

# CORTICAL EVOKED POTENTIALS TO SEMANTIC STIMULI

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## ABSTRACT

The influence of affective meaning on the photically evoked response was studied in male college students. Three sets of stimuli were used: taboo words, neutral words, and blank flashes. Two blocks of trials were run for each stimulus, one in which the *S* responded by calling the stimulus presented, and a second in which the *S* was not required to respond.

The late components of the evoked potential were significantly related to both the stimulus and response conditions. Amplitude 2 was larger for the taboo words than for either the neutral words or the blank flash. The taboo words had a significantly greater amplitude 3 than neutral words, and both sets of words had higher amplitude 3 than the blank flash. The stimulus effect was discussed in terms of the possible influence of anatomical structures involved in emotional behavior on the visual evoked response. The response effect was felt to be the result of the increased attention required under the response condition.

**DESCRIPTORS:** Visual evoked potentials, Semantic stimuli, Meaning, Affect.  
(H. Begleiter)

The relation between brain evoked potentials and perceptual processes is perhaps one of the most challenging problems facing psychophysiologicalists today. Over the last few years a number of investigators have attempted to find functional relations between physical characteristics of stimuli and changes in evoked potentials. More recently it has become increasingly evident that evoked potentials also reflect subtle differences in stimulus "meaning" which are independent of the external physical characteristics of the stimulus.

John, Herrington, and Sutton (1967) sought to study the relationship between the meaning or information content of a stimulus and the evoked potential. The authors were able to demonstrate that the waveform of the response evoked by a blank visual field is altered by the presence of a geometric form in the field and that different geometric forms of equal area elicit different responses. Furthermore, their findings indicate that identical geometric shapes of different area elicit similar responses, and that different words (e.g. "circle," "square") equated for printed letter area elicit different responses. This experiment suggests that the waveshape of the averaged evoked response is greatly influenced by the in-

We would like to thank Dr. Benjamin Kissin for providing the facilities for carrying out this research and Mr. William Panepinto for helping on the statistical analyses.

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formational significance of the stimulus, and shows that it is not solely determined by physical characteristics of the stimulus.

Recent studies from our laboratory have demonstrated the influence of stimulus meaning on evoked potentials. Begleiter, Gross, and Kissin (1967) studied the influence of affective meaning on visual evoked potentials. By means of a conditioning procedure, previously meaningless figures (CS) were conditioned to a positive, negative, or neutral affective response (CR). Amplitudes of the evoked potentials were found to differ significantly across the three affective conditions, with the unpleasant stimulus eliciting the lowest evoked response and the neutral the highest. Significantly shorter latencies were obtained to the unpleasant stimulus, whereas the latencies to the positive and neutral stimuli did not differ significantly from each other.

A subsequent study (Begleiter, Gross, Porjesz, & Kissin, 1969) showed this effect was dependent on the degree to which the *S* was aware of the CS-US contingency. In one experiment the *Ss* were informed that a CS-US connection existed; however, the nature of the relationship was not divulged. In the last experiment the *Ss* were explicitly informed of the correct CS-US contingency and of the entire conditioning paradigm. The data suggest that the level of awareness of the CS-US contingency might be reflected in the amplitudes of the evoked potentials to the CSs.

Lifshitz (1966) attempted to find evoked potential correlates of neutral and affectively loaded pictures and words. In one study, the stimuli were projected images of typed four and five letter taboo words and the same letters randomly scrambled. The words were white on a black background and displayed variably from one to two seconds. The author reports that semantic stimuli did not consistently produce differences in the evoked potential which he had found earlier with pictorial stimuli.

The averaged evoked responses of man to simple stimuli have been shown to vary with the state of personal involvement with the stimuli. Larsson (1960) demonstrated evoked response changes when a somatosensory stimulus was given importance by requiring a response from the *S*, and Davis (1964) demonstrated the same for auditory stimuli.

The present study sought to investigate further the influence of affectively loaded semantic stimuli on cortical evoked potentials, and the effects of the *S*'s involvement with the stimuli.

## METHOD

### *Subjects*

Eighteen male college students served as *Ss*. The active monopolar lead was an electrode placed at O<sub>2</sub> (2.5 cm above the inion and 2.5 cm to the right of the midline, according to the 10-20 International System). The combination of the two ear lobes formed the reference electrode. The electrodes were silver (Ag) cup electrodes, secured to the scalp with collodion. Resistances were kept below 5000 ohms.

### Apparatus

The *Ss* were seated in an acoustic enclosure (Industrial Acoustics Co., No. 1203A), looking directly into a viewing hood which was flush against the one-way vision mirror of the enclosure. On the other side of the glass window, a Grass PS-2 photo stimulator was mounted; it was located 50 cm from the *S*'s eyes and set at an intensity of 8. These precautions were taken in order to make the click of the photo stimulator inaudible to the *S*. While in the acoustic enclosure, the *S* could communicate with the *E* through a two-way communication system. The *S* was observable at all times through the one-way vision mirror.

The electroencephalographic (EEG) data were recorded by means of a Grass Model 7 P5A wide band AC EEG amplifier, whose low frequency cut-off filter was set at .15 cps. The driver amplifier high frequency cut-off filter was set at 75 cps, and the gain was set at 50.

Computation of the averaged evoked potentials was done with the Mnemotron Computer of Average Transients (CAT 1000) with a 1024 msec epoch. The evoked potentials were written out on a Moseley (Model 7590 CMR) XY plotter.

The explicit criteria for the measurement of the characteristics of the visual evoked response have previously been described (Begleiter et al., 1967). Amplitude A is measured as the perpendicular distance between latency 1 and latency 2. Amplitude B is the perpendicular distance between latency 2 and 3, and amplitude C the distance between 3 and 4, as illustrated in Figure 1.

The stimuli were black words mounted on a transparent background. Each letter was 2½ inches high and one-half inch thick. Two sets of stimuli were used—each set containing a taboo word, a neutral word, and a blank field. Within each set all stimuli were presented randomly for a total of 20 presentations

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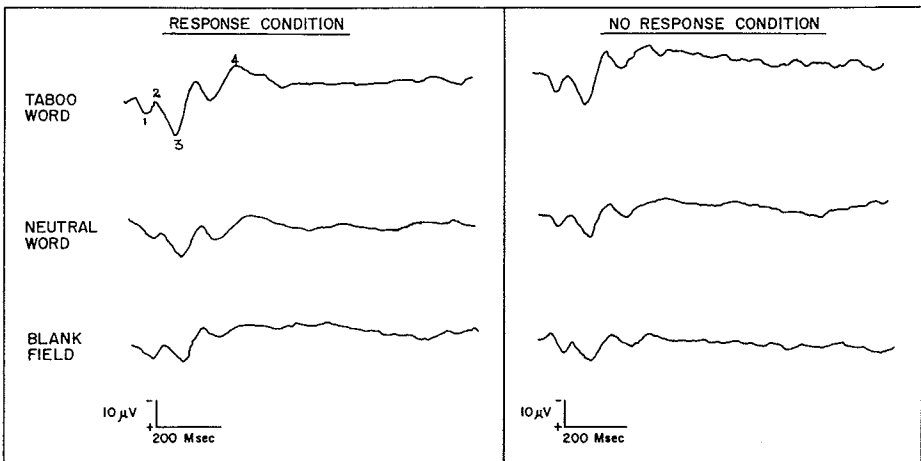


FIG. 1. Individual recording illustrating the cortical evoked response under the different stimulus and response conditions. Amplitudes B and C were significantly greater to the taboo words, and greater under the response conditions than under the no response condition. (Upward deflections are negative.)

per stimulus. The two sets of stimuli were counterbalanced across subjects. The words used were "shit" and "fuck" for the taboo condition, and "tile" and "page" for the neutral condition. All words were printed with capital letters, and equated for total area.

In contrast to Lifshitz's (1966) procedure the duration of exposure of all our stimuli was quite short, namely, 10 microseconds. This short duration ensured that a transient response occurred in the visual pathways. A transient response was chosen because the techniques of analysis of neuroelectric phenomena are considerably more advanced at present than for changes in steady state. All stimuli were always above recognition threshold and were presented with a random interstimulus interval from 2 to 4 seconds.

In order to study the effects of the *S*'s involvement with the stimuli, two additional conditions were investigated. In one condition the *S* was just asked to view all stimuli without responding. In the other condition the *S* was asked to call the word presented, and to say "flash" whenever the blank field was presented. Ertl and Schafer (1967) have reported that reliable non-random changes in the EEG of human *S*s may be detected preceding speech. In order to control for a possible contamination due to the verbal response, the *S* was asked to respond only after a buzz as signal, which was presented immediately after the 1024 msec epoch subsequent to the stimulus. The summated EEG waveform preceding onset of the spoken word is only observed in the first 200 msec.

Both conditions—response and no-response—were counterbalanced across *S*s.

## RESULTS

The mean values of the three amplitude and four latency measures of the cortical evoked response for the two experimental conditions are presented in Tables 1 and 2. The respective analyses of variance are summarized in Tables 3 and 4.

Amplitude A was related neither to the stimulus presented (neutral word, taboo word, or blank flash) nor the response condition (repeating aloud vs. not repeating the stimulus). However, amplitudes B and C were significantly related to both the stimulus and response conditions. The stimulus effect on amplitude B was significant beyond the .05 level with 2 and 34 degrees of freedom. Subsequent *t* tests between individual pairs of stimuli (Lindquist, 1953) indicate that amplitude B was significantly greater for the taboo words than for the

TABLE 1

*Mean amplitudes of the cortical evoked response to taboo and neutral words and blank flash\**

Stimuli	Response Condition			No Response Condition		
	A	B	C	A	B	C
Taboo	6.00	14.90	25.71	6.59	13.04	22.90
Neutral	5.54	12.31	19.95	5.36	11.32	18.02
Flash	6.61	10.75	17.79	6.61	10.41	15.54

\* Mean values for amplitudes are expressed in microvolts.

TABLE 2

*Mean latencies of the cortical evoked response to taboo and neutral words and blank flash\**

Stimuli	Response Condition				No Response Condition			
	1	2	3	4	1	2	3	4
Taboo	62.0	95.5	169.7	350.8	63.4	97.8	157.1	337.6
Neutral	61.9	94.7	157.9	351.4	61.0	97.1	161.8	342.2
Flash	57.4	94.4	159.9	385.8	60.3	97.4	162.8	369.1

\* Mean latencies expressed in milliseconds.

TABLE 3

*Summary of analyses of variance in amplitude scores\**

Source	A	B	C
Stimulus Effect	—	.05	.001
Response Effect	—	.05	.01
Interaction	—	—	—

\* The analyses of variance in tables 3 and 4 were computed as follows: stimulus (3)  $\times$  response conditions (2)  $\times$  subjects (18), with a total N of 108. *P* values are given for significant *F*'s; non-significant differences are indicated by a dash.

TABLE 4

*Summary of analyses of variance in latency scores\**

Source	Latency			
	1	2	3	4
Stimulus Effect	—	—	—	.001
Response Effect	—	.05	—	—
Interaction	—	—	—	—

\* Significance level of obtained *F*'s. Dash indicates non-significant differences.

neutral words ( $p < .01$  with 34 df) and the flash ( $p < .02$  with 34 df). The neutral words and flash were not significantly different. The response effect was also significant at the .05 level, with the greater amplitude occurring under the "repeat aloud" condition. The interaction between the stimulus and response conditions was not significant.

Similar effects were noted on amplitude C. The overall difference between stimuli was significant at the .001 level with 2 and 34 df. Again the amplitude of the evoked potential to the taboo words was significantly greater than to the neutral words ( $p < .01$  with 34 df) and to the blank flash ( $p < .01$ ). The neutral word-flash difference was also significant at the .01 level. The interaction between the stimulus and response conditions was not significant.

Inspection of Figures 2 and 3 illustrates the consistency of the experimental effects on the later components of the waveform. Under both response conditions

the taboo words elicit the largest response and the blank flash, the smallest response. Calling aloud the stimulus increases the amplitude of the cortical evoked potential to each kind of stimulus, but not differentially. No evidence of an interaction effect was found.

The mean latencies for the stimulus and response conditions are shown in Table 2. With two exceptions, none of the latencies of the evoked response was related to the experimental conditions. The exceptions are latency 2, which was significantly shorter for the response condition ( $p < .05$  with 1 and 17 df), and latency 4 which was related to the nature of the stimulus ( $p < .001$  with 1 and 17 df). In the latter, latency 4 of the cortical response to both the neutral and the taboo words was significantly shorter than to the flash ( $p < .001$  with 34 df). The duration of the response to the taboo and neutral words was not significantly different. None of the interactions between stimulus and response conditions was significant.

### DISCUSSION

The results of the present study corroborate earlier studies showing that the affective meaning of a stimulus as well as the response required of the subject affect the amplitude of the later components of the cortical evoked response. No effect was found on the first negative amplitude, nor were there any consistent

MEAN AMPLITUDE OF VISUAL EVOKED POTENTIALS  
OBTAINED UNDER THE NO-RESPONSE CONDITION

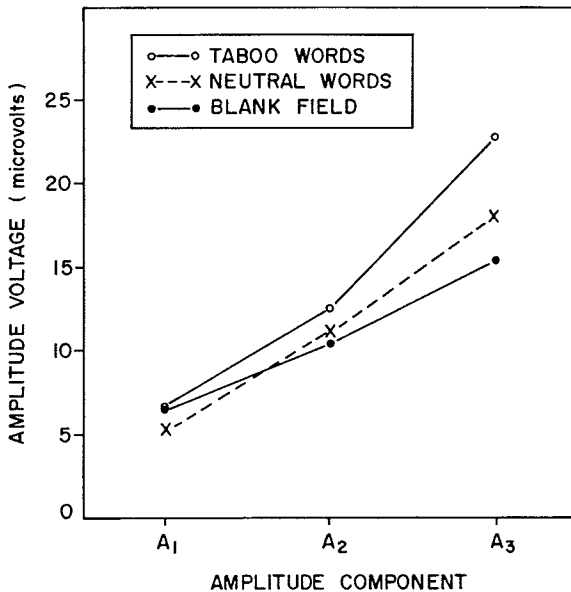


FIG. 2. Comparison of the mean amplitudes of the cortical evoked response to the neutral and taboo words and blank flash under the no response condition. Amplitude B is significantly greater to the taboo word than to either the neutral word or flash. Amplitude C is significantly greater to the taboo word than to the neutral word, and the response to both words is greater than to the blank flash.

differences in the latencies of the major amplitudes. In the further analysis of the stimulus effect, it was found that the neutral and taboo words not only differ from each other on amplitudes B and C, but also that both types of words elicit a larger response than the blank flash. (The neutral word-flash difference was significant only for C.) The difference between the neutral and taboo words parallels the findings reported by Begleiter, Gross, and Kissin (1967) and Begleiter, Gross, Porjesz, and Kissin (1969) showing that the same physical stimulus may elicit markedly different cortical evoked responses depending upon whether it had been previously associated with a positive, negative, or neutral affective state by means of a semantic conditioning procedure. Although they report that the emotional significance of the physical stimulus affected all latencies and amplitudes, the effect was most marked on the later amplitudes.

The word-flash difference is most probably related to physical differences in the stimuli rather than to differences in semantic meaning per se. Diffuse light as compared to patterned light (Spehlmann, 1965), focused versus unfocused slides (Lifshitz, 1966), the homogeneous light of a ganzfeld versus a structured field (White & Eason, 1966), and a blank field versus an arithmetic symbol (Chapman & Bragdon, 1964) all produce a marked attenuation of the response between 200 to 350 msec. In the present study amplitude C was significantly larger to both the neutral and taboo words than to the flash. Amplitude B was significantly smaller to the blank flash only in comparison with the taboo word. Although Spehlmann (1965) has argued for a physical interpretation of the effects

#### MEAN AMPLITUDE OF VISUAL EVOKED POTENTIALS OBTAINED UNDER THE RESPONSE CONDITION

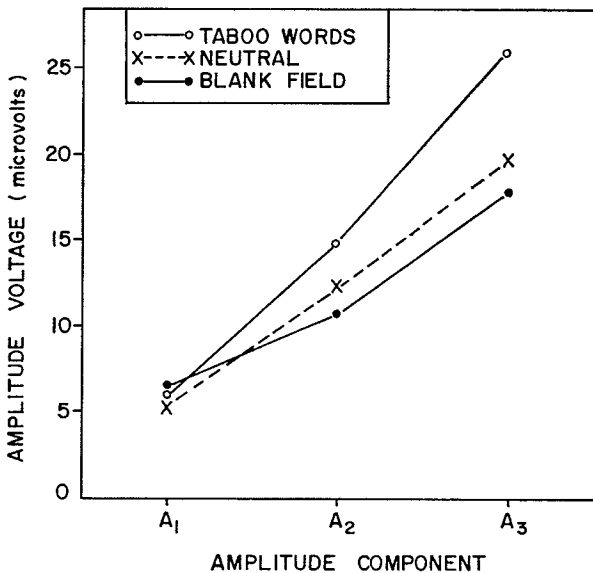


FIG. 3. Comparison of the mean amplitudes of the cortical evoked response to the words and flash under the response condition. Amplitudes B and C were significantly greater under the response condition than under the no response condition.

of patterned light, relating it specifically to activity in the visual pathways and most notably to excitation in the lateral geniculate which is maximal from 50 to 100 msec after stimulus onset, an equally plausible interpretation of the longer latency and heightened amplitude of the later response might be in terms of greater cortical and subcortical involvement and the longer processing time necessary for more complex visual stimuli.

The response effect on amplitudes B and C probably reflects a heightened state of attention or involvement due to the response requirement of the word recognition procedure used. These findings appear generally consistent with earlier studies by Chapman and Bragdon (1964) and Satterfield (1965) reporting larger evoked potentials to task relevant stimuli requiring some response from the subject than to task irrelevant stimuli. The possible emotional affect or arousal induced by having to say aloud taboo words may have added to the response effect.

The effect of attention on the visual evoked response seems clearly to be of central origin since controlling pupillary size either chemically (Chapman & Bragdon, 1964) or by means of an artificial pupil (Eason, Aiken, White, & Lichtenstein, 1964) does not appreciably alter the effect. Also, there is evidence indicating that the visual evoked response and peripheral sensory response mechanisms may vary independently of each other (Kooi & Bagchi, 1964). Chapman and Bragdon (1964) report a heightened cortical response to relevant number stimuli as compared to blank flashes even though there were no differences between the stimuli on electroretinogram recordings or differences in eye movement recordings.

The overall spatial and temporal stability of the visual evoked response taken in conjunction with the smaller, localized changes produced by the experimental manipulation of the stimulus or the *S*'s motivational state suggests that specific characteristics of the waveform may reflect different stages in the brain's processing of sensory input (Kooi & Bagchi, 1964). White and Eason (1966) distinguish three major components of the waveform: a "primary response" occurring during the first 80 msec after stimulus onset; a "secondary response" lasting from 80-300 msec; and an oscillatory after discharge commencing around 300 msec, which marks the end of the specific response to the sensory input. The earliest cortical response occurs in the primary projection area and is closely followed by activity in the surrounding functionally related cortical areas (Kooi & Bagchi, 1964). This response reflects the transmission of information into the nervous system by direct pathway from the receptor through the specific thalamic relays to the relevant sensory projection area of the cortex. Psychologically, the neural event appears to be related to the simple reception and identification of sensory modality, but is not in itself sufficient for either the conscious perception or storage of the sensory event (Brazier, 1964).

The later events of the cortical response are more diffuse and likely to consist of synchronous firing over wider areas of the cortex (Kooi & Bagchi, 1964). The time course suggests that the secondary response may reflect sensory input via indirect pathways through the brainstem reticular formation to cortical areas other than specific sensory projection areas. Psychologically, the later components



are responsive in some degree to the general arousal or activation level of the S and are necessary for the conscious perception and storage of sensory input.

The attempt to identify the primary response of the waveform with the simple transmission and reception of the physical stimulus, and the secondary response to the cortical processing corresponding to the conscious perception and attribution of meaning to the stimulus appears reasonably consistent with psychological data. A number of investigators have reported that the early component of the cortical evoked response is most sensitive to changes in stimulus intensity (Vaughan & Hull, 1965; White & Eason, 1966). The secondary response is susceptible to a number of experimental influences. Most important are perhaps those related to the conscious awareness of the physical stimulus as indicated in recordings of evoked potentials under anesthesia (Brazier, 1964); cortical surface recordings to supraliminal versus subliminal stimuli (Libet, Alberts, Wright, & Feinstein, 1967); or to a signal followed by a masking stimulus (Lindsley & Emmons, 1958). Haider, Spong, and Lindsley (1964) report that in a vigilance task the later components of the cortical evoked response to "missed" signals were considerably decreased in comparison to the response to detected signals. Libet et al. (1967) note that while the passage from supra to sub threshold stimulation diminishes the initial positive and negative peaks, the later components are completely eliminated. Finally, Lindsley and Emmons (1958) report that a masking stimulus presented within 50 msec of a signal blocks both the later amplitudes of the evoked response as well as the conscious perception and storage of the signal, without affecting the early stages of the cortical response. The later components, thus, appear to be related to both level of arousal and conscious experience. These findings are consistent with the view that input from the more indirect collateral pathways via the brain stem reticular formation is reflected in the secondary component of the evoked potential and performs an "alerting" function necessary for the conscious reception of sensory stimulation.

Manipulations which affect attention (e.g., stimulus variability, task relevance, response demands on the subject, etc.), while they may have an overall effect on all components of the waveform, have their greatest effect on the secondary component. Haider, Spong, and Lindsley (1964) showed both a momentary and a long term effect due to fluctuations of attention in a visual detection task. The major effects were on the latency and amplitude of the negative peak at approximately 160 msec. Long term habituation of a response has relatively little effect on the primary response but markedly dampens the later components (Brazier, 1964) and, in general, increases the similarity in evoked responses to different stimuli initially eliciting markedly different waveforms (John, Herrington, & Sutton, 1967). The latter finding reported by John et al. strongly suggests that differences in cognitive meaning (e.g., response to the word "square" vs. the word "circle") may be reflected in differences in the spatial characteristics of the later components. In conjunction with the present study these findings support the view that spatial and temporal characteristics of the later waveform may be determined by the meaning of the stimulus independently of its physical characteristics.

In summary these data support earlier findings indicating that internal or

subjective states of the perceiver affect primarily the later components of the evoked response. To date most studies have attempted to demonstrate the effects of manipulating the subject's attention or level of arousal on the cortical evoked response. More recently, several researchers have studied the effects of symbolic and affective meaning in altering the late component of the evoked potential. This procedure would appear to hold promise in the investigation of electrophysiological correlates of information processing.

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