.

An additional finding and one bearing considerable interest to the present study was that total alpha blocking did not necessarily result from attention. This lack of a one-to-one relationship between complete alpha blocking and attention suggests that the degree of attention to a particular stimulus at a particular time may be an important relationship to explore.

Studies using indices of activation other than EEG desynchronization have suggested that activation is greater when problems are more difficult (Berlyne, 1966). This result is likely due to the more intense and protracted attention required to successfully complete difficult tasks. However, while EEG studies have demonstrated primarily through the use of mental arithmetic tasks, that problem solving increases desynchronization, an attempt to find systematic changes in desynchronization in response to variations in problem difficulty was unsuccessful (Hadley, 1941). Systematic EEG changes have, however, been found to occur over the course of serial learning (Obrist, 1950; Thompson & Obrist, 1964; Thompson & Thompson, 1966).

Obrist (1950) who was the first to examine the relationship between EEG and verbal learning, hypothesized that the serial position effect could reflect differential degrees of arousal or attention along the serial list. Using summated voltage as an index of activation, Obrist (1950) failed to find any significant EEG changes over the course of learning and there was no significant relationship between rate of learning and this EEG index either. On the other hand, a significant correlation was found between rate of learning and the average frequency of the alpha rhythm when subjects were resting. This led Obrist to suggest that alpha frequency appeared to be a better indicator of rate of learning than amplitude. This hypothesis was followed up by Thompson and Obrist (1964.)

Using a period analyzer to count the number of waves in the following frequency ranges: alpha (8.5 - 12.5 c/s), beta or fast (>12.5 c/s), and slow (<8.5 c/s), Thompson and Obrist (1964) found that the alpha count was lower during learning and overlearning than in the non-learning control condition. On the other hand, fast EEG activity (>12.5 c/s) and superimposed activity (the number of waves in the three frequency ranges subtracted from the total number of waves counted) was greater during the learning and overlearning conditions. By dividing list presentation trials for each subject into four blocks, they found a significant change in EEG activity over the course of learning with the amount of desynchronization showing a tendency to increase with learning (i.e., a reduction in the number of alpha waves). Furthermore, by dividing the list syllables into four groups according to the rate at which they were learned, Thompson and Obrist found a significant syllable by quarter interaction which indicated that the amount of EEG desynchronization at different stages of learning was different for syllables learned at different rates. For each group of syllables, the least amount of alpha activity occurred in the quarter in which correct responses were first made. Contrary to expectations, overlearning did not result in significant changes in the EEG.

Thompson and Thompson (1966) investigated this lack of habituation further. They pointed out that the criterion of one errorless trial employed by Thompson and Obrist (1964) did not adequately differentiate between learning and overlearning since the syllables were learned at different rates and consequently, received different degrees of overlearning. They used the EEG data for each syllable only up to the trial in which that syllable was correctly anticipated and divided these trials into quarters. Overlearning consisted of twenty additional presentations of the entire list and the data for analysis was taken from the last ten of these trials. It was found that, during learning, alpha activity decreased while fast activity and superimposed activity increased. During overlearning, alpha activity returned to the resting control level.

These findings are cited by Germana (1968) as evidence that the activational peaking (AP) effect observed in a variety of conditioned response formation studies occurs in verbal learning situations as well. According to Germana (1968) the AP effect has "enjoyed considerable yet unacknowledged replication" (p. 106). It is a phenomenon representing the relationship of the activational response to various stages of the learning process. Germana describes the AP effect as follows: "as the stimulus takes on the properties of the CS, that is, during the initial stages of conditioning or learning, activational responses to the stimulus systematically increase over the level of response characteristic of the preconditioned habituated study. Further elaboration of the CR results in successive activational decrements" (p. 106).

In addition to this relationship there is evidence in the verbal learning studies cited earlier to suggest that the shape of the activation trend is related to the rate and degree of learning of particular serial items.

Thompson and Obrist's (1964) study suggests that earlier learned serial items are reflected by earlier occurring peak or maximum activation responses. The present study undertakes to confirm this relationship by correlating the rate of learning of specific serial items in a serial list with the trial in which the peak activation level occurred. As in Thompson and Obrist's (1964) study, EEG frequency is the variable examined. This stems from Obrist's (1950) suggestion that the frequency of waves appears to be a better indicator of rate of learning than wave amplitude. Obrist's (1950) own study was principally concerned with wave amplitude while Thompson and Obrist's (1964) study counted the number of waves in three different frequency ranges; alpha, beta or fast, and slow. The present study, on the other hand, examines the duration of EEG desynchronization associated with presentation of stimulus items where desynchronization is defined as EEG activity of greater than 12.5 c/s. The present study also undertakes to examine the relative magnitudes of the peak activation periods associated with the various list positions and to relate this characteristic to the rate of learning of the serial items as well as to the trial at which this peak occurred. This magnitude characteristic does not appear to have been considered in previous studies. It is hypothesized that the higher activation peaks will be found for the more difficult central serial positions. This follows from Berlyne's (1966) observation that activation is generally greater for more difficult problems and also from Germana's (1968) explanation of the AP effect incremental stage as the result of preparation for overt response. Less preparation for responding appears to be required for the initial and final positions in a serial list.

METHOD

Subjects

Subjects were 30 male Lakehead University undergraduates enrolled in the Introductory Psychology course. They ranged in age from 18 to 38 years. A total of 41 students were seen for the experiment, 11 being rejected. Eight were rejected, at the outset, because their resting EEGs either failed to show evidence of alpha activity (N = 2) or artifacts could not be eliminated from their EEG tracings (N = 6). The remaining three were rejected during the course of testing. An electrode became detached for one of the volunteers, while a power failure terminated the experiment for another. One volunteer chose to terminate the experiment because of alleged discomfort.

Apparatus

Electroencephalograms were recorded by means of Beckman biopotential skin electrodes filled with electrolyte gel and attached to the skin by Beckman disposable adhesive collars. The EEGs were traced on one channel of a Beckman eight channel, type R, high sensitivity dynograph set at a chart speed of 25 millimeters per second.

The serial list was pre-recorded on audio tape. The list consisted of ten CVCs selected from Archer's (1960) list of trigrams having an association value of thirty-one (see Appendix A). The trigrams were selected such that no consonant occurred more than once in the list.

Each trigram was spelled out in a normal voice at a one per second rate with a 5-second inter-item interval. The entire serial list was repeated ten times with a 3-minute rest period between presentations. The instruction "begin anticipation" preceded each list presentation, except the first, by 5 seconds. The first presentation was preceded by the instruction "learn". A Roberts 770 tape recorder was used for both the recording and playback of the serial list presentations. Each subject was fitted with earphones. The volume switch of the tape recorder was kept at a constant setting and a limiter built into the earphone jack reduced volume differences among and within the trigrams. An on-off switch attached to the earphone jack allowed interruption of the audio output to the subject. One of the internal speakers of the tape player was connected to one of the free channels of the dynograph, thereby permitting the audio output to be transduced onto the dynograph chart. This provided a concomitant record of the stimulus item and the EEG response. The dynograph timing channel was activated and set to record a 5-second interval every minute. This was used to obtain pretest EEG samples as basal EEG measures.

To simulate an eyes-closed condition, opaque ski glasses were used. Entering light was further reduced by a pad of cotton batten which was placed over the eyes and bridge of the nose and held in place by the glasses. Extra-experimental noise interference was eliminated with a white-noise generator.

Procedure

On arrival, subjects were informed that the experiment was concerned with the measurement of "brain waves". No further explanation about the purpose of the experiment was given. The subjects then were shown the EEG recording apparatus along with samples of typical EEG tracings. They were seated in a padded recliner adjusted to a 45° reclining position and advised to relax while the electrode placement sites were being cleaned with methyl hydrate. The electrodes then were attached. One electrode was placed slightly above the right occipital protuberance and held firm by an adjustable eleastic headband. The other electrode was attached behind the right earlobe. The ground electrode was attached to the right forearm.

The subjects were fitted with the ski glasses and earphones. The strap of the glasses was placed over the top of the headband thus applying additional pressure on the occipital electrode and ensuring good skin contact. The right earphone also served a dual purpose in that it applied pressure on the electrode behind the earlobe.

Following preparation, each subject was assigned to either the Experimental (E) or Control (C) group according to a predetermined order. Each subject was then given instructions appropriate to his group. The E group subjects were given instructions concerning the anticipation method of learning a serial list. The complete instructions used are presented in Appendix B. The C group subjects were told to merely sit quietly for 1 hour.

Following the instructions all questions concerning procedure were answered to the subjects' apparent satisfaction. The E group subjects were required to repeat the instructions and the experiment commenced only after each subject thus demonstrated a clear understanding of the task. Subjects then were told that the white noise generator was being turned on and informed of its purpose.

Once a clear and artifact free EEG was observed, a 10-minute basal period was begun. The basal EEG measures were based on 5-second samples taken once a minute during this resting period. The basal rest period was followed by the appropriate treatment condition. The entire audio tape was run for both the E and the C groups, the difference being that the E group heard the serial list presentations and were required to learn the list by the anticipation method whereas for the C group the earphones were switched off throughout the experiment. The trigram events were recorded on the dynograph chart for both groups.

Analysis of EEG Data

The EEG tracings were visually analyzed by two assistants naive about the purpose and design of the experiment. They had been trained to identify three classes of EEG activity: alpha rhythm (8 - 12.5 c/s), sub-alpha rhythm ($<$ 8 c/s). and fast or desynchronized EEG activity ($>$ 12.5 c/s) for the purpose of facilitating identification of alpha activity. The data used in this experiment were the measures of EEG activation or desynchronization occurring in each trigram interval.

For scoring purposes a 125 millimeter interval was marked off on the EEG tracing from the point of onset of each trigram. This interval corresponds to 5 seconds of chart run. It was found, however, that not all trigram intervals were exactly 125 millimeters long. Consequently, in cases where the interval was less than 125 millimeters the desynchronization score was estimated by interpolation. Where the interval was greater than 125 millimeters the score was based on the desynchronization occurring in the first 125 millimeters only.

Because prior experience had shown synchronized EEG activity to be easier to track visually than desynchronized activity, the procedure adopted was to mark off all alpha and sub-alpha waves present in the interval, add up the total duration of such activity present in terms of millimeters of chart space and then subtract this number from 125. The resulting raw score, representing the duration of desynchronization in each interval, was used as data for analysis. For graphing purposes, however, these raw scores were converted to percentages.

A blind scoring technique was employed. The EEG charts were coded and assigned in random order to the assistants for analysis. To determine scorer reliability, two charts, one from each group, were selected randomly and scored independently by both assistants.

Statistical Analysis of EEG Data

The desynchronization time (duration of time not in alpha frequency) was examined first to determine whether overall differences existed between the two groups and whether the desynchronization time varied with serial position and trials.

Secondly, the longest duration of desynchronization for each serial position (each syllable) over the ten trials was determined. This duration will be referred to as the activation peak. Two characteristics of the activation peaks were analyzed: the actual level reached (in terms of duration of desynchronization), and the trial during which the peaks occurred. This present definition of activation peak should not be confused with the activational peaking (AP) effect as outlined by Germana (1968). In the present case, the activation peak represents an average activation level for the entire group, the trial of this peak event being the same for all subjects. In Germana's (1968) analysis, on the other hand, the peaks ensued from a determination of the point of correct response acquisition for each subject. The activation trend was demonstrated by assigning a plus or minus value to the pre- and post-acquisition trials according to their direction and distance away from this critical point. Since the purpose of the present study was to determine whether serial position activation levels reflected the serial learning curve, and not to demonstrate the activational peaking (AP) effect, group measures of activation and learning were used in the analysis, rather than individual measures.

RESULTS

Desynchronization Time

The design was a 2 X 10 X 10 factorial design with the last two factors being the repeated measures of trials and serial positions. Table 1 shows significant F ratios for the following:

(1) Treatment Groups ($p < .01$)
(2) Serial Position ($p < .01$)
(3) Groups X Serial Position ($p < .05$)

The E group had a significantly higher overall mean level of desynchronization (50.4%) than the C group (20.2%). Although the Serial Position effect was significant for the combined groups, the significant Groups X Serial Position interaction suggests that the Serial Position trend behaved differently for each group. Inspection of Figure 1 reveals that the E group declined to a greater extent over serial positions than did the C group. A separate analysis of the data for each of the two groups reveals that only the E group showed a significant effect of Serial Position ($p < .01$, see Tables 2 and 3).

A trend analysis (Hays, 1964, p. 540) was performed on the serial position means of the E group. This analysis revealed both a significant linear component ($F = 39.89$, $p < .01$) and a significant quadratic component ($F = 4.99$, $p < .05$). The quadratic component appears to reflect the smaller decline in mean desynchronization at the ending positions.

TABLE 1

Analysis of Variance for Desynchronization Scores

Source	df	MS	F	P
Treatment Groups	1	1063894.000	14.536	<.01
Subjects Within Groups	28	73189.563		
Trials	9	2004.889	0.753	NS
Groups X Trials	9	4187.777	1.574	NS
Subjects Within Groups X Trials	252	2661.055		
Serial Position	9	3285.889	6.190	<.01
Groups X Serial Position	9	1296.778	2.443	<.05
Subjects Within Groups X Serial Position	252	530.837		
Trials X Serial Position	81	524.988	1.213	NS
Groups X Trials X Serial Position	81	519.950	1.201	NS
Subjects Within Groups X Trials X Serial Position	2268	432.939		
Total	2999			

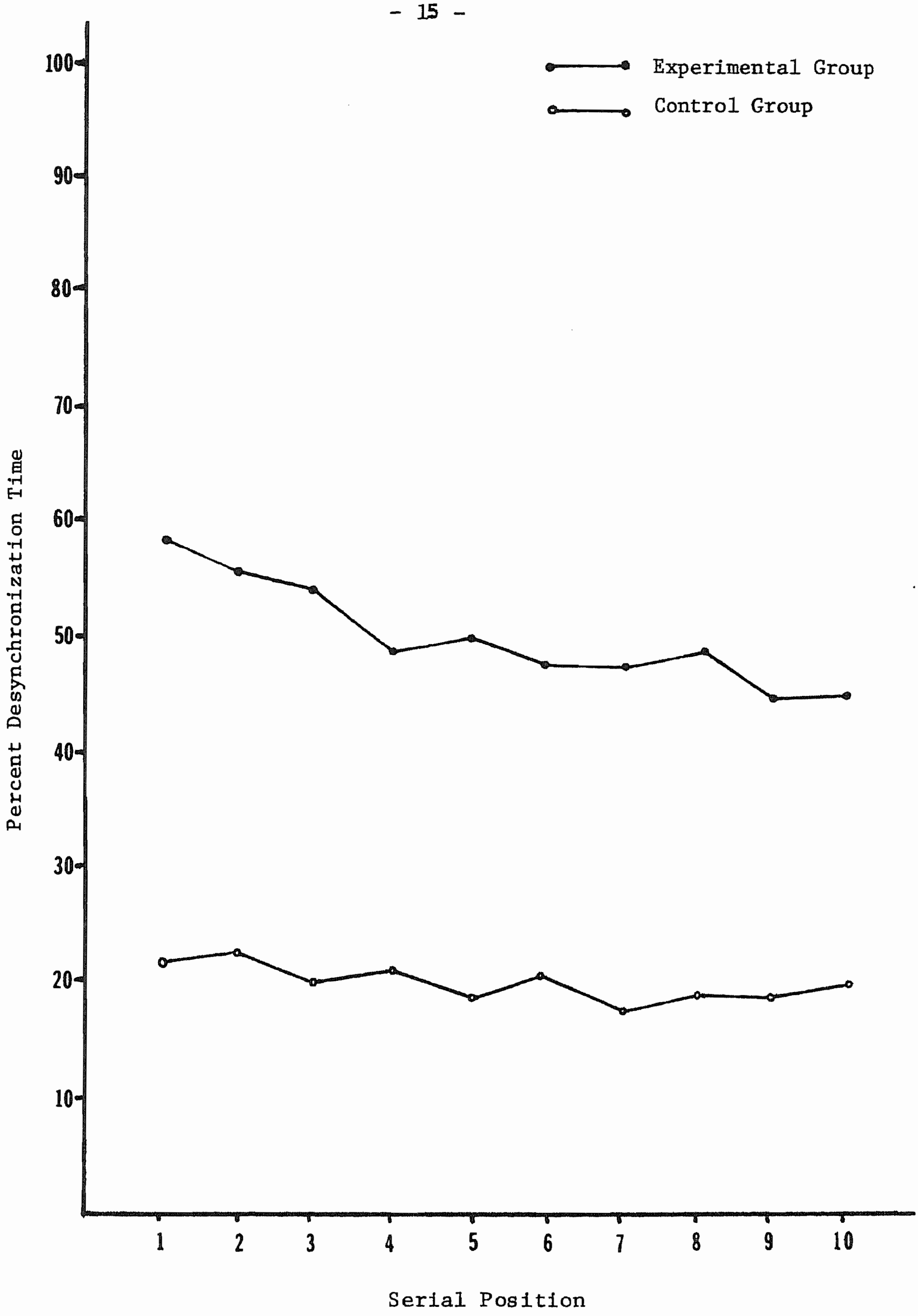

Figure 1. Percent Desynchronization Time for Each Serial Position.

TABLE 2

Analysis of Variance for Desynchronization Scores
of the Experimental (E) Group

Source	df	MS	F	P
Trials	9	2670.778	1.212	NS
Subjects Within Trials	126	2202.770		
Serial Position	9	4084.444	5.719	<.01
Subjects Within Serial Position	126	714.175		
Trials X Serial Position	81	717.481	1.425	<.05
Subjects Within Trials X Serial Position	1134	503.346		
Total	1485			

TABLE 3

Analysis of Variance for Desynchronization Scores of the Control (C) Group

Source	df	MS	F	P
Trials	9	3521.903	1.129	NS
Subjects Within Trials	126	3119.324		
Serial Position	9	498.146	1.434	NS
Subjects Within Serial Position	126	347.497		
Trials X Serial Position	81	327.461	0.903	NS
Subjects Within Trials X Serial Position	1134	362.530		
Total	1485			

Examination of the relationship between the serial position mean desynchronization levels and the number of anticipation errors committed at each serial position revealed a significant negative correlation ($r = -0.672$, $p < .01$). This indicates that serial positions associated with higher desynchronization levels were learned more quickly (i.e., fewer errors committed) than were serial positions with lower mean desynchronization levels.

It is worth noting that no Trials effect appeared in either the combined or separate analyses. This indicates an absence of significant change in mean desynchronization level in either group. However, a significant ($p < .05$) Trials X Serial Position interaction was found for the E group when taken separately. This suggests that while the mean desynchronization time did not vary across Trials, there were differences in desynchronization time within Trials, i.e., the level of desynchronization of specific serial positions changed, to some extent, across trials.

Peak Activation Levels

The relationship between the errors committed during the learning of each serial position and two characteristics of the activational trend for each serial position, namely (1) highest activational level reached, and (2) the trial on which this peak level occurred, was examined for the E group. Figure 2 shows the levels of the activational peaks plotted together with the number of anticipation

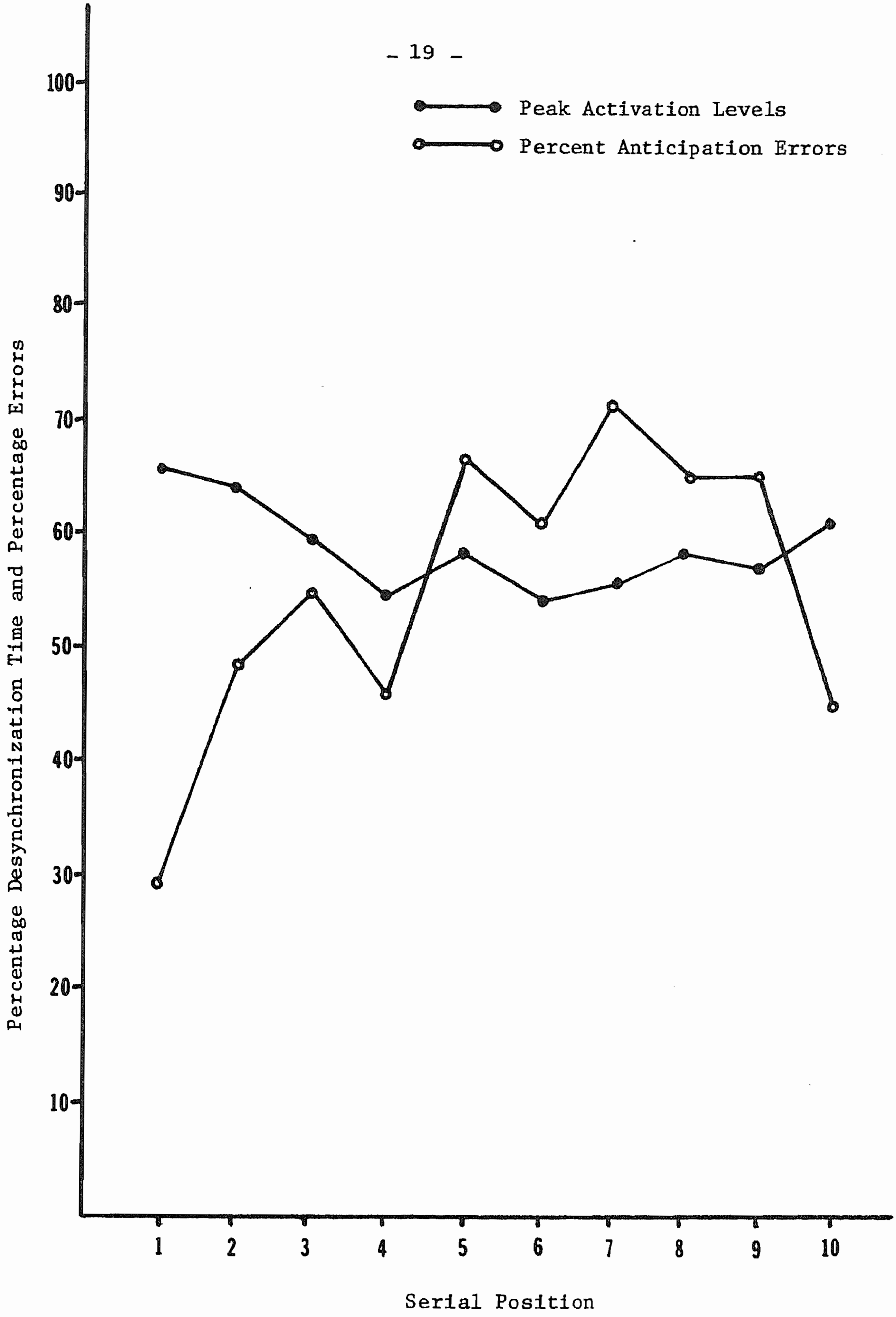

Figure 2. Relationship Between Peak Activation Levels and Percent Anticipation Errors for Each Serial Position.

errors for each position. It is clear that easier positions corresponded to higher activational peaks. This relationship is significant ($r = -0.625$, $p < .025$). However, peak level was also found to have a highly significant relationship ($r = 0.755$, $p < .005$) with mean activation level for specific serial positions

Examination of the trial on which the peaking occurred revealed a similar, though inverse, pattern to that of peak levels. There was a positive correlation ($r = .670$, $p < .025$) between the trial of peaking (i.e., 1 to 10) and the number of errors for a particular syllable position. Easier positions were therefore not only associated with higher peak activation levels but reached peak level earlier in the experiment. The relationship between the level of the peak and the trial on which it occurred is highly significant ($r = -0.894$, $p < .005$). The means of the three variables examined are shown in Table 4.

Activation Level and Learning Rate

No significant correlations were found between the learning rate of individual subjects in the E group and mean desynchronization time in either the pre-experiment resting period or the learning condition.

Anticipation Errors

Analysis of the error scores reveals a significant Serial

TABLE 4

Peak Desynchronization Levels, Anticipation Errors, and Trial of Peaking for Each Serial Position

Mean Values

Serial Position	Peak Desynchronization Level (raw scores)	Anticipation Errors (raw scores)	Peak Trial (Trial of Peak Occurrence)
1	83	42	3
2	80	73	5
3	74	82	6
4	67	69	8
5	73	102	6
6	67	93	8
7	70	108	9
8	72	98	7
9	71	98	7
10	76	66	7

Position effect ($p < .001$, see Table 5). Inspection of the error curve reveals a characteristic inverted U-shaped serial learning curve. The analysis also shows a significant Subjects effect ($p < .01$) which indicates that subjects were not homogenous in their rates of learning.

Separate Analysis for Good and Poor Learners

Since a significant difference was found in the rate of learning between subjects, the mean activation levels for the five best and five poorest learners were examined. No significant F ratios were found in this analysis (see Table 6) which indicates that there were no differences between the most efficient and inefficient learners in either overall activation level or trends across trials and serial positions during learning.

In order to examine possible differences between the good and poor learners in resting EEG, an analysis was performed on the basal EEG scores for these two groups. The results again show that the good and poor learners did not differ in resting EEG levels (see Appendix C).

Basal Desynchronization Levels

Analysis of Variance performed on the basal desynchronization levels of the subjects in both groups reveals no significant F ratios (see Appendix D). This indicates that there was no difference in the level of desynchronization in the resting EEGs of the two groups. Differences found during the experiment may therefore be attributed to

TABLE 5

Analysis of Variance for the Experimental (E) Group Anticipation Errors

Source	df	MS	F	P
Subjects	14	23.211	4.930	$<.01$
Serial Position	9	28.170	5.988	$<.01$
Subjects Within Serial Position	126	4.705		
Total	135			

TABLE 6

Analysis of Variance of Desynchronization Scores of the Top Five and Bottom Five Learners

Source	df	MS	F	P
Treatment Groups	1	256960.000	2.884	NS
Subjects Within Groups	8	89098.375		
Trials	9	1913.555	1.280	NS
Groups X Trials	9	1042.444	0.697	NS
Subjects Within Groups X Trials	72	1495.222		
Serial Position	9	3001.222	3.409	NS
Groups X Serial Position	9	825.000	0.937	NS
Subjects Within Groups X Serial Position	72	880.472		
Trials X Serial Position	81	680.210	1.228	NS
Groups X Trials X Serial Position	81	548.037	0.990	NS
Subjects Within Groups X Trials X Serial Position	648	553.739		
Total	990			

the different treatment conditions.

Scorer Reliability

The results of the Pearson correlation (r) performed on the data of the two complete records scored independently by each of the two scorers shows an overall correlation of 0.73, indicating a satisfactory degree of correspondence between the two scorers ($p < .005$).

DISCUSSION

The purpose of this research was to examine the EEG desynchronization trends associated with the individual items in a serial list in order to determine the relationship between desynchronization level and learning rate. In addition to the relationship between learning rate and the overall or mean desynchronization levels for the serial items two other characteristics were examined; maximum desynchronization level for each serial position and time of occurrence of the maximum or peak level.

A significant difference was found for mean desynchronization levels associated with the different serial positions. The activation level was shown to be inversely related to the number of anticipation errors for specific syllable positions. This indicates that the learned syllables had higher overall activation levels.

This finding appears to confirm Obrist's (1950) original hypothesis that differential degrees of arousal or attention along a serial list may explain the serial position effect. Furthermore, the fact that the present activation data was taken from intervals beginning with the stimulus onset is further support for Obrist's belief that rate of learning may be related to variations in the excitatory effects of different stimuli. In view of the considerable body of evidence linking desynchronization with attention (Adrian and Mathews, 1934; Bagchi, 1937; Lindsley, 1951), it would be reasonably safe to conclude that the present findings reflect differences in attention to different parts of the serial list. This is in line with an explanation of the serial position effect offered by Fiegenbaum and Simon (1962). According to them, serial learning proceeds item by item with the attention given to a particular item determined by the saliency of the item position. Because the first two serial syllables represent the first S-R pair, these are learned first. Attention is then focussed on the next most salient item (i.e. that adjacent to an anchor point) which, according to the authors, is the third and/or last in the list. Support for such an explanation also comes from studies which have systematically altered the shape of the learning curve by manipulating the subjects' attention to various parts of the serial list (Wallace, 1965).

At this point some comment seems appropriate on the seeming contradiction between this present finding of higher activation levels for items learned more rapidly and the results of other studies showing lower activation on easier problems. (Berlyne, 1966). This is explained by the fact that the present study employed serial items of equal difficulty, all being selected from the same association value list. Consequently, any differences in activation must be attributed to serially induced differences in learning difficulty rather than to intrinsic differences in item difficulty. It is likely that a comparison of activation level associated with serial lists of different objective difficulty would reveal greater activation for the more difficult list. Such was not the intent or design of the present study, however.

The present findings with respect to level and time of occurrence of the activation peak for each serial position can be interpreted as further supportive evidence of an explanation of the serial position effect in terms of the degree of attention for different serial positions but also point to the involvement of inhibitory factors. The present results reveal that the maximum activation level is greater and occurs earlier for the more rapidly learned syllables. This may be explained in terms of a progressive build up of reactive inhibition over the course of trials which would tend to depress the activational response to later attended to syllables more so than those selected for learning earlier in the experiment.

It could be suggested, therefore, that there is no causal relationship between the level of the peak activation period and the learning rate for a particular serial item. The significant inverse correlation between the number of anticipation errors and the activation peak of specific serial positions may simply represent the parallel effects of reactive inhibition on both of these variables. This is unlikely, however, in view of other evidence relating the quality of performance to differences in activation level (Duffy 1962).

It is noteworthy also that there was no significant Trials effect either in the experimental or control conditions. This is inconsistent with the findings of Thompson and Obrist (1964).

A likely explanation for the lack of habituation of the EEG response over trials in the E group seems to be the relatively limited opportunity for overlearning permitted in the experiment and the intersubject variability with respect to learning rate. Examination of the learning records of the E group reveals that only one third of the 15 E group subjects were able to correctly anticipate the entire serial list within the ten trials of the experiment. Four of these learned the list on the eighth trial while the fifth subject correctly anticipated the list on the ninth trial. It is apparent, therefore, that the majority of subjects found the number of trials insufficient even to learn, not to mention overlearn, the serial list. The second factor which may have acted to minimize any Trials effect is the fact that subjects were not preselected according to learning ability. Germana (1968) has noted that in conditioned response formation the AP effect may not appear when subjects are heterogeneous with respect to learning. This is apparently due to the fact that the activational peaks which accompany correct response formation tend to cancel each other out unless response formation occurs at approximately the same time for the majority of subjects. It is likely that the same conditions would apply for the activation levels associated with the serial list as well.

The lack of significant difference in activation across trials for either of the two treatment conditions was unexpected. The lack of habituation in the E group may be accounted for by the relative difficulty of the learning task and the limited number of learning trials which did not permit complete learning of the list by the majority of the E group subjects. In the case of the C group on the other hand, the activation level was lower during the experiment than even the basal measure. This suggests that subjects responded to the task instructions, which followed the basal period, with increased relaxation. It is likely then that by the first trial the C group subjects were already relaxed to a degree which they deemed appropriate to the situation.

The fact that activation did not differ across trials for the E group is also interesting for the reason that the first trial in this treatment condition differed from the remaining trials by being a non-anticipating trial. As such the only difference between the first trial of the E group and the C group condition was in the stimuli presented to the E group. This suggests that the highly significant difference in activation between the two treatments is not due to activational effects of verbal responding. Future research should, however, provide for a more adequate control of response effects. Previous studies which have controlled for this variable have, however, shown rather conclusively that activation levels are higher under conditions requiring mental effort as opposed to resting states. (Obrist, 1950; Thompson and Obrist, 1964).

While there was no difference in the activation level compared across trials, the E group did show a significant Trial x Serial Position interaction. This indicates that the activation trend was different across trials for different syllables. This adds support to a similar finding by Thompson and Obrist (1964) and is consistent with the previously discussed present finding of systematic differences among the serial positions with respect to the trial and magnitude of the activational peaks.

Finally, the investigation into possible differences in EEG activity between subjects who learned at different rates failed to establish any significant relationships. The lack of significant correlation between learning rate and mean EEG activation level during the basal portion of the experiment fails to add to Obrist's (1950) finding of a significant rank differences correlation between the average frequency of the alpha rhythm during the resting portion of the subjects' EEG records and their rate of learning. Furthermore, the failure to find any significant EEG differences between the E group's best and poorest learners in basal EEG is inconsistent with Beckman and Stein's (1961) findings that more efficient learners have less alpha activity in their resting EEG's.

The insignificant findings with respect to activation levels between good and poor learners during the anticipation portion of the experiment, however, adds to a previous finding by Shagass (1946) of no relationship between a subject's EEG rhythm frequency and his performance on a mental test. This question of relationship between efficiency of learning and individual EEG differences deserves further investigation.

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LIST OF APPENDICES

APPENDIX A

List of syllables presented for serial learning:

NYM

WUV

CAK

ZIR

CYQ

LUH

BEX

DUY

TAJ

FYZ

APPENDIX B

Experimental (E) Group Instructions

"You will be presented with ten, three-letter syllables such as P-U-B, L-U-T, R-Y-Z, etc. The syllables will be spelled out in the same manner as I have just done and will be presented at the rate of one every 5 seconds. You are to try to memorize the ten syllables in the same order they are presented. The entire syllable list will be repeated ten times. Each time you hear the list you are to try to learn the syllables and their order. The first time the list is presented, you should just listen. On every trial thereafter, however, you will be required to anticipate each syllable in the list before you hear it. This means that you should spell out the syllable you think will be presented next in the list before it is given to you. You will be told when to begin anticipating. Only spell out one syllable at a time. Always wait to have your response confirmed before you try to anticipate the next syllable. There will be a rest period between each list trial during which you can move if necessary. However, try to keep all movements down to a minimum so as not to loosen the electrodes. During the list presentations try to refrain from moving. Are there any questions?"

Control (C) Group Instructions

"You are required to lie here for approximately 50 minutes. You will be told when the time is up. You can move if you have to but try to keep movement down to a minimum so as not to loosen the electrodes. Are there any questions?

APPENDIX C

Analysis of Variance for Basal Desynchronization Scores of the Top Five and Bottom Five Learners

Source	df	MS	F	P
Groups	1	6241.063	0.734	NS
Subjects Within Groups	8	8501.875		
Trials	9	570.118	0.757	NS
Groups X Trials	9	223.215	0.296	NS
Subjects Within Groups X Trials	72	753.125		
Total	99			