71-15,926

MARTIN, James Ingram, 1944-
EFFECTS OF FAMILIARITY WITH STIMULUS CONTENT
ON THE CORTICALLY EVOKED POTENTIAL.

University of Arizona, Ph.D., 1971
Biopsychology

University Microfilms, A XEROX Company, Ann Arbor, Michigan

EFFECTS OF FAMILIARITY WITH STIMULUS CONTENT ON THE CORTICALLY EVOKED POTENTIAL

by

James Ingram Martin

A Dissertation Submitted to the Faculty of the

DEPARTMENT OF PSYCHOLOGY

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 7 1

THE UNIVERSITY OF ARIZONA

GRADUATE COLLEGE

I hereby recommend that this dissertation prepared under my direction by James Ingram Martin entitled Effects of Familiarity with Stimulus Content on the Cortically Evoked Potential be accepted as fulfilling the dissertation requirement of the degree of Doctor of Philosophy

Robert W. Lansing — Dissertation Director

Nov. 20, 1970 — Date

After inspection of the final copy of the dissertation, the following members of the Final Examination Committee concur in its approval and recommend its acceptance:*

Robert Lansing	Nov. 20, 1970
Neil R. Bartlett	Nov. 23, 1970
Salvatore V. Zagona	Nov. 23, 1970
Earl A. Rogers	Nov. 23, 1970
Roger J. Weldon	November 23, 1970

*This approval and acceptance is contingent on the candidate's adequate performance and defense of this dissertation at the final oral examination. The inclusion of this sheet bound into the library copy of the dissertation is evidence of satisfactory performance at the final examination.

STATEMENT BY AUTHOR

This dissertation has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this dissertation are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his judgement the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: Jim Martin

TO MY PARENTS

ACKNOWLEDGMENTS

Acknowledgment is made to Dr. Robert W. Lansing, Dissertation Director, for his kind assistance during the development of the experiment and dissertation and to Dr. Neil R. Bartlett and Dr. Cecil A. Rogers, the other two members of the major committee, for their constructive suggestions concerning the preparation of the manuscript.

Many thanks are also due Dr. Salvatore V. Zagona and Dr. Roger J. Weldon, members of the minor committee, for their careful attention to the drafting of the manuscript. Special thanks are given Dr. Weldon who designed the ANOVA 45 program which greatly facilitated the computation of some of the results given in this paper.

The author expresses appreciation to Dr. Peter D. Crown for having initially drawn his attention to the area of research covered in this paper.

Special gratitude is expressed to the Department of Psychology, the Graduate College, and The University of Arizona, not only for the financial support which enabled me to complete my graduate studies, but for providing a nutritive atmosphere which has made the period of my graduate education a stimulating, rewarding, and enjoyable phase of development.

TABLE OF CONTENTS

TABLE OF CONTENTS--Continued

LIST OF TABLES

LIST OF ILLUSTRATIONS

ABSTRACT

Although the reports of several experiments have suggested that the degree of familiarity of the subject with the stimulus material might be a relevant factor in determining the form of the cortically evoked potential, the effects of that factor have not been specifically studied. If an electrophysiological counterpart of the recognition of a stimulus pattern as being familiar or unfamiliar were time-locked with the onset of the stimulus presentation, it might be expected that the averaged cortical potential evoked by familiar patterns could be distinguished from that evoked by unfamiliar patterns.

Cortical potentials, evoked by the presentation of stimuli of varying degrees of familiarity to the subject, were recorded from nine subjects. For both the familiar and unfamiliar series, three categories of complexity were used: single-digit, three-letter, and trademark patterns. The unfamiliar series consisted of rearrangements of the component elements of the familiar series. By counterbalancing the total area, contour, and color of each pair of familiar and unfamiliar stimuli, variables attributable to the secondary, physical aspects of the stimuli were held constant and the phenomenal aspect of stimulus familiarity was manipulated.

The procedures of analysis of the waveforms were based on the amount of fluctuation of the electrical activity (the RMS value) and

on the extent to which variations in one waveform were correlated with variations in another (the correlation coefficient). Several different treatments of these measures were used in analyzing the data.

The results indicated that no differences between the waveforms elicited by familiar and unfamiliar stimuli could be measured consistently, although the potentials evoked with stimuli from the most complex category (trademark) did appear to indicate weak effects due to the degree of familiarity. Some general findings of the research were that waveforms could usually be distinguished as to whether they were evoked by patterned or unpatterned stimuli, whether they were evoked during the same or different recording sessions, and whether they were elicited by the same or different categories of pattern complexity.

INTRODUCTION

Of the numerous factors which have been found to affect the waveshape of the cortically evoked potential generated by visual stimuli, the role of the familiarity of the subject with the stimulus content has not been closely examined. At a time when several studies have attempted to show that characteristics of the cortically evoked potential are closely related to the attentional or information-carrying aspect of the visual stimuli, and when other studies have concentrated on characteristics which might be related to an emotion-arousing nature of the stimuli, it appears that knowledge of the effects of familiarity of the stimulus content on the averaged evoked potential would be a valuable contribution. In addition to the information which such knowledge might yield on a basic perceptual process, the knowledge of the unconfounded effects of familiarity would facilitate the assessment of the afore-mentioned studies in which the effects of familiarity were coupled with attentional or emotion-evoking factors.

A continuing effort is being made to find physiological correlates of perceptual events by making use of the cortically evoked potential. At a very basic level in the cognitive process, the content of a visual stimulus must register as a familiar or unfamiliar signal. Studies of instances of perceptual defense suggest that the recognition of the stimulus pattern as a familiar object must occur at an early stage in the construction of the perception. It is possible that an electrophysiological manifestation of the recognition of the stimulus material as being familiar might be obtained. If such a phenomenon were time-locked with the stimulus onset, a waveform characteristic of the recognition might be revealed by noting consistent differences in the averaged cortically evoked potentials obtained with stimuli of different degrees of familiarity to the subject.

The electrophysiological measure referred to as the evoked potential waveform consists of the record of minute electrical variations which occur over a period of time in response to some alteration of the stimulus field. Variations in the electrical potentials recorded over the parieto-occipital cortex are continually occurring. When the onset of a particular stimulus results in a particular sequence of electrical potentials each time that it occurs, it is said that the waveforms are time-locked with the stimulus onset. It is often the case that the characteristics of the time-locked response are of sufficiently small magnitude that they are swamped by the other, continuing, background electrical activity on a given presentation. By making repeated presentations of the stimuli and summing the record evoked after each stimulus onset, the wave components which are time-locked with the stimulus onset will be enhanced by the summation whereas the wave components which are the result of the non-time-locked background electrical activity will be cancelled as the peaks and troughs of the electrical activity occur at random. By averaging the cortical response, the evoked potential waveforms characteristic of the response to the onset of a particular stimulus are clearly drawn out from the background noise.

Attentional Aspects

The amount of information contained in or assigned to the stimulus and the recognition of the stimulus as being familiar may have related effects on the evoked potential waveforms. In both instances, the arousing stimulus would be recognized by the subject as a familiar one, one which contained information, but the significance assigned the stimulus would be different in the condition of passive recognition from the condition of active, task completion.

Stimuli which are of a similar physical nature to one another have been found by some researchers to evoke cortical potentials which are markedly different. A factor which has been manipulated in these studies is the attentional aspect of the stimuli, i. e., the enhanced significance which the stimuli have for the subject in performing an assigned task. Larsson (1960) had found that there was a strong correlation between the psychological significance of the visual stimuli and the magnitude of the evoked potentials. Many researchers have found that the "complex evoked patterns being studies do indeed correlate with the information-processing activities of the brain" (White, 1969, p. 211).

Chapman and Bragdon (1964) obtained different responses to relevant and irrelevant stimuli when they instructed their subjects to perform the task of deciding which of two numbers contained in a sequence of four stimulus presentations was the larger. The numbers comprised the relevant stimuli in the sequence, while a plus sign and a blank field served as the irrelevant stimuli. The responses evoked by the numbers were of greater amplitude than those evoked by the plus sign. The blank field was found to evoke the response of the least amplitude.

Using unitary stimuli in the auditory modality, Sutton, Tueting, and Zubin (1967) found that the evoked potentials generated by clicks differed conspicuously from one another depending on whether the waveform resulted from a stimulus which was fully expected or from one which may or may not have occurred. The task of the subject was to guess at which of three times during a one-second interval the second stimulus would be delivered. The authors found that a particular response was evoked when the ambiguity about the delivery or non-delivery of the final stimulus click was resolved, regardless of whether the resolution was brought about by the presence or absence of an evoking stimulus. In the latter case, information was conveyed without the possibly confounding effects ascribed to the stimulus characteristics, although the experimenters did not make a close comparison of the waveforms evoked under the two conditions.

A study which indicates the complexity of the relation between attentional effects and the waveform of the evoked potential is that of Kopell, Wittner, and Warrick (1969). A portion of their study confirms the finding of Chapman and Bragdon (1964) in that the evoked response elicited by flashes of light when the subject was not instructed to attend to the stimuli were related to stimulus intensity, whereas when the subject was attending to the stimuli, the evoked responses were of a similar, maximal amplitude regardless of the stimulus intensity. Kopell, Wittner, and Warrick found different responses with regard to the potentials evoked by reversals of the continually-illuminated, patterned, smaller, and more centrally-located background patterns. In the case of measuring the potentials evoked by reversals of the background patterns, the amplitude of the evoked potential was found to be related to the stimulus intensity, but the amplitude was not found to change as a function of whether or not the subject was paying attention to the shifts in the pattern. The authors speculated on some of the reasons which might explain the failure for attention to have the predicted results on the potentials evoked by shifts in the background patterns.

Kopell, Wittner, and Warrick suggest that some of the apparently contradictory findings in studies of the effects of attention on the evoked potential may be due to "the unwitting use of stimuli whose different physical characteristics were not apparent" (Kopell et al., 1969, p. 621). These experimenters caution that the relation between the amplitude of the evoked response and the attentional aspect of the stimuli may well be confounded by other factors. In addition to the effects of the physical characteristics which Kopell et al. have emphasized, a factor which might need to be considered as a source of additional effects is that of stimulus familiarity.

Emotional Aspects

Closely related to the problem of the effect of stimulus familiarity on the waveform of the evoked potential are portions of experiments by Lifshitz (1966), Weinberg and Cole (1968), and Cohen and Walter (1966). These studies reported differences in evoked potentials obtained with different classes of visual stimuli. Lifshitz and Cohen and Walter used photographic transparencies whereas Weinberg and Cole used printed letters and words. In all three cases, the researchers utilized a category of illicit or taboo stimuli and compared the results obtained with that stimuli with waveforms obtained with legitimate or normal stimuli. Aside from the uncertainty, which was not resolved, of whether or not the subjects were familiar with the stimuli in the taboo category, the emotion-arousing aspect of the stimuli prohibits the deduction of the effect of familiarity of stimulus content on the evoked potential waveform.

Cohen and Walter (1966) obtained different averaged evoked potentials to stimuli of geometrical figures, of complex figures, and of semi-nude females. Lifshitz (1966) obtained differential responses to "art" and "scenic" stimili. The response to black and white art slides was conspicuously more closely related to the colored art slides than to the colored scenic slides.

In order to rule out the possibility that the differential responses were due to the emotion-evoking capacity of the slide series, Lifshitz presented his subjects with two word series, one "regular" and one "dirty," and found that no differential responses were obtained. Weinberg and Cole (1968), utilized four classes of stimuli: blank flashes, letters, taboo words, and neutral words. The resulting waveforms were analyzed by spectral analysis and produced results in which the evoked potentials generated by neutral words were found to be statistically different from those evoked by stimuli from the other classes, but that the potentials generated by the other classes were indistinguishable from one another. The difference in the results obtained by Lifshitz and by Weinberg and Cole cannot be explained on the basis of the information provided in their reports. It is possible that the differences may be attributed to the differences in the sensitivity of the analyses involved, to the stimuli selected, or to the relative familiarity of the stimulus sequences to the subjects.

Physical Aspects

Several experiments have compared the potentials evoked by stimuli which were judged by the experimenters not to differ in terms of attentional or emotional aspects but only in terms of some varying physical characteristic.

John, Herrington, and Sutton (1967) found that the potentials evoked by different sizes of different geometrical forms showed greater resemblance to one another along the form dimension than the size dimension, although the physical energy transmitted by the stimuli of the same size but different forms was more nearly equal than that transmitted by the stimuli of different size but having the same form. The experimenters conclude that the evoked potential differences "seem to constitute a physiological correlate of perceptual rather than sensory processes" (John et al., 1967, p. 1442). It is possible, however, that the characteristic responses were due to the differential stimulation of the direction-oriented receptors in the eye. John et al. also obtained differential responses for repeated presentations of the words "circle" and "square."

In comparing the waveforms generated by two sets of 40 scenic slides, Lifshitz (1966) found that they resembled one another closely.

Similarly, three sets of 40 words, one set of which consisted of taboo expressions, yielded waveforms which were virtually indistinguishable.

The results of these studies seem to indicate that when the physical components of the visual stimuli are essentially equivalent and when attentional and strongly emotional aspects are held constant, the waveforms generated will tend to reflect similarity to the extent that the physical aspects of the stimuli are similar.

Perceptual Aspects

In studies by Berlyne and McDonnell (1965) and by Buchsbaum and Fedio (1969), attentional, emotional, and physical aspects of the stimuli were held constant while the perceptual aspects of complexity, incongruity, meaningfulness, and familiarity were varied.

Berlyne and McDonnell (1965) found that when paired slides were presented to a subject, those members of the pair which had greater irregularity of arrangement of the content induced a significantly longer period of EEG desynchronization. In studies with other pairs of slides, they found similar results with slides containing a larger amount of material, with slides containing incongruous representations, and with slides containing a random redistribution of the patterned material. The authors suggest that the desynchronization in the EEG pattern is related to the assimilation of the information contained in the patterns, and that the more complex or incongruous ones, having a higher information content, prolong the period of desynchronization. Whether the cortically evoked potential would show a differential response to a similar presentation of material is a matter of conjecture.

With three categories of different arrangements of stimuli, Buchsbaum and Fedio (1969) obtained evoked potentials which differed significantly in amplitude and in correlation with one another. The three categories of stimuli, formed from dot elements, consisted of random distribution, symmetrical patterns, and three-letter words. Because of the dot configuration generation utilized, the stimuli were closely matched so that their physical properties were balanced between the three categories. Thus the differences in the potentials produced could not be attributed to the differences in stimulus properties but to the information contained in the various patterns. Replicates of the series yielded evoked potentials which were more similar to those potentials evoked by stimuli from the same category than from different categories.

The results of these two experiments suggest that perceptual aspects, which are not a consequence of the task established for the subject, which are not a result of the emotion-evoking characteristics of the stimuli, and which are not inherent in the physical attributes of the stimuli presented, may evoke waveforms which are significantly different. It is apparent that the electrophysiological response of the evoked potential is related, in some manner, to the content of the visually-presented stimulus. Whether a portion of the response is sensitive to the familiarity of the subject with the stimulus content cannot be determined from the above-mentioned studies.

The study reported in this paper is similar to that of Buchsbaum and Fedio (1969) in that the physical, emotional, and attentional aspects of the stimuli are held, essentially, constant. The perceptual variable manipulated is the degree of familiarity which the content of the stimuli presents to the subject. In this latter aspect, the experiment differs from that of Buchsbaum and Fedio, for they were concerned with manipulating verbal and non-verbal information-processing aspects of the categories of stimuli. Another crucial difference is that the characteristics of the physical stimuli, round, blue dots in the experiment of Buchsbaum and Fedio, were given greater variation in the present study. A third major difference arises from the fact that, in the experiment reported in this paper, replications were conducted using a different set of stimuli from that originally used.

The aim in the experiment of Buchsbaum and Fedio was to determine whether there were significant differences in the processing of the visual input in the different hemispheres of the brain.

The aim in the experiment discussed in this paper was to determine whether there were significant differences in the potentials evoked by various categories of familiarity of stimulus content.

METHOD

Nine volunteers with normal, uncorrected vision or with vision corrected to 20/20 by contact lenses were used as subjects in the experiment. The adults ranged in age from 18 to 26 years.

Experimental Design

The experiment was conducted in two sessions. In each session, each of nine subjects was presented with a complete range of stimuli, including three levels of "degree of familiarity" within each of three levels of "category of complexity." The nucleus of the experiment consisted of a three by three factorial composed of degrees of familiarity (familiar, unfamiliar, and blank) and categories of complexity (single-digit, three-letter, and trademark). The factorial design was replicated on the second day with a different set of stimuli for each series.

For each subject on a given day, the order of presentation of the categories was randomized. Within each category, the stimuli in the familiar, unfamiliar, and blank series were randomized both within and between the series with the restriction that each stimulus pattern would be presented a total of four times. Within the two sessions, each subject was presented with all the series indicated in the experimental paradigm given in Table 1.

Stimulus Patterns

As is indicated in Table 1, for a given day, there were three series of stimulus patterns within each of three categories. In each

Table 1. Experimental Design

Session	Category	Series	
Day 1	Single-Digit	Familiar	(A)
		Unfamiliar	(B)
		Blank	
	Three-Letter	Familiar	(A)
		Unfamiliar	(B)
		Blank	
	Trademark	Familiar	(A)
		Unfamiliar	(B)
		Blank	
Day 2	Single-Digit	Familiar	(B)
		Unfamiliar	(A)
		Blank	
	Three-Letter	Familiar	(B)
		Unfamiliar	(A)
		Blank	
	Trademark	Familiar	(B)
		Unfamiliar	(A)
		Blank	

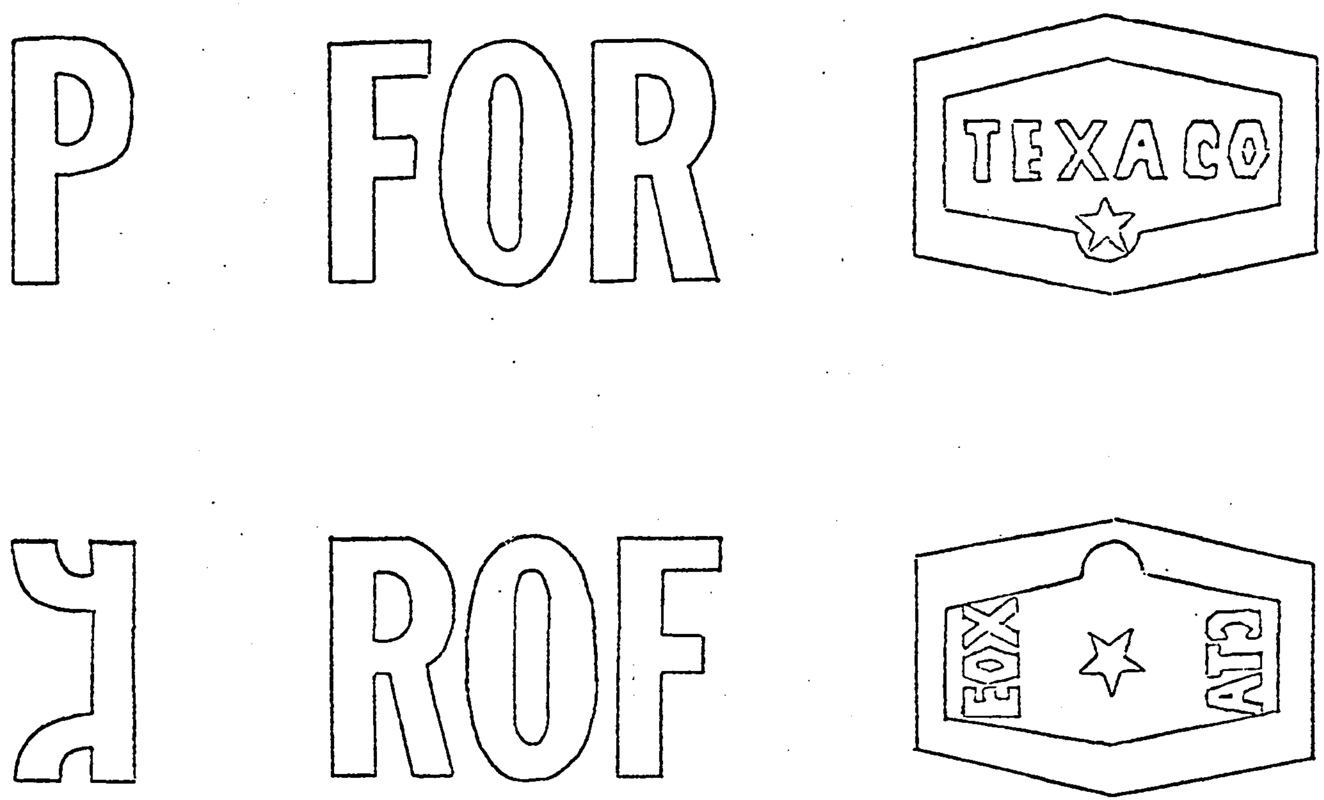
Table 2. Stimuli

Category	Single-Digit				Three-Letter				Trademark			
	Familiar Series		Unfamiliar* Series		Familiar Series		Unfamiliar* Series		Familiar Series		Unfamiliar* Series	
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
	1	2			WIN	FEW	NIW	WEF	Coke	7-Up		
	3	4			BEG	BOY	GEB	YOB	Amer. Air	Communist Sgn.		
	5	8			DAY	MAN	YAD	NAM	Peace Sgn.	Pan Am. Air.		
	6	9			PEN	BOX	NEP	XOB	Westinghouse	Gen. Electric		
	7	C			HOT	HIS	TOH	SIH	Bell Tel.	Volkswagen		
	D	F			FOR	SIT	ROF	TIS	Chevrolet	Mobil		
	E	G			SUN	YET	NUS	TEY	Gulf	Union 76		
	O	K			BUY	CAN	YUB	NAC	Enco	Chevron		
	P	R			BIT	BAY	TIB	YAB	Shell	Phillips 66		
	Q	S			HAS	RUN	SAH	NUR	Texaco	Yellow Pages		

* The unfamiliar series, A and B, consist of rearrangements of the components of the stimuli comprising the corresponding familiar series, A and B, of each category. See Figure 1 for examples of the transformation of a familiar into an unfamiliar stimulus pattern.

Familiar

Unfamiliar



Single-Digit Three-Letter Trademark

Figure 1. Examples from Each Category of the
Transformation of a Familiar into an Unfamiliar Stimulus Pattern

category, one series consisted of familiar stimuli, another of unfamiliar stimuli, and a third of unpatterned, blank stimuli. The content of the familiar and unfamiliar series in each of the categories for each of the two sessions is given in Table 2. Each unfamiliar stimulus pattern was composed of rearrangements of the component elements of a familiar stimulus. Typical examples of the transformation of a familiar stimulus into an unfamiliar pattern are given, for each category, in Figure 1. The first category contained the least complex visual stimuli, single-digit numerals or letters in the familiar series and unitary nonsense sybmols in the unfamiliar series. The second category contained three-letter words and three-letter nonsense syllables. The third category consisted of commonly-found trademarks and of mosaics composed of rearrangements of the elements of the trademark symbols.

Each category, in addition to the familiar and unfamiliar series, contained a series of blank cards. Each series within each category consisted of ten different cards. Two complete sets of stimulus patterns for each of the three series within each of the three categories were used, a separate set for each of the two sessions given the subject.

The stimulus patterns were on white posterboard, occupying an area of approximately 2 inches by $3\frac{1}{2}$ inches. At the viewing distance of 38 inches, the stimuli appeared in an area approximately 3° by 5°.

Each familiar stimulus was counterbalanced by an unfamiliar stimulus composed of its component parts. In designing the stimuli to be used in the unfamiliar series, certain restrictions were maintained. The area occupied by the unfamiliar stimulus was equal to that of its familiar counterpart. In so far as possible, the perimeters of the familiar and unfamiliar figures were the same length. The total colored area in each pair was the same. The orientation of the outermost perimeter of the figure was maintained the same in each of the stimulus pairs whenever it was possible to do so without too readily disclosing the familiar nature of the original form. Similarly, when it was possible to do so, the components of the figure were rearranged in a symmetrical manner. In the case of the single-digit symbols, the transformations undertaken had to violate some of the above-listed constraints, otherwise, the stimulus would be immediately recognized as a familiar one. The last two-listed specifications were followed only when it was possible to do so and to still generate a figure which would not be recognized as consisting of familiar parts. The occasional violations of the restrictions were necessary and were not thought to greatly detract from the general effectiveness of the stimulus patterns.

The amount of area and contour were carefully counterbalanced in the familiar and unfamiliar series because these variables have been found (Spehlmann, 1963, 1965; Harter and White, 1968) to have significant effects on the resulting waveforms. Although Lifshitz (1966) did not find that color played an important part in determining the shape of the waveform, other experimenters (Shipley, Jones, and Fry, 1965) have found some effects which they attribute to color. In the slides of the third category, therefore, the colors used in the trademark symbols were duplicated in the unfamiliar symbols so that the total amount of color and of color combinations presented in the two series was equal.

The stimuli in the first two categories consisted of black lettering on a white background. The numbers and letters used were produced by Instantype, No. L-1288, and were approximately 2 inches in height with an average width of 1 inch. The colors used in the trademark category were cut from sheets of colored paper so that the colors in the different series could be closely matched.

Tables A-1 and A-2 in the Appendix specify some of the more important characteristics of the stimuli in each series. The tables indicate, for each category, the close match in the average score of familiarity of the familiar series of one session to the familiar series of the other, and of the unfamiliar series of one to the unfamiliar series of the other. In the case of stimuli from the three-letter category, familiarity scores for both the three-letter words and the three-letter nonsense syllables were taken from Thorndike and Lorge (1944). The three-letter configurations were chosen for inclusion in the stimulus series on the basis of their familiarity scores; values of AA or M generally being desired for the words, and values below 60 on the G scale or below 75 on the K scale being generally desired for the nonsense syllables.

The stimuli from the single-digit and trademark categories were presented to a sample of 35 individuals who ranked the stimulus patterns on a five-point scale in terms of degree of familiarity. The sample of subjects used for ranking the familiarity of the stimuli was taken from the same population from which the subjects whose evoked potentials were recorded were drawn. It may be considered, therefore, that the initial degree of familiarity with the stimulus patterns of the subjects who served in the evoked potential recording sessions was approximated by the scores obtained from the larger sample which evaluated the stimulus patterns. Within each category, the average values of the familiarity scores obtained for the familiar and unfamiliar series of one session matched closely with the average values for the familiar and unfamiliar series of the other session. With respect to the average degree of familiarity, the two sets of familiar series and the two sets of unfamiliar series, used in the two sessions given the subject, may be considered equivalent. Although the differences in the average scores of familiarity between the familiar and unfamiliar series of the single-digit category were greater than the differences in the average scores of familiarity between the familiar and unfamiliar series of the trademark category, the differences in both categories were marked and consistent.

As Table A-2 in the Appendix indicates, the stimuli in the trademark category were closely matched in each of the two sets of familiar series in terms of symbolic content, i. e., each stimulus representing an airline corporation, an oil company, etc., in one familiar series was matched in the other set of familiar stimuli by a trademark representing another airline, oil company, etc. The stimuli were also closely matched in terms of shape, color, and total area. For each set of familiar stimuli, presented in different sessions, the close matches between the stimulus series were made in order that the connotative, emotion-evoking, and physical characteristics of the two series would be nearly the same, and the differences in each set in terms of degree of familiarity between the familiar and unfamiliar series would remain strong.

A problem in working in studies involving degrees of familiarity is that every pattern or object is recognized as being somewhat familiar. When a stimulus pattern is more complex, there are more elements in it which allow it to be classed as a familiar object. The differences in the average score values of the stimuli in the familiar and unfamiliar series were sufficiently strong that it could be concluded that different levels of familiarity were represented by the series.

Stimulus Presentation

The stimuli were presented to the subject for binocular viewing through a Scientific Prototype Three-Channel Tachistoscope, Model G. The patterns were illuminated by a flash of 45 msec. duration, a time period similar to that of 50 msec. used by Weinberg and Cole (1968) and Kopell et al. (1969) and to that of 40 msec. used by Buchsbaum and Fedio (1969). This length of time was sufficient for identification of the stimulus as familiar or unfamiliar but was not sufficiently long to encourage the subject to attempt to decipher the components of the unfamiliar figure. A short time period for presentation was also desirable to minimize the effects of eye movements which the subject might make as a consequence of the stimulus patterns.

Between stimulus presentations, a second chamber in the tachistoscope provided the subject with a fixation point and with a level of illumination matched to that provided by the stimulus chamber. When a blank pattern was present in the stimulus chamber, the only indication of the stimulus presentation was a brief, slight shift in apparent color of the illuminated target area. This shift, although unwanted, was not considered undesirable. The continuous illumination made it more likely that a shift in the stimulus patterning, rather than a gross shift in the level of illumination, would be the primary source of the potential evoked in the subject.

The interstimulus interval was set for 9.955 seconds so that, from stimulus onset to stimulus onset, the average time lapse was ten seconds. The length of the interval was established to allow the experimenter ample time to remove one stimulus card, to place another in position, and to prepare the averager which recorded the evoked potential to allocate the forthcoming response to the channel appropriate for the particular stimulus series employed.

In placing the stimulus cards into the rack, some noise was produced. Placing foam rubber at the bottom of the slot reduced the noise considerably and introducing white noise to the shielded room made the sound of the stimulus shifts virtually inaudible. The time interval was of sufficient length that the cue provided by the noise of setting the stimulus in place was not indicative of an immediate presentation of a flash illumination. The interstimulus interval was also sufficiently long that the ability of the subject to pace himself to the occurrence of stimulation was reduced. The length of the interstimulus interval was occasionally changed during the course of the experiment to further guard against the subject's developing a precise expectation of stimulus onset.

General Procedure

The subject seated himself at the face mask opening into the tachistoscope. He was instructed to attend to the stimuli which would be presented to him. No overt task was assigned, but he was asked to classify, silently, to himself, the stimuli into categories of "familiar" and "unfamiliar" patterns.

The experiment was conducted in two sessions on days at least a week apart. Each session consisted of three runs, each run lasting approximately 20 minutes, during which time stimuli were randomly presented from one set of the familiar, unfamiliar, and blank series of a given category. A five-minute break was held between each run to dissipate fatigue in the subject and to permit the experimenter to plot out the averaged waveforms, obtained in response to the different series, on the x-y plotter.

During the run for each category, 120 presentations of stimuli were made. Each of the ten cards in each of the familiar, unfamiliar, and blank series was presented a total of four times, giving a grand total of 40 presentations for each of the series. Forty presentations from each series was desirable to produce an averaged waveform in which random components would be averaged out and the components time-locked to the stimulus onset would be summed. The randomly arranged re-presentation of each card four times was not sufficiently frequent to destroy its value as an unfamiliar stimulus. Cantor and Cantor (1966) had originally found that as few as five repetitive stimulations would result in stimulus familiarization in children, but later Cantor and Fenson (1968) revised the estimate to 18.

Recording

Commercially available silver disc electrodes were employed. Recording was done monopolarly, with the active electrode positioned on the midline an inch anterior to the inion and with the reference and ground electrodes attached to the lobes of the ears. In each recording session, the scalp potentials were passed through a Grass Instruments Preamplifier Model 7P3A and a Grass Polygraph DC Driver Amplifier 7DAC and displayed in a continuous record on paper by a polygraph. The ½ high frequency filter was set at 75 cycles per second and the ½ low frequency filter was set at 0.3 cycles per second. The combined effect of these two filters was that potentials from 2 to 46 cycles per second were passed without attenuation.

The averaged evoked potentials for the different stimulus conditions were extracted by a Fabri-tek Computer of Average Transients (CAT) 1052. The averager was triggered by the stimulus onset and averaging was done for 1024 msec. For each waveform, the amplitude of the potential at 256 points in time was averaged. Each point on the waveform represented, in sequence, 4 msec. of response time beginning with stimulus onset.

Control measures were taken by occasionally triggering the CAT during the interstimulus interval. The waveforms which were obtained under these conditions were markedly uniform, although one subject, whose continuous record showed massive amounts of alpha waves, appeared to have some background alpha averaged as well.

Graphs of the computer-averaged evoked potentials obtained for each of the 18 conditions were plotted by a Moseley 7035 AM X-Y Recorder. In order to allow statistical comparisons between the various waveforms for a given subject, the amplitude of each evoked potential at 40 points, located every 10 msec. apart during the first 400 msec. after stimulus onset, was measured, recorded, and punched into data cards. An additional

20 points, located every 20 msec. apart from 400 msec. after stimulus onset to 800 msec., were measured and, together with every other data point from the first, "short record," provided a second, "long record" of 40 equally-spaced data values. This procedure of measuring the amplitude of the waveform was possible because the record of the evoked response was plotted as a continuous curve; the measurement of points 10 msec. apart would sometimes be taken at the 4 msec. points sampled by the averager, at others, it would be taken midway between points and would, therefore, reflect the average value of two adjacent points which had actually been sampled. With the points in the short run, having been measured every 10 msec., the data series was able to reflect frequencies up to 100 cycles per second; the points in the long run, having been measured every 20 msec., the series was able to reflect up to 50 cycles. The obtained data series were submitted to computer analysis to determine, by several methods, the degree of resemblance of the waveforms to one another.

Procedures of Analysis

In order to treat of the similarities and differences in the waveforms of the evoked potentials statistically, it was necessary to convert the 40 values of each data series describing a waveshape into a unitary value which would specify either a specific characteristic of a waveform or which would specify the relationship of a waveform to a given waveform or which would specify the relationship of a given waveform to another. Two methods of treatment of the data series were employed. The root mean square was computed to obtain a single value which described the amount of fluctuation of the amplitude of the evoked potential. The correlation coefficient was computed to obtain a single value which expressed the extent to which variations in the shape of one waveform were matched by variations in the shape of another.

Root Mean Square

In obtaining a value which expresses the shape of a waveform, two techniques of computing the area under the curve of the evoked potential may be followed. The first, more commonly used technique, takes the average of the amplitude of the waveform at equal intervals of time. This technique requires the establishment of a meaningful, uniform baseline beneath each waveform. A second technique, which is independent of the baseline and which requires only that the amplification of the recorder be constant, involves the computation of the root mean square (RMS) of the waveform. The RMS measures the fluctuation of the amplitude of a waveform. It is related to the amount of power in the transmission of alternating current and is computed by taking the square root of the mean of the squares of the deviations at equally-spaced points in time of the waveform from the grand mean. In the particular instance of computing the RMS of an evoked potential, the formula used is identical with that for calculating sigma, the standard deviation. The RMS technique was utilized because it is independent of the need of establishing a uniform baseline, and because it is more expressive of the characteristics of the waveshape than is a simple mean. (The mean gives an average of the amplitude of a waveform, and identical means could be obtained for both waveforms with large, clearly defined peaks and for waveforms with little or no modulation; the RMS is based on deviations of the waveform from its mean, a fact which makes the RMS value sensitive to the magnitude of the peaks and troughs of the evoked potential waveform.) With neither the simple mean nor the RMS is it possible to discriminate as to which wave component contributes most heavily to the resulting value.

Analysis of Variance. The waveforms of five subjects had been printed by the x-y plotter under the same amplification. The long and short records, consisting of 40 values of the amplitude of the waveform at equally-spaced points in time, were converted to RMS values by computing the standard deviation for each data series. For each subject, 18 values of the RMS, one for each of the evoked potentials, were obtained for both the short and long records.

The appropriate values of the RMS were entered as data into a program which computed a four-way analysis of variance. The extremely versatile program was that designed by Weldon and Humphrey (1970), the ANOVA 45. The experimental design involved was a three by three factorial with replications in two sessions for each of the subjects.

Correlations

Several procedures which have proven valuable in analyzing the similarities and differences between evoked potentials have been based on the computation of the Pearson product moment correlation between the various waveforms. The computation of the product moment correlation coefficient is independent of the baseline from which the amplitude of the wave is measured and is also independent of the amplification of the waveform when it is plotted. The correlation coefficient yields a single value which expresses the extent to which variations in one waveform are related to similar variations in another. Because it is independent of the amplitude and the mangitude of the fluctuations in amplitude of the waveform, the correlation coefficient is sensitive to the extent to which the peaks and troughs of one waveform correspond to the peaks and troughs of another. (The RMS method yields identical values for waveforms which deviate from the mean to the same extent, and it would be possible to obtain identical values for waveforms which were complete inversions of one another, provided that the magnitudes of the deviations were the same.) Although the correlation coefficient is sensitive to the similarities in the shapes of two waveforms, it does not identify which components of the waveforms are in agreement with one another.

In the discussion of correlation coefficients which follows, a particular convention has been utilized. When referring to the waveforms generated by the presentation of a familiar stimulus, the letter f is used; an unfamiliar stimulus, uf; and a blank stimulus, b. The subscripts 1 and 2 refer to the day on which the waveforms were evoked. When the day comparisons were not important, but the comparisons were made between waveforms evoked on the same day with those evoked on the different days, the letters s and d serve to denote the distinction.

Product moment correlation coefficients were calculated for every possible combination of the 18 waveforms generated for each subject. A separate set of correlations was computed for the data series of the short record and for the long record.

Although the correlation coefficient is an effective device for describing the extent to which two waveforms are related, it does not lend itself to ready comparison between multiple waveforms. The difficulty in making multiple comparisons arises, in part, from the aforementioned fact that the correlation coefficient is not sensitive to which portions of two waveforms are in agreement and which are not. For a given set of three waveforms, the finding that an identical correlation coefficient is obtained for two pairs of waveforms may mean that the three waveforms are all very much alike one another or that two are similar in some portions of the waveforms while two are similar in other portions of the waveforms. Several treatments, the three-way comparison, the zeta index, and the ranking of correlations, were employed to determine similarities and differences between evoked response waveforms.

Three-Way Comparison. A procedure which was considered for distilling the data provided by the matrices of correlation coefficients was similar to that of Martin (1970) in which a t-statistic was computed for several three-way comparisons. This technique allows one to determine which two of a given set of three waveforms more closely resemble each other and to determine whether the difference in degree of correlation is significant. For the many three-way combinations possible, the technique would have been tedious to utilize and would have produced results which would have been difficult to summarize. In order to determine whether the data obtained by the experiment gave results which were sufficiently rewarding to merit analysis by this method, some preliminary comparisons were made.

Zeta Index. Buchsbaum and Fedio (1969) devised a discrimination index, zeta, based on an elaboration of a technique attributed to Callaway and Buchsbaum (1965), which allowed them to compare the shapes of the waveforms of the responses evoked by four stimulus conditions. The purpose of the zeta is to generate a single number which specifies the relation between four waveforms. The zeta is based on Fisher z scores derived from the product moment correlations between each of the waveforms with the others. A heavier weight is assigned to a given pair of correlations, although all six correlations between the four waveforms are entered into the formula. The formula for the computation of the zeta index is given in Table C-1 in the Appendix. The result of the formula is that, were all the correlations equally strong or weak, the zeta index would be zero. Were a given pair of correlations especially stronger than the other four, if that pair were in the first part of the formula, the value of the zeta obtained would be positive; if that pair were in the second, less heavily weighed part, the value obtained would be negative.

As is indicated in Table C-1, three types of zeta indices were computed. Each type was named on the basis of which pair of correlations was assigned the heavier weight in the formula. The "similar" type consists of the correlations $z_{f_1f_2}+z_{uf_1uf_2}$ being assigned the larger weight; similarly, the "day" type consists of $z_{f_1uf_1}+z_{f_2uf_2}$; and the "dissimilar" type consists of $z_{f_1uf_2}+z_{f_2uf_1}$. These computations exhausted the logical comparisons which might be made with the four waveforms. The net result of the summation of the three computations for a given set of evoked potentials is zero. Hence, Buchsbaum and Fedio

(1969) tested the means of the zeta indices of a given type, by t-tests, for significant differences from zero.

Zeta indices for each of the three types of zeta and for each of the three categories of complexity of the stimulus patterns were obtained for each subject. The means of the zeta indices of a given type, averaged across subjects, were tested for differences from zero. Comparisons were also made between the different types of zeta to determine whether significant differences could be obtained.

Ranking of Correlations. From the data series obtained for each subject, correlations had been made between each of 18 waveforms. Within each category, correlations were made with waveforms evoked on the same day and with waveforms obtained on the different day. A particular waveform, either familiar, unfamiliar, or blank (f_s, uf_s, or b_s) obtained on a given day was compared with the others evoked in the same session and with the three corresponding waves (f_d, uf_d, and b_d) obtained during the other session. The correlations were ranked and the scores, ranging from 1 to 5, were entered in a grid. The rankings obtained facilitated computations and enabled the experimenter to perceive patterns which otherwise might have been hidden.

Three four-way analyses of variance, utilizing the ANOVA 45 program, were conducted. An analysis was made for the rankings of the correlations of f_s with others in the given block of uf_s, b_s, f_d, uf_d, and b_d; another for uf_s with others in the given block; and a third for b_s with others in the given block.

Each of the three analyses was composed of an analysis of a three by five factorial design with two replications for each subject. The means obtained by averaging the ranks of the correlations were tested for differences from the mean of 3.00 which would have been obtained had the ranks been randomly assigned to the correlations.

The averaged ranks of the correlations were ranked, in turn, and the various rankings obtained for a given subdivision of the analysis were assigned probability values on the basis of principles of permutations and combinations of ordered sets (Kemeny, Snell, Thompson, 1957; Hodges and Lehmann, 1965; Johnston, Price, Van Vleck, 1968).

RESULTS

Visual inspection of the graphs of the evoked potentials obtained from the two sessions for each subject revealed virtually no conspicuous characteristics which would permit discrimination between the waveforms elicited within a given category on the basis of the familiarity of the subject with the stimulus content. The waveforms obtained on a given day appeared to bear closer resemblance to each other than to those obtained during the other day. The waveforms obtained on a given day for a given category appeared to be more closely related to each other than to those obtained for different categories. Figures 2 and 3 depict the evoked potential records obtained from one subject for each stimulus condition.

From the visual inspection of the graphs, it may be noted that the major wave fluctuations generally occurred within the first 400 msec. after stimulus onset, i. e., during the short record of the data series. This finding held for most subjects. The several statistical treatments to which both the short and long record of the data series were submitted yielded essentially the same results, indicating that the latter part of the waveform contributed little to the discrimination between the evoked potentials.

The results which are presented in this section of the paper are given under the different types of statistical analysis and are then reclassified under the general findings of the study.

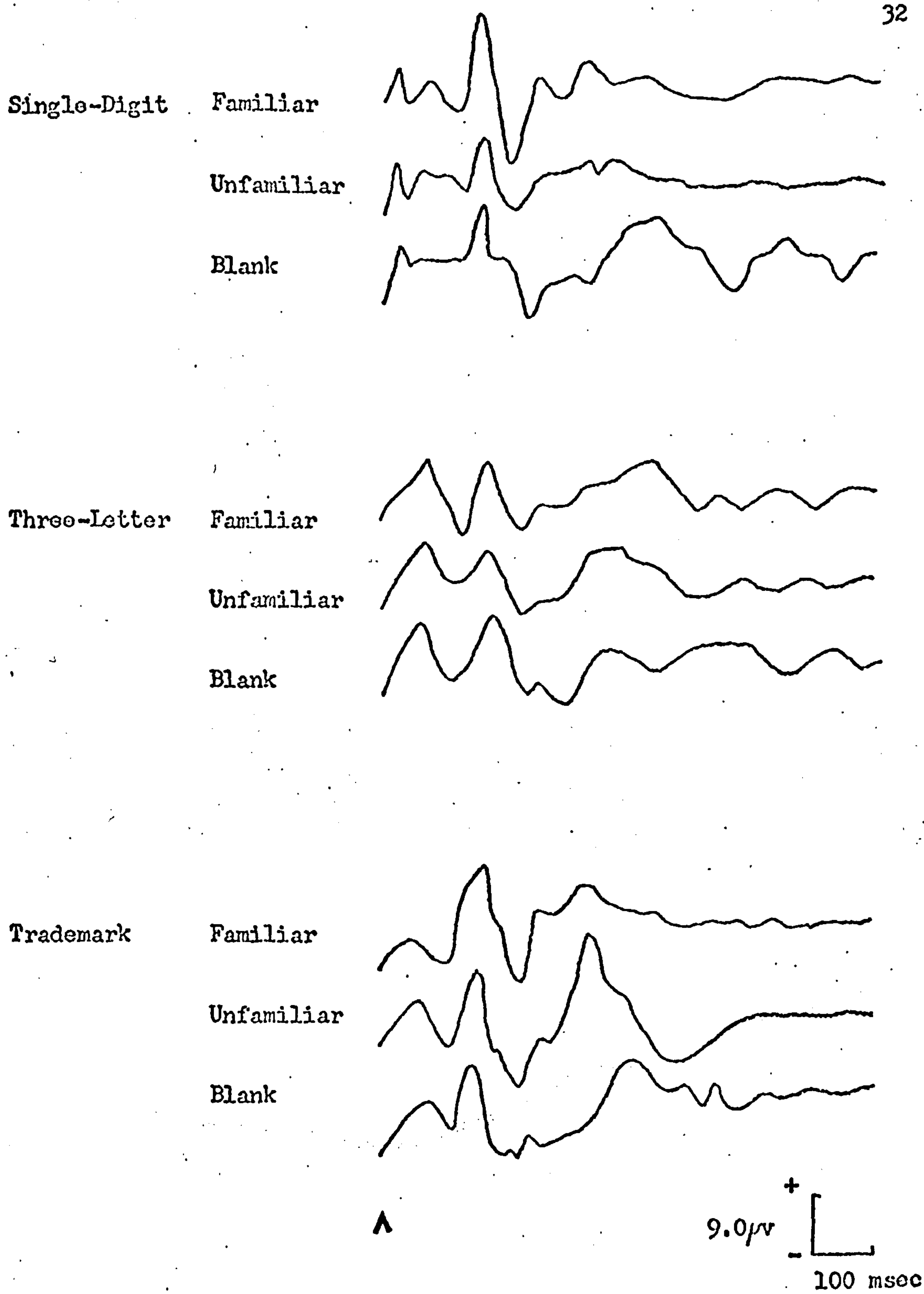


Figure 2. Evoked Potentials
Obtained from Subject PS During the First Session

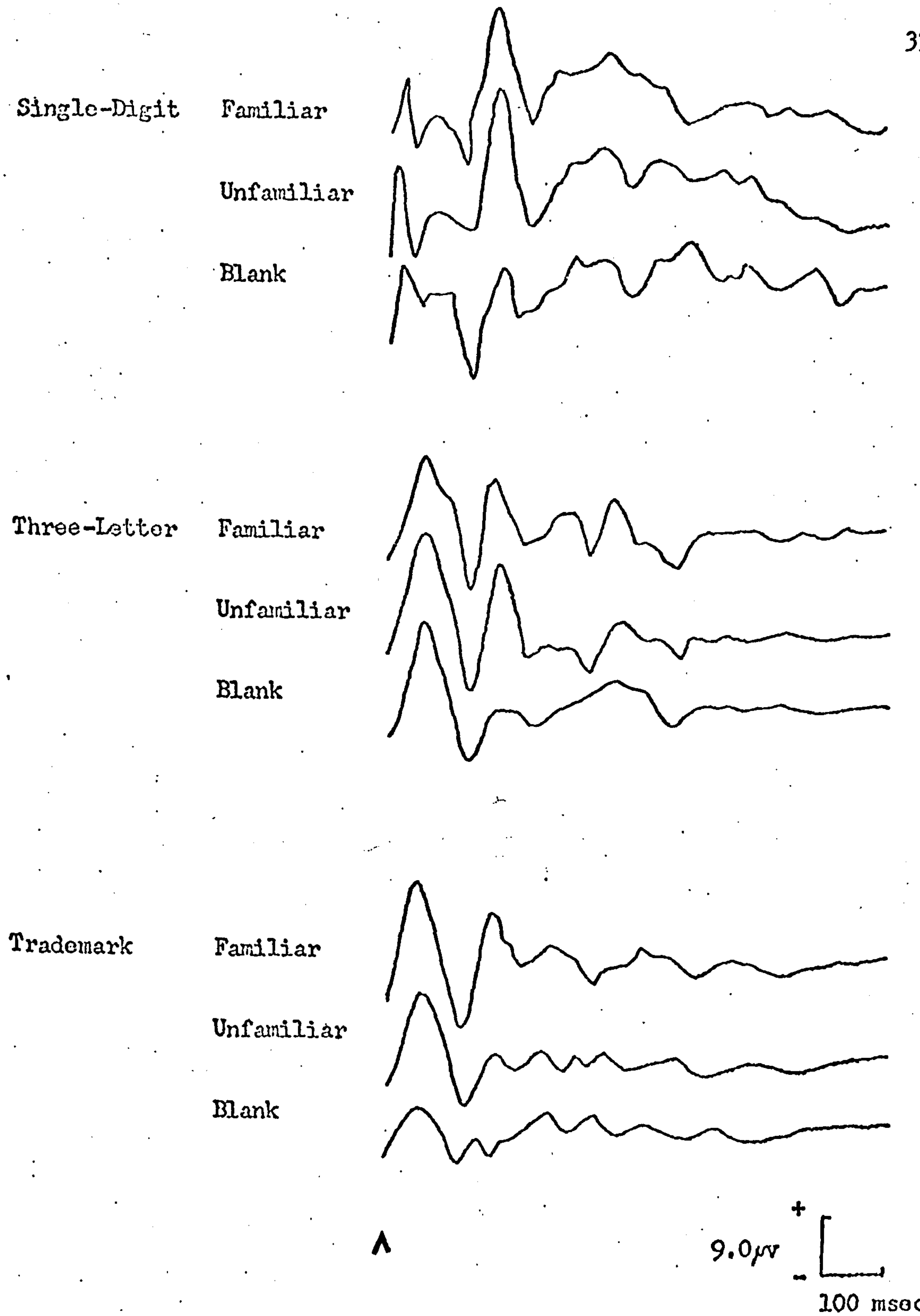


Figure 3. Evoked Potentials
Obtained from Subject PS During the Second Session

Root Mean Square

The major results of the analysis of variance of the root mean sqaure values obtained for the different waveforms are given in Table B-1 in the Appendix. The analysis of variance yielded only one F ratio significant at the .05 level for the major sources of variance; the F which was obtained for the category source of variance.

In Tables 3 and 4, the results of the comparison of means of the RMS values are given, both for the comparison of means of the three categories of complexity and the comparison of means of the three levels of familiarity. The results indicate that the RMS values obtained for the single-digit and three-letter categories do not differ significantly from one another, but do differ, at the .01 level, from the values obtained for the trademark category. The results indicate that the RMS values obtained for the familiar and unfamiliar levels do not differ significantly from one another, but do differ, at the .05 level, from the values obtained for the blank level.

Correlations

The correlations which were obtained between each of the 18 waveforms for each subject displayed a great range of values. The larger number of correlations occurred in a range of from .3 to .9, although a fair number of correlations occurred below .3 and at least a few for each subject occurred as negative values.

Three-Way Comparison

In order to determine whether the computation of a t-statistic between the various three-way comparisons of correlations would have

Table 3. Comparison of Means of the RMS Values Obtained for Three Categories of Complexity

Comparison	MS	Error	F	Level of Significance
single-digit compared with three-letter	851.266	14966.44	0.059	NS
single-digit and three-letter compared with trademark	103200.556	14966.44	6.896	.01

Table 4. Comparison of Means of the RMS Values Obtained for Three Levels of Familiarity

Comparison	MS	Error	F	Level of Significance
familiar compared with unfamiliar	1972.266	14966.44	0.131	NS
familiar and unfamiliar compared with blank	64222.222	14966.44	4.291	.05

been warranted, some preliminary comparisons were made. Comparisons were made between the correlations $r_{f_1f_2}$ and $r_{f_1uf_2}$, and between the correlations $r_{uf_1f_2}$ and $r_{uf_1uf_2}$. The comparison was made by noting which of the correlations in a given pair was larger, regardless of the magnitude of the difference. Because there were two comparisons for each of the three categories for the nine subjects, there was a total of 54 comparisons made. Of the total number, 29 were in the direction which indicated that the waveforms which matched more closely were related in terms of degree of familiarity, whereas 25 indicated that the reverse was the case. On the basis of these findings, it was decided that the computation of t-statistics between the various triads could not have been expected to be a profitable endeavor, and further consideration of employing this technique of analysis was rejected.

Zeta Index

Three types of zeta indices were computed for each subject for each category of stimulus complexity. The raw scores for the different zetas are given in Table C-2 in the Appendix.

The means of the zeta indices for each of the three types of zeta and for each of the three categories were obtained by averaging the zeta scores across the subjects. The results, given in Table 5, were all found to differ significantly from zero at at least the .02 level. The means obtained for the "day" type of zeta had positive values, indicating that the waveforms evoked on the same day were more closely related to each other than to the waveforms evoked on the second day.

Table 5. Averaged Zetas

Type of Zeta	Category	Short Record*			Long Record*
		Zeta	T-Score	Level of Significance	Zeta
Similar	Single-Digit	-.3165	3.324	.02	-.2934
	Three-Letter	-.2399	2.904	.02	-.2347
	Trademark	-.2777	3.753	.01	-.3140
Day	Single-Digit	.6779	3.644	.01	.5928
	Three-Letter	.4834	3.634	.01	.5113
	Trademark	.6344	4.541	.01	.6915
Dissimilar	Single-Digit	-.3614	3.578	.01	-.2993
	Three-Letter	-.2435	3.731	.01	-.2766
	Trademark	-.3567	5.246	.001	-.3773

* Short record: zetas computed on the basis of 40 points, equally-spaced during the first 400 msec. Long record: zetas computed on the basis of 40 points, equally-spaced during the first 800 msec.

Table 6. Comparison of Zetas

Types of Zeta Compared	Category	Short Record*		Long Record*	
		Wilcoxon Sign Test Score	Level of Signif.	Wilcoxon Sign Test Score	Level of Signif.
Similar with Dissimilar	Single-Digit	19	NS	21	NS
	Three-Letter	20	NS	16	NS
	Trademark	4	.05	6.5	NS
Day with Similar	Single-Digit	0	.001	0	.001
	Three-Letter	1	.01	0	.001
	Trademark	1	.01	0	.001
Day with Dissimilar	Single-Digit	0	.001	0	.001
	Three-Letter	0	.001	0	.001
	Trademark	0	.001	0	.001

* Short record: zetas computed on the basis of 40 points, equally-spaced during the first 400 msec. Long record: zetas computed on the basis of 40 points, equally-spaced during the first 800 msec.

Using the raw score data, Wilcoxon sign test comparisons were made between paired listings of the zetas obtained from the subjects. Comparisons were made in the three ways possible between the three types of zeta computed, i. e., between the similar, day, and dissimilar types. In Table 6, the results of the comparisons are given. The results confirmed the finding that the day effects were very strong; the zetas computed for the similar and the dissimilar types were significantly different from the zetas computed for the day type (at the .01 level).

The tests of the comparisons between the similar and dissimilar types of zetas showed that their values did not differ significantly, except for those obtained under the third, trademark, category. The difference between the zetas obtained under the trademark category was significant at the .05 level for the short record and barely missed attaining significance at the .05 level for the long record. These findings indicate that the waveforms evoked by familiar stimuli on one day are almost equally as alike the waveforms evoked by the familiar or the unfamiliar stimuli on a second day; although, in the case of waveforms evoked by familiar stimuli of the trademark category, the correlation with the familiar waveform of the second day is significantly greater than the correlation with the unfamiliar waveform of the second day.

Ranking of Correlations

Within each block of six waveforms obtained in a given category, the ranks of the correlations of f_s with the other five waveforms, the ranks of the correlations of uf_s with the other five waveforms, and the ranks of the correlations of b_s with the other five waveforms were obtained. The resulting values were used as the data for three analyses of variance.

The three analyses of variance each yielded an F ratio significant at beyond the .001 level. These significant ratios were obtained for the differences between the ranking source of variance, and are indicated in Table D-1 in the Appendix. The fact that significant F ratios were obtained for the ranking source may be taken to mean that the procedure of assigning ranks to the correlations was not a random process but that inherent differences in the degree of correlation between various waveforms were preserved.

The results of the averaged ranks for the short and long records, averaged across subjects, days, and categories, are given in Table 7. Had the degrees of correlation between the waveforms in a given block been randomly generated, the ranking of the correlations would have produced a random distribution, and the average of the ranks of the correlations would have been 3.00 as that was the average of the range of possible rank values from one to five. The t-test and the Wilcoxon sign test were used to determine the significance of the difference from a mean of 3.00 of the averages obtained. In each separation according to the comparisons made, two or three significant t's were obtained.

The results of the averaged ranks were ranked for the facilitation of noting the trend of the effects. In the compilation provided in Table 7, it may be seen that a given waveform correlated more closely with others produced during the same session as the ranks of 1 and 2 are found only for the correlations with waveforms evoked on the same day. When the original waveform was produced by stimuli containing

Table 7. Averaged Ranks of Correlations

* Correlations are between waveforms evoked by familiar (f), unfamiliar (uf), and blank (b) stimuli on the same (s) or different (d) day from that on which the waveform designated in the left column was evoked. In each block, the correlations between the waveform indicated on the left and the five on the right were ranked in descending order (ie., 1 = strongest correlation, 5 = weakest). The ranks of the different types of correlations were averaged across subjects, days, and categories to yield the "average of rank of correlations" for a particular type of correlation.

Table 7. Averaged Ranks of Correlations

Correlations Between Waveform and Waveform*		Short Record					Long Record		
		Average of Rank of Correlations	T-Score	Level of Signif.	Wilcoxon Level of Signif.	Rank	Average of Rank of Correlations	Wilcoxon Level of Signif.	Rank
f_s	uf_s	1.425	13.749	.001	.001	1	1.444	.001	1
	b_s	3.000	0.000	NS	NS	2	2.537	NS	2
	f_d	3.536	2.492	.05	.02	4	3.593	NS	4
	uf_d	3.148	0.836	NS	NS	3	3.444	.01	3
	b_d	3.888	5.333	.001	.001	5	3.982	.01	5
uf_s	f_s	1.685	8.455	.001	.001	1	1.481	.001	1
	b_s	2.759	1.146	NS	NS	2	2.426	.05	2
	f_d	3.481	1.998	NS	NS	4	3.796	.01	4
	uf_d	3.055	0.214	NS	NS	3	3.240	NS	3
	b_d	4.018	5.442	.001	.001	5	4.056	.001	5
b_s	f_s	2.518	1.775	NS	NS	2	2.315	NS	2
	uf_s	2.333	3.895	.01	.01	1	1.944	.001	1
	f_d	3.741	5.957	.001	.001	5	3.703	.001	4
	uf_d	3.518	3.012	.02	.01	4	3.741	.001	5
	b_d	2.889	1.106	NS	NS	3	3.278	NS	3

* An explanation of the arrangement of the Table is given on the facing page.

some configuration (i. e., by f or uf) it correlated more closely with waveforms evoked by configurations than with those evoked by blank patterns. It may also be seen that, of the correlations with waveforms generated during the different session, blank waveforms correlated most closely with blank ones, whereas both familiar and unfamiliar waveforms correlated most closely with the patterned configurations. The finding that the correlation of the f_s with f_d ranked below the correlation of f_s with uf_d indicates that there was no consistent relation between the waveforms on the basis of the degree of familiarity.

In Tables D-2 and D-3 in the Appendix, the averages of the ranks of correlations are given under various subdivisions of the analyses of variance. The raw scores of the averages of the ranks of correlations are given in Table D-2, and the ranking of the raw scores is given in Table D-3. For each block of analyses which was made, the general rank order was compared with the specific rank orders obtained for each subdivision of the analysis. The probability values of obtaining repetitions of the rank ordering are indicated in Table D-3. The generally low values of the probability scores indicate that the ordering expressed in the general rank of the averages showed remarkable perseverance in the subdivisions of the analysis.

Familiarity Effects

The major finding, as far as the intended purpose of the study was concerned -- determining whether the waveforms evoked by familiar stimuli would resemble one another more closely than those evoked by less familiar stimuli -- was a negative one. The responses to familiar stimuli on two days could not be distinguished from the responses to unfamiliar stimuli, although they could generally be distinguished from the responses to blank stimuli. For stimuli of the trademark category, the zeta analysis suggested that the familiar responses matched one another more closely than the unfamiliar, and that the unfamiliar responses matched one another more closely than the familiar. The rank analysis upheld this finding of a difference due to the level of familiarity in the responses to the trademark category, but the finding was not consistently maintained in the subdivisions of the analysis (see Table D-3).

Complexity Effects

A difference in response dependent on the complexity of the visual stimulus was confirmed by the analyses of the RMS, the zeta, and the ranking of correlations. Two aspects of stimulus complexity must be considered. The physical aspect of stimulus complexity devolves to a consideration of the amount of contour, colored areas, etc. The phenomenal aspect pertains to the interpretation given the stimulus pattern by the subject. Differences obtained between the categories of stimulus patterns may be attributed to both the physical and phenomenal aspects of complexity because stimuli of the single-digit category are less complex than stimuli of the trademark category both in terms of contour, colored areas, etc., and in terms of the significance of the interpretation given the stimulus. Differences obtained within a category between the levels of familiarity of the familiar and unfamiliar series may be attributed to the phenomenal aspects, but not to the physical, because the physical elements remained the same in each series. Differences obtained within a category between the unpatterned, blank stimulus responses and the patterned, familiar and unfamiliar stimulus responses may be attributed to the physical aspects of stimulus complexity.

With regard to the physical aspects, the RMS values of the responses to patterned stimuli, which did not differ significantly from each other, did differ significantly (at the .05 level) from the RMS value for the blank evoked responses. Differences in the RMS value between the categories of complexity were highly significant (at the .01 level) for the responses evoked by trademark stimuli. By means of the ranks of correlations analysis, it was found that the responses to patterned stimuli, both familiar and unfamiliar, on one day were correlated more strongly with the responses to patterned stimuli on the other than to the blank stimuli. Similarly, the responses to the blank stimuli on a given day were correlated more strongly with the responses to blank stimuli than to patterned stimuli on the other day. It may be concluded, therefore, that the evoked response was related to differences in the physical aspects of stimulus complexity.

With regard to the phenomenal aspects, the zeta analysis found that although the relation of familiar waveforms evoked in one session to the familiar and unfamiliar waveforms evoked in the other session was not significantly different for single-digit and three-letter stimulus series, it was different for the responses to the most complex, trademark, stimuli. The finding that differences in the RMS value between the single-digit and three letter-categories were not significant whereas the differences were significant (at the .01 level) between the most complex, trademark category and the less complex ones suggests that differences attributable to increasing stimulus complexity in terms of phenomenal aspects were also present.

Day Effects

Similarities in the waveforms evoked on the same day were noted as being especially strong by the zeta and rank analyses. The fact that positive zeta indices were obtained when the waveforms of pairs of responses elicited on the same day were correlated indicated that the similarities on the basis of day of presentation were considerably greater than the similarities found on the basis of familiarity. The fact that in ranking the means of the ranks of the correlations in a given block of responses, the rank values one and two were almost always assigned to the correlations with the waveforms elicited on the same day confirmed the finding of the importance of day effects.

Individual Variations

The general trends which were obtained by averaging the response measurements across subjects, days, and categories seldom were found to hold, in entirety, for the response measurements within subjects, days, and categories. Considerable variation in the characteristics of the subjects' responses was indicated by the RMS analysis and by the rank analysis. For individual subjects, the magnitude of the variations in amplitude of the evoked potential often shifted in no consistent way between the responses elicited under the various conditions. The complete rank order of the strength of the correlation coefficients between the various responses evoked for a particular block of stimuli was seldom repeated uniformly across subjects or even within subjects for different days and categories. Despite the large individual variations under the stimulus conditions, certain trends, treated of in the following paragraph, were readily apparent.

Individual Consistencies

A general finding of the rank analysis was that the extreme values of the ordering of correlations, i. e., the strongest and weakest correlations, between one waveform and the others in the block to which it was compared tended to remain constant both across categories and days and, generally, across the various subjects. Most of the fluctuations within the order of ranks tended to come from the middle three ranks. It may be concluded with a fair degree of certainty that the waveform evoked for the familiar series from a particular subject on a particular day for a particular category correlated most highly with the waveform for the unfamiliar series of the same day, and that the waveform for the familiar series correlated least highly with the waveform for the blank series obtained in the other session. For most subjects under most conditions, the waveforms evoked by the unfamiliar series on one day correlated most closely with the waveform evoked by the familiar series on the same day, and correlated least closely with the waveform evoked by the blank series on the second day. Similarly, for most subjects under most conditions, the waveform evoked by the blank series on one day usually showed the closest correlation with the unfamiliar and familiar waveforms evoked on the same day, whereas the least strong correlation was with the waveforms of the familiar and unfamiliar series of the other session.

Summary

The general conclusion of this study is that, with the methods used in this experiment, no differences between the waveforms elicited by familiar and unfamiliar stimuli could be measured consistently. The responses obtained to the trademark category of stimulation constitute an exception to this general finding, but the strength and consistency of the exception were not especially strong.

Several strong relationships between the waveforms were found. Waveforms elicited by patterned stimuli showed a higher relationship with waveforms elicited by other patterned stimuli than with waveforms elicited by blank stimuli. Waveforms elicited by stimuli of greater stimulus complexity, both in terms of physical aspects and phenomenal aspects, could be related more closely to waveforms elicited by other stimuli of similar levels of complexity than to waveforms elicited by stimuli of higher or lower levels of complexity. Waveforms elicited on the same day exhibited a greater degree of similarity to one another than to the waveforms elicited on the different day. Although individual differences were often conspicuous, the extreme values of the ranks of the correlations of a given waveform with others in its block were generally consistent.

The findings reported in this summary were usually supported by each of the three procedures of analysis, the RMS, the zeta index, and the ranking of correlations, used in this experiment.

DISCUSSION

The experiment had as its major purpose the discovery of whether certain aspects of the visually evoked potential could be distinguished which would characterize it as having been evoked by stimuli which were familiar or unfamiliar to the subject. In order to minimize the influence of variables which have been found to affect the form of the evoked potential, the attentional, emotional, and physical characteristics of the stimuli were held constant or were counterbalanced in both sessions. With this experimental design, differences in the waveforms obtained for a subject during a given session under different categories of complexity and degrees of familiarity might be attributed to the effects of the familiarity of the stimulus content to the subject.

Familiarity Effects

The data gathered in this experiment have failed to indicate any prominent differences in the waveforms due to the operationally-defined levels of stimulus familiarity. Everything is familiar to some degree. Even the most unfamiliar object will have elements which are familiar to an adult. Although scores indicating marked differences in the degree of familiarity were obtained for the stimuli in each series from a sample from the same population as that from which the subjects in the experiment were chosen, it might have been that the differences in the stimuli in terms of familiarity were not sufficient to evoke different responses in the subjects. The verbal reports of the subjects indicated, though, that they could and did distinguish between the stimuli on the basis of whether or not the patterns were recognized as familiar. It appears, therefore, that the stimulus series designed for the task were effective, phenomenally, and that there was a failure to obtain a physiological response in the evoked potential which corresponded with the phenomenal interpretation.

It was possible that, even though the selection of the stimuli for the experiment was effective, the methods used to analyze the data were not sufficiently acute to permit the relevant differences in the waveforms to be detected. The procedures used to draw out the relations between the waveforms were based on the amount of variation in the electrical activity, as determined by the RMS, and by the extent to which one waveform varied with another, as determined by the correlation coefficient. The relative insensitivity of these measures to specific components of the waveform has been discussed earlier. Nevertheless, despite the insensitivity of the procedures used and despite the great individual variations in the response measures obtained, several prominent overall effects did emerge. These effects, such as the strong similarity between waveforms evoked on the same day and the strong differences between waveforms evoked by patterned and unpatterned stimuli, persisted in the various subdivisions of the analysis. It must be concluded that, although other significant effects could be detected, the effects due to the familiarity of the subject with the stimulus content, if they exist, could not reliably be detected by the techniques utilized in this experiment.

Some of the strongest differences obtained between the waveforms elicited by the experiment were between those of the trademark category and those of the other categories of complexity. The analysis of variance of the RMS indicated that the results obtained for the trademark category were significantly larger than those obtained for the other two categories. It is possible that much of the difference between the characteristics of the waveforms was simply the result in of the increase in stimulus complexity in terms of the increased amount of contour. Were the increase in contour alone sufficient to explain the increased RMS value of the trademark-elicited responses over the others, it would have been expected that the RMS values evoked by both the familiar and unfamiliar stimuli would have been the same. As this was not the case, alternative explanations must be sought. Another possibility, which needs to be considered, is that the differences were due to phenomenal effects.

The momentary presentation of a trademark stimulus might result in a saturation of the information-processing capacities as it would contain considerably more in terms of content, contours, colors, lettering, arrangements, and significance than would have stimulation with patterns from the lower categories. In the case of stimulation with a familiar trademark symbol, the emblem could be readily classified as a familiar object and the stimulus features could be ignored. The unfamiliar symbols could not be readily classified and, as a consequence, the subject might have been expected to have paid greater attention to the multiple sources of information, colors, contours, arrangements, etc., in an effort to classify the object. As with the study of EEG desynchronization by Berlyne and McDonnell (1965), the incongruous, unfamiliar stimuli might have resulted in an alteration of the brain wave patterns which was more pronounced than that caused by familiar patterns. The reason this effect might not have been observed with the less complex stimuli might be attributed to the fact that the restricted amount of content and limited variations in physical characteristics afforded by the single-digit and three-letter stimulus series would be more rapidly processed and dismissed than would the complex characteristics provided by the trademark series. This speculation suggests that effects due to the familiarity of the stimulus content to the subject might be more readily obtained, if they exist, with the presentation of highly complex stimulus patterns in extremely restricted time periods.

Experiments Related to Familiarity Effects

No other experiments dealing with the relation between evoked potentials and the familiarity of the stimulus content to the subject are known to have been conducted and reported at this time. Several studies have touched on the subject peripherally, although differences in the experimental design generally prohibit the reinterpretation of the results of those experiments with respect to distinguishing between waveforms on the basis of degree of familiarity of the stimuli.

Earlier studies which had found differences in the waveforms of the evoked potentials and attributed them to differences in the phenomenal stimulus content had confounded their discoveries by the presence of emotion-arousing characteristics (Lifshitz, 1966; Cohen and Walter, 1966; Weinberg and Cole, 1968) or by the presence of physical characteristics which were not counterbalanced (John, Herrington, and Sutton, 1967). In the latter-mentioned study, it was possible that the differential responses obtained with different geometric forms of the same area were due to the differential stimulation of orientation receptors rather than to the phenomenal interpretation of the stimulus patterns. In the afore-mentioned studies, the use of verbal and pictorial stimuli of a taboo nature rendered differences which might have been due to familiarity masked by emotion-arousing factors.

The study which comes closest, in design although not in aim, to the one reported in this paper is that of Buchsbaum and Fedio (1969). As was indicated in the introduction, the differences between the two experiments are substantial. Buchsbaum and Fedio obtained differential responses to words, patterns, and randomly distributed dots, and found, using the zeta index, that the responses evoked by the left and right hemispheres yielded different discrimination indices indicating that the left hemisphere discriminated better between words and dots whereas the right hemisphere discriminated better between words and patterns. These findings suggest that the evoked potential does reflect characteristics of the visual material which is being processed. The words, being familiar, can be classed immediately by naming them whereas the random dots, being unfamiliar, cannot be classed, verbally, as belonging to a particular configuration. These results suggest that similar results might be found for familiar and unfamiliar series of stimuli. Several omissions in the experimental design of Buchsbaum and Fedio revent the drawing of conclusions with regard to the differences which might be obtained with degrees of stimulus familiarity.

The fact that Buchsbaum and Fedio (1969) obtained responses to words, patterns, and randomly distributed dots which could generally be distinguished from one another should not be compared with the general failure to obtain differential responses in a particular category to the familiar and unfamiliar stimulus series in this experiment. The equivalent of Buchsbaum and Fedio's words, patterns, and dots series would more properly be the trademarks, three-letter, and single-digit category series rather than the familiar, unfamiliar, and blank series within each category. In the experiment reported in this paper, differences between the responses to the categories were obtained. Within a given category, however, between the familiar and unfamiliar series, differences were not consistently obtained.

From the report made by Buchsbaum and Fedio (1969), it appears that the same stimuli were used in the two sessions given each subject, although the stimuli were presented in different orders. It is impossible to determine, therefore, whether the effects obtained were peculiar to the particular sets of stimuli (32 in each of their categories), or whether they could be generalized to any series composed of words, patterns, and random dots. Their experimental design may not be equated with the experiment reported in this paper because, in this experiment, different stimulus series were used for each session.

As with the earlier-mentioned studies, the fact that the experimenters were seeking to examine hypotheses different from that of major interest to this researcher caused them to design experiments which, appropriate for their aims, were often inappropriate or incomplete when examined for effects of familiarity.

Experiments Related to Other Effects

The data collected in this experiment, although providing essentially negative results with respect to finding differential effects due to the degree of familiarity of the stimulus content, did provide confirmation and elucidation of a number of earlier findings.

The different levels of stimulus complexity used in the experiment reported in this paper were found to result in RMS values for the evoked potentials which were of significantly different magnitudes. As the complexity of the stimuli increased, from the single-digit and three-letter to the trademark category, the magnitude of the RMS, indicating the amount of fluctuation in the electrical potentials, increased. This finding confirms those of Chapman and Bragdon (1964), and Cohen and Walter (1966). In the experiment by Chapman and Bragdon, the magnitude of the evoked response to numbers was larger than that to a plus sign or blank field. Chapman and Bragdon interpreted the differences as being due to the differences in "meaningfulness" of the stimuli with regard to an assigned task. The experiment of Sutton, Tueting, and Zubin (1967) suggests that the differences in potentials might have resulted from the amount of information contained in the two categories. Cohen and Walter (1966) found that when geometric stimuli of the same configuration were repeatedly presented, the responses were less large than when the stimuli of different configurations were mixed. Numbers would vary considerably more than plus signs and blank fields; a variety of geometric shapes would vary considerably more than a series of the same shape. When the stimuli could assume a variety of values the amount of information conveyed by the presentation of a given stimulus would be greater than would occur if the stimuli were all the same. Hence, visual stimuli of greater variety would elicit larger evoked potentials. From the results of these experiments it is impossible to determine whether differences in magnitude of the evoked potential were mainly the result of the uncertainty as to which stimulus would be presented or were also the result of the differences in the complexity of the stimuli.

In the experiment reported in this paper, the stimuli, patterned and blank field, were presented in random order. The uncertainty as to which stimulus would be presented was present on every stimulation. Had the differences in amplitude of the evoked potential been due solely to the unordered presentation of the stimuli, differences between the presentation of the blank and patterned stimuli should not have been apparent. The experiment found that the amplitudes of the RMS increased from the blank to the patterned responses, indicating that uncertainty, alone, could not account for the differences in the waveform characteristics.

Differences in the RMS values of the evoked potentials for the familiar and unfamiliar stimulus series, significant for the waveforms elicited by the trademark category, indicate that the information contained in the various stimulus series had some effect on the RMS values.

Differences obtained with the responses evoked by different categories of complexity might also have been due to the increasing amount of stimulus complexity in terms of the amount of contours present, a finding which Spehlmann (1965) had made with checkerboard patterns of varying degrees of complexity.

The results of this experiment, while confirming those which suggest that stimulus uncertainty and the amount of contour are relevant factors affecting the amplitude of the RMS, suggest that an additional, possibly more minor factor is the level of information contained in the stimulus.

In the experiments employing different sets of words as stimuli, a variety of results has been obtained. John et al. (1967) obtained differential responses to the two words "square" and "circle." Whether these differences were due to the phenomenal differences in the interpretation assigned to the words or, more directly, to the differences in physical stimulation provided by the letters of the words could not be determined from their experiment. In experiments by Lifshitz (1966) and by Weinberg and Cole (1968), series of words in each of two categories were provided the subject. The effects due to the physical characteristics of the individual words were, therefore, assumed to have been cancelled out whereas the effects due to the phenomenal content remained. In both cases, the division into two categories was made on the basis of "normal" and "taboo" words, hence, the outcomes of both experiments were confounded, with respect to familiarity effects, by emotional factors. Lifshitz, by visual inspection, obtained no differences between the waveforms elicited by the two categories of words whereas Weinberg and Cole did obtain differences when the shapes of the waveforms they obtained were analyzed by spectral analysis. The results of the experiment reported in this paper leave unanswered the question of the effects of emotion-arousing characteristics on the evoked potential. They suggest that there are no significant differences between the waveforms obtained with familiar three-letter words and with unfamiliar three-letter nonsense syllables, and that, therefore, the effort to obtain differences between the two categories on the bases of the familiarity of the subject with the stimulus content is unrewarding.

Procedures of Analysis

There is a need for more sophisticated statistical analyses of waveforms of evoked potentials. Depending on the amplitude of the waveform, while providing a convenient, readily quantifible measure, does not take into account the complexities of the waveform generated by the brain. This study has demonstrated that more complex techniques of analyzing the waveform data provide the experimenter with measurements which reveal relationships which might not be apparent with other techniques. The different techniques of measurement are sensitive to different parameters. The RMS is sensitive to overall variations in electrical activity whereas the correlational coefficient is sensitive to the shape of one waveform as it relates to the shape of another.

These different techniques of measurement, because they are based on assessing different characteristics of the waveforms, may yield different results. The different results, obtained with different techniques, should not be regarded as incorrect for they merely reflect different sensitivities to characteristics of the waveforms. It is possible that many of the apparently conflicting results obtained in the field of evoked potentials may be attributed to differences stemming from the measurement techniques.

The RMS value seems to be monotonically related to the complexity of the stimulus employed. This finding suggests that the RMS measure may be a valuable one when seeking to determine the effects of stimulus complexity on the evoked potential.

The zeta index, as a device for summarizing some complex interactions between the correlations of four waveforms, has demonstrated its value in the experiment of Buchsbaum and Fedio (1969) as well as in the present experiment. The RMS analysis and the zeta index technique have proven themselves to be useful processes for analyzing and summarizing particular relationships between waveforms.

The introduction of correlation ranking techniques to the study of complex comparisons between waveforms of evoked potentials has provided an additional valuable tool. Correlation ranking allows for relations between many waveforms, which might not have been conspicuous when regarding the raw correlations, to become apparent. As the mathematics of the probability of permutations of rank-ordered sets is more extensively applied, the effectiveness of the technique will be greatly enhanced.

Conclusions

The evoked potentials obtained in response to simple visual stimuli (single-digit and three-letter categories) of varying degrees of familiarity to the subject do not appear to reflect any uniform relation between the waveforms which would permit one to characterize them as having been evoked by familiar or by unfamiliar stimuli. The potentials obtained in response to complex visual stimuli (trademark category) did appear to exhibit such characteristics due to the level of familiarity when the response measures were averaged across subjects, categories, and days, but the results were not persistent in the subdivisions of the analysis. It must be concluded that effects on the cortical potential due to familiarity, if they exist, are either weak or especially unsusceptible to detection by the present means of analysis.

Differences in the waveforms of the evoked potentials due to the session in which they were evoked were found; waveforms evoked on the same day were more similar to each other than to those evoked on different days. Differences in waveforms evoked by patterned and unpatterned stimuli were also prominent. Differences in the waveforms due to increasing stimulus complexity were significant.

The usefulness of two techniques of analysis, the root mean square (RMS) and the zeta index, was confirmed. The introduction of the procedure of ranking correlations, a third technique of analysis, has provided an addtional valuable tool for the investigation of similarities and differences in several evoked potentials.

APPENDIX A

STIMULUS CHARACTERISTICS

In preparing the different familiar and unfamiliar series of stimulus patterns for each category, it was necessary to know to what extent the individual stimulus patterns would be recognized as familiar objects. This knowledge was especially necessary because two sets of stimulus series were being designed, a different one to be used in each session, and these sets needed to be matched in terms of degree of familiarity.

Tables A-1 and A-2 give the familiarity scores obtained for each stimulus pattern in a series. When it was possible to do so, the average of the scores of the individual stimulus patterns in each series has been computed and entered in the tables. In each category, the means of the two sets (A) and (B) of the familiar series are closely related and the means of the two sets of the unfamiliar series are also closely related, indicating that no substantial differences between the sets in terms of degree of familiarity existed.

Table A-1. Single-Digit and Three-Letter Stimuli

Single-Digit						Three-Letter							
Stimuli		Familiarity Scores *				Stimuli				Familiarity Scores **			
Familiar Series		Familiar Series		Unfamiliar Series		Familiar Series		Unfamiliar Series		Familiar Series		Unfamiliar Series	
(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
1	2	5.00	4.89	2.31	2.73	WIN	FEW	NIW	WEF	AA 650	AA M	47 61	20 67
3	4	4.89	5.00	2.39	3.97	BEG	BOY	GEB	YOB	A 400	AA M	20 64	47 62
5	8	5.00	4.98	2.50	2.05	DAY	MAN	YAD	NAM	AA M	AA M	47 43	87 85
6	9	4.95	4.88	2.42	1.75	PEN	BOX	NEP	XOB	A 200	AA M	73 86	13 38
7	C	4.98	4.80	2.56	1.67	HOT	HIS	TOH	SIH	AA M	AA M	33 74	20 78
D	F	4.92	4.95	3.40	1.61	FOR	SIT	ROF	TIS	AA M	AA M	53 85	47 88
E	G	5.00	4.98	1.85	2.73	SUN	YET	NUS	TEY	AA M	AA M	60 77	33 81
O	K	5.00	5.00	1.61	1.36	BUY	CAN	YUB	NAC	AA M	AA M	13 46	47 90
P	R	4.98	4.98	2.15	2.58	BIT	BAY	TIB	YAB	AA 700	AA 700	73 78	13 50
Q	S	4.80	4.58	2.38	2.97	HAS	RUN	SAH	NUR	AA M	AA M	60 81	53 86
Mean Score		4.95	4.90	2.44	2.44					cannot be computed with data			

* Based on a five-point scale. (See text, p. 17.)

** Based on Thorndike and Lorge (1944). (See text, p. 17)

Table A-2. Trademark Stimuli

Number	Stimuli: Familiar Series (A)	Stimuli: Familiar Series (B)	Stimulus Characteristics: Shape	Stimulus Characteristics: Colors**	Stimulus Characteristics: Relationship A-B		Familiarity Scores*: Familiar (A)	Familiarity Scores*: Familiar (B)	Familiarity Scores*: Unfamiliar (A)	Familiarity Scores*: Unfamiliar (B)
1	Coke	7-Up	square	r,w	1-1	drink	4.57	4.60	1.85	2.78
2	Amer. Air.	Communist Sgn.	round	r,w	2-3	airline	4.57	4.93	3.45	4.18
3	Peace Sgn.	Pan Am. Air.	round	b,w	3-2	symbol	4.21	4.98	1.78	3.28
4	Westinghouse	Gen. Electric	round	b,w	4-4	electric	4.85	4.92	3.75	2.91
5	Bell Tel.	Volkswagen	round	b,w	5-10	telephone	4.98	4.89	2.03	3.36
6	Chevrolet	Mobil	oblong	r,w,b	6-5	automobile	4.45	4.95	3.79	3.73
7	Gulf	Union 76	round	o,w,b	7-7	gasoline	5.00	4.95	4.49	3.34
8	Enco	Chevron	odd	r,w,b	8-8	gasoline	5.00	5.00	4.40	4.21
9	Shell	Phillips 66	odd	---	9-9	gasoline	4.98	4.80	4.46	3.70
10	Texaco	Yellow Pages	odd	---	10-6	gasoline	4.89	4.36	1.82	3.91
Mean Score							4.75	4.84	3.18	3.54

* Based on a five-point scale. (See text, p. 17.)

** Color code: r, red; w, white; b, blue; o, orange; ---, unmatched mixture.

APPENDIX B

ROOT MEAN SQUARE

Table B-1. Root Mean Square Analysis

Source**	df	MS	Error*	F	Level of Significance
F	2	33097.24	A	2.2114	NS
C	2	52025.91	A	3.4762	.05
D	1	9140.54	B	0.3659	NS
S	4	34851.23	A	2.3286	NS
FC	4	23853.02	A	1.5937	NS
FD	2	6452.04	B	0.2584	NS
CD	2	36013.64	B	1.4417	NS
FCD	4	10191.19	B	0.40798	NS

*

Error	df	MS	Sources**
Error A	32	14966.44	CS FS FCS
Error B	36	24979.35	DS FDS CDS FCDS

** Source: degree of familiarity (F); category of complexity (C); day (D); subject (S).

APPENDIX C

ZETA INDEX

Table C-1. Zeta Index

Type of Zeta**	Formula*
Similar	$zeta = \frac{1}{2}(z_{f_1f_2} + z_{uf_1uf_2}) - \frac{1}{4}(z_{f_1uf_2} + z_{f_2uf_1} + z_{f_1uf_1} + z_{f_2uf_2})$
Day	$zeta = \frac{1}{2}(z_{f_1uf_1} + z_{f_2uf_2}) - \frac{1}{4}(z_{f_1uf_2} + z_{f_2uf_1} + z_{f_1f_2} + z_{uf_1uf_2})$
Dissimilar	$zeta = \frac{1}{2}(z_{f_1uf_2} + z_{f_2uf_1}) - \frac{1}{4}(z_{f_1f_2} + z_{uf_1uf_2} + z_{f_1uf_1} + z_{f_2uf_2})$

* The z's entered into the formula for zeta are Fisher z-scores. The subscripts denote the different waveforms between which the coefficients of correlation, converted into z-scores, were computed. Correlations were between waveforms evoked by familiar (f), unfamiliar (uf), and blank (b) stimuli on the first day (1) or the second (2) day.

** The types of zeta differ from one another according to which correlations are more heavily weighed by entry in the first part of the formula.

Similar: The first part of the formula is the sum of the z-scores of the correlation between the waveforms evoked by the familiar stimuli on the two sessions and the correlation between the waveforms evoked by the unfamiliar stimuli on the two sessions.

Day: The first part of the formula is the sum of the z-scores of the correlation between the waveforms evoked by the familiar and unfamiliar stimuli on the first day and the correlation between the waveforms evoked by the familiar and unfamiliar stimuli on the second day.

Dissimilar: The first part of the formula is the sum of the z-scores of the correlation between the waveforms evoked by the familiar stimuli on the first day and the unfamiliar stimuli on the second, and the correlation between the waveforms evoked by the familiar stimuli on the second day and the unfamiliar stimuli on the first day.

Table C-2. Zetas Averaged

Type of Zeta	Category	Subjects*									Zetas Averaged
Similar	Single-Digit	-131	-711	-245	-573	-143	006	-126	-138	-784	-.3165
	Three-Letter	-174	-776	-321	-264	-101	-113	-188	139	-358	-.2399
	Trademark	-297	-668	-203	-436	-257	078	-164	-461	-088	-.2777
Day	Single-Digit	531	1399	164	1137	418	447	208	179	1616	.6779
	Three-Letter	465	1391	593	639	442	330	207	008	223	.4834
	Trademark	649	1392	343	890	665	-032	475	988	338	.6344
Dissimilar	Single-Digit	-399	-688	081	-563	-275	-453	-082	-040	-831	-.3614
	Three-Letter	-290	-615	-271	-425	-340	-216	-018	-147	135	-.2435
	Trademark	-351	-723	-139	-453	-408	-045	-311	-527	-250	-.3567

* Zetas given for each subject under the categories and types are for the short record only (ie., zetas were computed on the basis of 40 points, equally-spaced during the first 400 msec after stimulus onset).

The decimal point has been deleted from the data appearing in the body of the table.

APPENDIX D

RANKINGS OF CORRELATIONS

Table D-1. Analyses of Ranks of Correlations

Common Element of Correlations	Source**	df	MS	Error*	F	Level of Significance
Familiar Waveform Correlated with Others in its Block	R	4	48.30	1.58	30.4135	.001
	RC	8	1.36	1.58	0.8569	NS
	RD	4	1.73	1.22	1.4135	NS
	RCD	8	0.50	1.22	0.4157	NS
Unfamiliar Waveform Correlated with Others in its Block	R	4	41.29	1.93	21.3908	.001
	RC	8	2.19	1.99	1.1390	NS
	RD	4	1.01	1.04	0.9717	NS
	RCD	8	1.39	1.04	1.3295	NS
Blank Waveform Correlated with Others in its Block	R	4	20.33	2.15	9.4408	.001
	RC	8	0.93	2.15	0.4321	NS
	RD	4	0.925	1.68	0.5509	NS
	RCD	8	0.578	1.68	0.3443	NS

* Error sources: (1) For the Error Terms for R and RC in the three analyses, CS, FS, and FCS.
(2) For the Error Terms for RD and RCD in the three analyses, DS, FDS, CDS, and FCDS.

** Source: rank values of correlations (R); category of complexity (C); day (D).

Table D-2. Averages of Ranks of Correlations

*

Correlations are between waveforms evoked by familiar (f), unfamiliar (uf), and blank (b) stimuli on the same (s) or different (d) day from that on which the waveform designated in the left column was evoked. In each block, the correlations between the waveform indicated on the left and the five on the right were ranked in descending order (i. e., 1 = strongest correlation, 5 = weakest). The ranks of the different types of correlations were averaged across subjects, days, and categories to yield the "average of ranks of correlations" entered for each particular type of correlation under the heading "General." The ranks of the different types of correlations were averaged across subjects and days, but not across categories to yield the means entered under the heading "Category."

Table D-2 Averages of Ranks of Correlations*

Effects		General	Category			Day		Category by Day					
Correl. Between			C_1	C_2	C_3	D_1	D_2	$D_1 C_1$	$D_1 C_2$	$D_1 C_3$	$D_2 C_1$	$D_2 C_2$	$D_2 C_3$
f_s	uf_s	1.42	1.38	1.72	1.16	1.59	1.25	1.66	1.77	1.33	1.11	1.66	1.00
	b_s	3.00	2.88	3.05	3.05	3.11	2.88	3.00	3.33	3.00	2.77	2.77	3.11
	f_d	3.57	3.83	3.55	3.22	3.55	3.51	3.88	3.44	3.33	3.77	3.66	3.11
	uf_d	3.14	3.16	2.94	3.33	2.85	3.44	2.88	2.77	2.88	3.44	3.11	3.77
	b_d	3.88	3.72	3.72	4.22	3.88	3.88	3.55	3.66	4.44	3.88	3.77	4.00
uf_s	f_s	1.68	1.72	2.00	1.33	1.63	1.74	1.66	1.88	1.33	1.77	2.11	1.33
	b_s	2.75	2.50	2.66	3.11	2.96	2.55	3.00	3.00	2.88	2.00	2.33	3.33
	f_d	3.481	3.88	3.38	3.16	3.55	3.40	3.77	3.33	3.55	4.00	3.44	2.77
	uf_d	3.05	3.22	2.83	3.11	2.92	3.18	3.11	2.88	2.77	3.33	2.77	3.44
	b_d	4.01	3.66	4.11	4.27	3.92	4.11	3.44	3.88	4.44	3.88	4.33	4.11
b_s	f_s	2.51	2.44	2.50	2.61	2.59	2.44	2.55	2.55	2.66	2.33	2.44	2.55
	uf_s	2.33	2.27	2.16	2.55	2.51	2.14	2.55	2.33	2.66	2.00	2.00	2.44
	f_d	3.74	3.66	3.72	3.83	3.66	3.81	3.55	3.66	3.77	3.77	3.77	3.88
	uf_d	3.51	3.38	3.66	3.50	3.48	3.55	3.44	3.77	3.22	3.33	3.55	3.77
	b_d	2.88	3.22	2.94	2.50	2.74	3.03	2.88	2.66	2.66	3.55	3.22	2.33

* An explanation of the arrangement of the Table is given on the facing page.

Table D-3. Ranks of Averages of Ranks of Correlations

*

The entries in this Table follow essentially the same format as that used in Table D-2. The averages entered in Table D-2 have been converted to rank scores, and the ranks have been entered in this Table.

The values entered in the columns labeled "Prob." express the probability of obtaining the recurrence of the same rank score as that given in the column labeled "Gen." the number of times it occurs in a particular segment of a row. The probabilities were computed by assuming that, were the assignment of rank values done at random, a particular value would be likely to occur on 1/5 entries.

The values entered in the rows labeled "Prob." express the probability of obtaining the recurrence of the same order of rank scores as that given in the column labeled "Gen." If the order were duplicated in its entirety, the likelihood of such an occurrence would be .01; were it duplicated in only three of the five positions, the probability was .08; were it duplicated in only two of the five positions, the probability was .26; etc.

Table D-3. Ranks of Averages of Ranks of Correlations*

Effects	Correl. Between	Gen.	Category C_1	C_2	C_3	Prob.	Day D_1	D_2	Prob.	Category by Day D_1C_1	D_1C_2	D_1C_3	D_1C_1	D_1C_2	D_1C_3	Prob.
f_s	uf_s	1	1	1	1	.008	1	1	.040	1	1	1	1	1	1	.001
	b_s	2	2	3	2		3	2		3	3	3	2	2	2½	.017
	f_d	4	5	4	3		4	4	.040	5	4	4	4	4	2½	.017
	uf_d	3	3	2	4		2	3		2	2	2	3	3	4	
	b_d	5	4	5	5		5	5	.040	4	5	5	5	5	5	.002
Prob.			.08	.08	.08		.08	.08		.63	.08	.08	.01	.01	.08	
uf_s	f_s	1	1	1	1	.008	1	1	.040	1	1	1	1	1	1	.001
	b_s	2	2	2	2½	.008	3	2		2	3	3	2	2	3	
	f_d	4	5	4	4		4	4	.040	5	4	4	5	4	2	
	uf_d	3	3	3	2½	.008	2	3		3	2	2	3	3	4	
	b_d	5	4	5	5		5	5	.040	4	5	5	4	5	5	.017
Prob.			.08	.01	.01		.08	.01		.08	.08	.08	.08	.01	.26	
b_s	f_s	2	2	2	3		2	2	.040	1½	2	2	2	2	3	.002
	uf_s	1	1	1	2		1	1	.040	1½	1	2	1	1	2	.017
	f_d	5	5	5	5	.008	5	5	.040	5	4	5	5	5	5	.002
	uf_d	4	4	4	4	.008	4	4	.040	4	5	4	3	4	4	.017
	b_d	3	3	3	1		3	3	.040	3	3	2	4	3	1	
Prob.			.01	.01	.26		.01	.01		.01	.08	.01	.08	.01	.26	

* An explanation of the arrangement of the Table is given on the facing page.

Table D-3. Continued

Effects Correl. Between		Gen.	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
f_s	uf_s	1	1	1	1	1	1	1	1	1	1
	b_s	2	4	2	$2\frac{1}{2}$	2	2	4	4	4	2
	f_s	4	5	5	4	$4\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{1}{2}$	3	2	4
	uf_d	3	3	4	$2\frac{1}{2}$	3	$3\frac{1}{2}$	$2\frac{1}{2}$	2	3	4
	b_d	5	2	3	5	$4\frac{1}{2}$	5	5	5	5	4
uf_s	f_s	1	1	1	1	1	1	1	1	1	1
	b_s	2	3	2	4	2	3	4	4	1	2
	f_d	4	4	5	$1\frac{1}{2}$	4	4	3	3	5	3
	uf_d	3	2	4	3	3	2	2	2	3	5
	b_d	5	5	3	5	5	5	5	5	4	4
b_s	f_s	2	5	$1\frac{1}{2}$	1	1	2	$3\frac{1}{2}$	2	4	2
	uf_s	1	$3\frac{1}{2}$	$1\frac{1}{2}$	2	2	1	2	1	1	3
	f_d	5	$3\frac{1}{2}$	$4\frac{1}{2}$	5	3	5	5	3	5	4
	uf_d	4	2	3	4	5	$3\frac{1}{2}$	$3\frac{1}{2}$	5	3	5
	b_d	3	1	$4\frac{1}{2}$	3	4	$3\frac{1}{2}$	1	4	2	1

REFERENCES

Berlyne, D. E., and McDonnell, P. Effects of stimulus complexity and incongruity on duration of EEG desynchronization. Electroencephalography and Clinical Neurophysiology, 1965, 18, 156-161.

Buchsbaum, M., and Fedio, P. Visual information and evoked responses from the left and right hemispheres. Electroencephalography and Clinical Neurophysiology, 1969, 26, 266-272.

Callaway, E., III, and Buchsbaum, M. Effects of cardiac and respiratory cycles on the averaged visual evoked response. Electroencephalography and Clinical Neurophysiology, 1965, 19, 476-480.

Cantor, G. N., and Cantor, J. H. Discriminative reaction time in children in relation to amount of stimulus familiarization. Journal of Experimental Child Psychology, 1966, 4, 150-157.

Cantor, G. N., and Fenson, L. New data regarding the relationship of amount of familiarization to the stimulus familiarization effect. Journal of Experimental Child Psychology, 1968, 6, 167-173.

Chapman, R. M., and Bragdon, H. R. Evoked responses to numerical and non-numerical visual stimuli while problem solving. Nature, 1964, 203, 1155-1157.

Cohen, J., and Walter, W. G. The interaction of responses in the brain to semantic stimuli. Psychophysiology, 1966, 2, 187-196.

Harter, M. R., and White, C. T. Effects of contour sharpness and checkerboard size on visually evoked cortical potentials. Vision Research, 1968, 8, 701-711.

Hodges, Jr., J. L., and Lehmann, E. L. Elements of Finite Probability. San Francisco: Holden-Day, Inc., 1965.

John, E. R., Herrington, R. N., and Sutton, S. Effects of visual form on the evoked response. Science, 1967, 155, 1439-1442.

Johnston, J. B., Price, G. B., and Van Vleck, F. S. Sets, functions, and probability. Reading, Mass.: Addison-Wesley Publishing Co., 1968.

Kemeny, J. G., Snell, J. L., and Thompson, G. L. Introduction to Finite Math. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1957.

Kopell, B. S., Wittner, W. K., and Warrick, G. L. The effects of stimulus differences, light intensity, and selective attention on the amplitude of the visual averaged evoked potential in man. Electroencephalography and Clinical Neurophysiology, 1969, 26, 619-622.

Larsson, L-E. Correlation between the psychological significance of stimuli and the magnitudes of the startle blink and evoked EEG potentials in man. Acta Physiologica Scandinavica, 1960, 48, 276-294.

Lifshitz, K. The averaged evoked cortical response to complex visual stimuli. Psychophysiology, 1966, 3, 55-68.

Martin, J. I. Effects of binocular fusion and binocular rivalry on cortically evoked potentials. Electroencephalography and Clinical Neurophysiology, 1970, 28, 190-201.

Shipley, T., Jones, R. W., and Fry, A. Evoked visual potentials and human color vision. Science, 1965, 150, 1162-1164.

Spehlmann, R. Occipital evoked response to diffuse and patterned light in the human. Federation Proceedings, 1963, 22, 577.

Spehlmann, R. The averaged electrical responses to diffuse and to patterned light in the human. Electroencephalography and Clinical Neurophysiology, 1965, 19, 560-569.

Sutton, S., Tueting, P., and Zubin, J. Information delivery and the sensory evoked potential. Science, 1967, 155, 1436-1439.

Thorndike, E. L., and Lorge, I. The teacher's wordbook of 3,000 words New York: Columbia Bureau of Publishing, 1944.

Weinberg, H., and Cole, R. E. Averaged evoked potentials to classes of visual stimuli. Psychonomic Science, 1968, 11, 71-72.

Weldon, R. J., and Humphrey, A. B. A flexible computer program for the analysis of variance: Instructions for ANOVA 45. Unpublished manuscript, The University of Arizona, 1970.

White, C. T. Evoked cortical responses and patterned stimuli. American Psychologist, 1969, 24, 211-214.