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VISUAL EVOKED POTENTIALS AND AFFECTIVE RATINGS OF SEMANTIC STIMULI

H. Begleiter, B. Porjesz, and R. Garozzo

State University of New York
Downstate Medical Center
Brooklyn, New York

In the last decade it has become quite evident that event-related brain potentials not only reflect changes in the physical parameters of a stimulus but are also quite sensitive to psychological variables. The relationship between event-related brain potentials and concomitant ongoing cognitive processing has been the subject of numerous investigations which have been thoroughly reviewed (Regan, 1972; Beck, 1975; Callaway, 1975; Thatcher and John, 1977).

A number of investigators have studied the question of whether the processing of specific informational content of a stimulus is reflected in the morphological characteristics of the evoked brain potential. Lifshitz (1966) used groups of photographs intended to induce positive, neutral or negative affective states. Potentials evoked by the three classes of stimuli were found to be different in some subjects. Begleiter, Gross and Kissin (1967) studied the influence of affective meaning on visual evoked potentials, by means of a classical conditioning procedure. Previously meaningless figures (CS) were conditioned to elicit a positive, negative or neutral affective response (CR). Waveforms of the evoked potentials were found to differ significantly across the three effective conditions. These results have been replicated by Gliddon, Busk and Galbraith (1971). Using the same conditioning procedures previously used in our laboratory, Lenhardt (1973) reported results quite consistent with ours. In another approach, Shevrin (Shevrin and Fritzler (1968; Shevrin, Smith, and Fritzler, 1971) reported that stimuli presented subliminally with the use of a tachistoscope, resulted in significantly different evoked potentials.

In 1967, John, Herrington and Sutton reported that different words equated for the area covered by the printed letters elicited different evoked potential waveforms. Differences in evoked potentials, concomitant with differences in semantic meaning were also reported by Begleiter and Platz (1969). Changes in evoked potentials related to semantic stimuli have also been reported by a number of investigators (Buchsbaum and Fedio, 1969; Morrell and Salamy, 1971; Matsumiya, Tagliasco, Lombroso and Goodglass, 1972; Wood, Goff and Day, 1971; Neville, 1974; Ratliff and Greenberg, 1972; Thatcher, 1976; Friedman, Simson, Ritter and Rapin, 1975a; 1975b; Chapman, Bragdon, Chapman and McGrary, 1977).

In all of the aforementioned studies, the observed relationship between stimulus meaning and evoked potentials was not independent of changes in the physical structure of the stimuli. In order to establish robust relationships between stimulus content and neuroelectric events, it is critical to control for the effects of the physical structure of the stimuli (Schwartz, 1976). In recent years, some investigators have made use of a paradigm in which evoked potentials are recorded to identical stimuli under different conditions. This design makes it possible to vary the meaning of the stimulus by embedding it in different contexts, by using the same stimulus to deliver different kinds of information or by presenting the same stimulus under different psychological sets.

Jenness (1972) reported that identical stimuli conveying different informational contents result in significantly different evoked brain potentials. Brown, Marsh and Smith (1973; 1976) found that evoked potentials to the word "fire" differed when the word appeared in the phrases "sit by the fire" and "ready, aim, fire." When the word appeared in the initial position in the phrases "fire is hot" or "fire the gun" the evoked potentials to the word fire were not significantly different. The findings indicate that context-produced differences in the meaning of a word produced significant differences in evoked potential waveform. A related experiment was conducted by Teyler, Roemer, Harrison and Thompson (1973). The authors instructed the subjects to think about one or the other of two meanings of ambiguous words during the presentation of click stimuli. The results of this experiment indicated that thinking about the noun and verb meanings of the ambiguous words produced differential waveforms to the click stimuli.

The technique for classification of evoked potentials according to the subjective interpretation of the stimulus has been utilized in experiments using other than semantic stimuli. Spunda, Radil-Weiss, and Radilova (1975) used a necker cube as a pattern stimulus. They reported different evoked potentials to the same stimulus depending on the subjective perception of the stimulus. A recent study by Johnston and Chesney (1974) illustrates the use of context-sensitive symbols as an elegant approach for investigating the representation of meaning in the brain. Evoked potentials to the same symbol were recorded in two different contexts. In one, the symbol was embedded in the temporal context of numbers, in the other it appeared in the temporal context of letters. Their findings indicate that the frontal evoked potentials reflect the change of meaning of a symbolic stimulus when it appears in different temporal contexts. More recently, Begleiter and Porjesz (1975) studied evoked potentials to physically identical stimuli in trials resulting in different behavioral decisions. The authors report that when a subject is presented with a stimulus of medium intensity and decides that it is "bright," the evoked potential to that stimulus is quite different from the evoked potential elicited by an identical stimulus that he decides is "dim." Significantly different evoked potentials to the same physical stimulus were obtained in trials that resulted in different behavioral decisions.

Taken together these studies strongly support the notion that when the physical characteristics of the stimulus are held constant, it is quite possible to obtain differences in evoked potential which are attributable to the context of the stimulus and to its subjective informational content.

We now report a study in which evoked potentials to the same semantic stimuli were recorded under two different task conditions. In one condition the subjects are attending to the structural content of the words by identifying certain letters. In the second condition, the subjects are attending to the connotative content of the words, and the individual letters are less important.

METHODS

Ten, right-handed males with a mean age of 23 volunteered to participate in the experiment. Gold electrodes (Grass instrument) were attached with collodion at F3, F4, C3, C4 P3 and P4 in accordance with the 10-20 electrode system of the International Federation (Jasper, 1958). All recordings were referential to linked ears with differential ear resistance maintained below 500 ohms and electrode resistance kept below 4000 ohms; an electrode placed on the nasion served as subject ground. The frequency bandpass of the recording system (Grass polygraph, Model 78B) was set between 0.1 to 100 Hz. Eye movements were continuously monitored with EOG averages using the same gain frequency response.

In order to cull a sizeable number of appropriate words for this experiment, we asked 245 medical students to rate 439 five-letter words on a seven point semantic differential scale going from pleasant to unpleasant. From the ratings, we chose the 62 most positive words, the 62 most neutral words and the 62 most negative words, thus obtaining a total of 186 words which were used as visual stimuli in our study.

A computer-controlled CRT display system (Tektronix #635) presented the words individually to a dark-adapted subject seated in a darkened, sound-treated chamber (IAC enclosure). All words were randomly presented foveally, as briefly flashed stimuli subtending a visual angle 11.8° with a duration of 20 ms. The interstimulus interval (ISI) was randomized between 3.5 to 6 seconds. During that interval a fixation target was present in the form of a dimly illuminated dot on the CRT. Stimulus presentation and data collection were achieved on line with the use of a PDP 11-40 computer. Individual evoked potentials were digitized for 50 msec. prior to stimulus presentation and for 450 msec. post-stimulus presentation.

Each subject participated in two experimental runs. In the Letter Identification run (LI) the subject was told to actively attend to a series of words (N=186); each time a word was presented he was asked to press one of five buttons to indicate the position of the last vowel in that word. In the middle of the run the position of the five buttons was switched. In the Affective Rating run (AR) each subject was requested to press one of the buttons to indicate his personal rating of the affective loading imparted by each word. Button 1 indicated a positive loading, Button 2 slightly positive, Button 3 neutral, Button 4 slightly negative and Button 5 indicated a negative loading. For half of the Ss this order was reversed. All subjects were asked to use both hands to press the buttons and were not instructed to press the buttons as quickly as possible. In the middle of each run, the amplifiers and A/D converters used to record from each hemisphere were reversed in order to correct for amplifier or A/D converter bias.

At the end of the experiment, all individual evoked potentials were retrieved and averaged in accordance with the various behavioral response conditions, as follows:
Composite 1: Evoked potentials in the LI run were averaged for each response condition (button press to indicate the position of the last vowel). There were five possible button-pressing responses.
Composite 2: Evoked potentials in the AR run were also averaged for each response condition (button press indicating affective loading) separately, yielding 5 averaged evoked potentials.
Composite 3: Evoked potentials to all stimuli in LI run were also averaged in accordance with their respective responses in the AR run. Condition 3 enabled us to compare the evoked potential to a word when the subject was rating its affective loading, to the evoked potential to the very same word when the subject responded by indicating the position of the last vowel.

In this paper we will only report our findings recorded at P3 and P4. Evoked potential recordings are illustrated in Figure 1 and are reported here in terms of peak-to-peak amplitudes and

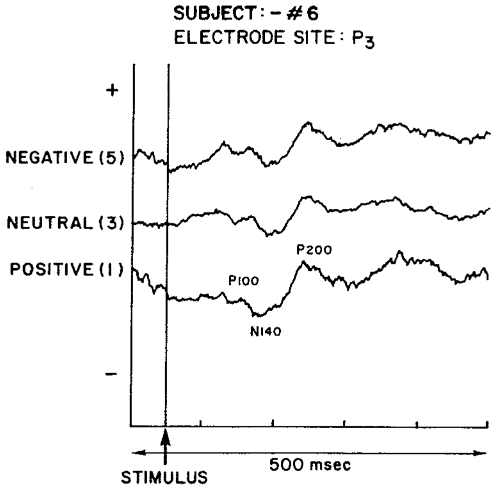

FIGURE 1
Visual evoked potentials obtained from left parietal of a subject. The three traces represent the averaged evoked potentials in composite 2 when the subject was pressing one of five buttons to indicate his affective ratings of semantic stimuli. The top trace represents the average evoked potentials to stimuli rated negative, the middle trace is evoked by stimuli rated neutral and the bottom trace is obtained to stimuli rated positive.

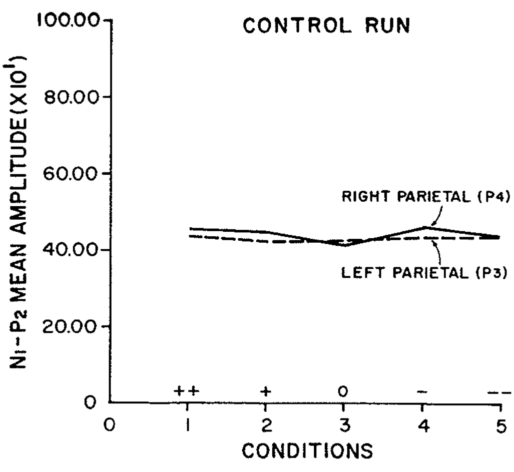

FIGURE 2
N1-P2 amplitude of evoked potentials recorded at left and right parietal electrodes. The evoked potentials were obtained in the LI run when the subject was pressing a button to indicate the position of the last vowel. (composite 1)

latencies. Preliminary statistical analyses were accomplished with the use of analyses of variance for 2 factors with repeated measurements, performed on all individual amplitudes and latencies (Winer, 1962).

RESULTS

We performed a number of analyses of variance on the peak-to-peak amplitudes (P1-N1, N1-P2, P2-N2, N2-P3) and latencies (P1, N1, P2, N2, P3) for electrodes at the right parietal (P4) and left parietal (P3) electrodes. The means of the five averaged evoked potentials obtained in Composite 1 (searching for the position of the last vowel) were subjected to an alalysis of variance. The F ratios for all amplitudes and latencies of evoked potentials obtained at both electrode sites were not significant. The identical statistical analyses was performed on the five averaged evoked potentials derived in Composite 3. These are evoked potentials to identical semantic stimuli in the LI run averaged in accordance with their respective affect rating in the AR run. F ratios for all amplitudes and latencies at both parietal leads were not significant (Figure 2).

An analysis of variance was also performed to compare the five averaged evoked potentials obtained in Composite 2. These are evoked potentials to semantic stimuli presented in the affective rating run (AR). The only statistically significant differences ($P<.01$) were obtained for the N1-P2 amplitude (140-200 msec) at the right (P4) and left parietal (P3). Individual comparisons of all possible pairs of evoked potential means (N1-P2 component) obtained during the affective rating runs (AR) are summarized in Table 1 for the right parietal and summarized in Table 2 for the left parietal.

Finally, we compared the five averaged evoked potentials obtained in the AR run, when the subject was rating the affective loading of each word, to the averaged evoked potential to the identical words but when the subject performed the letter identification task (Composite 3). The analysis of variance yielded F ratios which indicated that there were no significant difference for latencies of evoked potential components obtained at both P3 and P4. The only statistically significant differences were obtained for the N1-P2 amplitude (140-200 msec.) at both P3 and P4. The analysis of variance performed on the N1-P2 component recorded at P3 yielded an F ratio of 21.46 significant at $p<.0001$ level (Figure 3). The analysis of variance performed on the N1-P2 component recorded at P4 yielded an F ratio of 4.36 significant at $p<.01$ level (Figure 4). Because we found significant differences in evoked potentials obtained to the identical words under the two different task conditions we proceeded to perform t tests for correlated means. The results are summarized in Table 3.

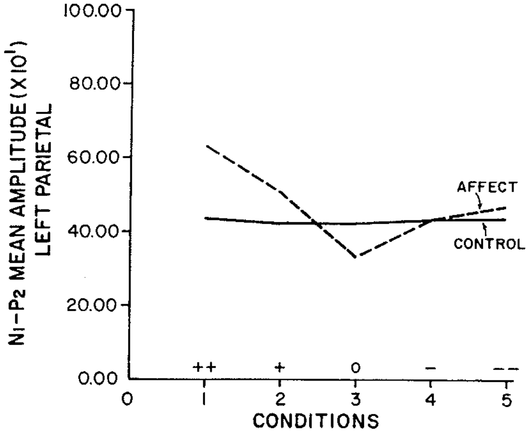

FIGURE 3
N1-P2 amplitude of averaged evoked potentials recorded at left parietal (P3). The solid line represents the five averaged evoked potentials obtained in the control condition (composite 3). The broken line represents the averaged evoked potentials obtained in the AR run when the subjects pressed one of five buttons to indicate the affective rating of each semantic stimulus.

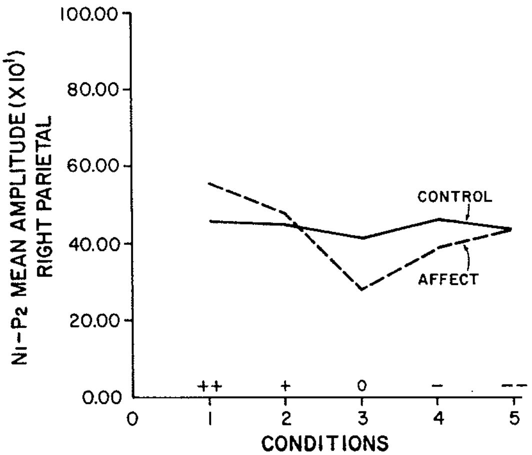

FIGURE 4
N1-P2 amplitude of averaged evoked potentials recorded at right parietal (P4). The solid line represents the five averaged evoked potentials obtained in the control condition (composite 3). The broken line represents the averaged evoked potentials obtained in the AR run when the subjects pressed one of five buttons to indicate the affective rating of each semantic stimulus.

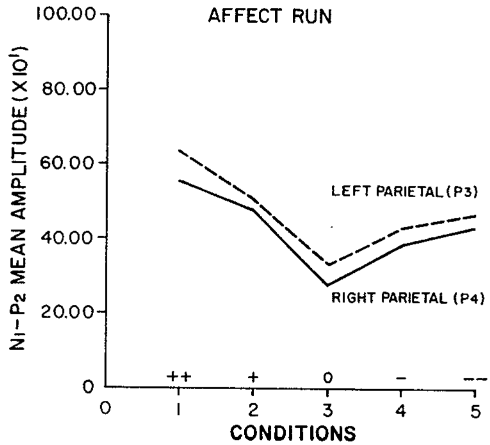

FIGURE 5
N1-P2 amplitude from left and right parietal recordings obtained in the AR run.

TABLE 1

	Positive Affect Rating	Slightly Positive Affect Rating	Neutral Rating	Slightly Negative Affect Rating	Negative Affect Rating
Positive Affect Rating		N.S.	4.35 p<.01	N.S.	2.45 p<.05
Slightly Positive Affect Rating			3.13 p<.01	N.S.	N.S.
Neutral Rating				2.56 p<.05	3.21 p<.01
Slightly Negative Affect Rating					N.S.
Negative Affect Rating					

Individual t-test comparisons of N1-P2 amplitude means for all five averaged evoked potentials obtained during the Affect Rating run at the right parietal electrode (P4).

TABLE 2

	Positive Affect Rating	Shortly Positive Affect Rating	Neutral Rating	Slightly Negative Affect Rating	Negative Affect Rating
Positive Affect Rating		5.39 p <.001	9.71 p <.001	8.94 p <.001	4.00 0<.001
Slightly Positive Affect Rating			6.83 p <.001	2.48 p <.05	1.85 p <.05
Neutral Rating				4.76 p <.01	4.56 p <.01
Slightly Negative Affect Rating					N.S.
Negative Affect Rating					

Individual t-test comparisons of N1-P2 amplitude means for all five averaged evoked potentials obtained during the Affect Rating run at the left parietal electrode (P3).

In order to assess possible hemispheric differences we compared all amplitudes and latencies across tasks between right and left parietal recordings. While none of the statistical tests reached significance, it should be noted (Figure 5) that the N1-P2 component was suggestive of a possible hemispheric difference.

TABLE 3

	Right Parietal (P4)		Left Parietal (P3)	
	t-test	p value	t-test	p value
Positive Affect Rating Composite 3	1.87	< .05	6.89	< .001
Slightly Positive Affect Rating Composite 3		N.S.	3.01	< .01
Neutral Rating Composite 3	2.75	.05	3.33	.01
Slightly Negative Affect Rating vs Composite 3		N.S.		N.S.
Negative Affect Rating vs Composite 3		N.S.	1.83	< .05

Individual t-test comparisons for N1-P2 amplitude of averaged evoked potentials obtained in Condition 2 (Affect Rating) versus Condition 3 (composite of identical words obtained while performing Letter Identification) for electrodes P3 and P4.

DISCUSSION

Our results indicate that tasks requiring different kinds of information processing may involve different neurophysiological transactions which are reflected in scalp-recorded evoked potentials. In the present study, the physical structure of the stimuli was identical across runs. In one run, the subjects performed an analytical task by extracting specific structural features from the semantic stimuli. In the second run they performed a more global or wholistic task by rating the connotative meaning of the words. Our findings suggest that certain aspects of the evoked potential waveform may reflect neural activity correlated with the subjective connotative meaning imparted by the stimulus that are not attributable to changes in the physical characteristics of stimulus. When the subject is engaged in a task requiring active and sustained attention to specific alphabetical features, which may also impede his active processing of connotative meaning, the scalp-recorded potentials appear to be similar across the five groups of words (Composite 3). However, when the subject is requested to respond to each word by rating his feelings about the word, the evoked potentials to the various groups of words ranging from positive to negative are quite different from one another. At both the left and right parietal, the comparison of evoked potentials to the same words obtained between Composite 2 and Composite 3 yielded significant results for only the N1-P2 component. These differences were statistically significant for all but one condition, namely the slightly unpleasant condition.

It is quite possible that the 5 point affective rating scale which we arbitrarily imposed on the subject does not in any way represent a scale with equal incremental steps. Consequently the difference between the slightly negative and negative conditions may be quite negligible and may be less than is necessary to be reflected in the N1-P2 component of the evoked potential. This possibility is suggested by the individual statistical comparisons between all possible pairs of evoked potential means within the affect rating run. Comparisons of all evoked potential pairs were significant except for the comparison of the slightly unpleasant condition with the unpleasant condition.

The results obtained at the right hemisphere electrode site are not as striking as those obtained at the left and suggest that the left hemisphere may be more involved, and/or more responsive to connotative meaning elicited by semantic stimuli. It should be noted that the amplitude of the N1-P2 component is somewhat greater over the left hemisphere than on the right. However, in our study these results are only suggestive and are not statistically significant. Our findings do suggest the use of caution in the interpretation of the asymmetric role of the cortical hemispheres in dealing with semantic information. The lack of hemispheric asymmetry in the processing of linguistic material has been reported by a number of investigators (Shelburne, 1972, 1973, Galambos et al, 1975, and Friedman et al., 1975a; 1975b).

In general our findings are in keeping with earlier reports from our laboratory (Begleiter and Platz, 1969; Begleiter, Gross, and Kissin, 1967) in which we suggested that the processing of specific connotative content of a stimulus is encoded in the waveform of the human evoked potential. Our present results and those of other investigators suggest that internal experiences of feelings or mental imagery about semantic stimuli may indeed be reflected in the electrical activity of the human brain. We do not suggest that this neural representation of feelings is determined by the specific affective state which a word explicitly names or describes, so that the evoked potential obtained to the word LOVE does not represent an electrical sign of the specific feeling of love but may possibly represent the general connotative properties of the word which might possibly vary from individual to individual.

In the last decade numerous investigations have demonstrated that event-related brain potentials are quite sensitive in encoding the content of the eliciting stimulus. Our present findings and those of other investigators strongly suggest that the connotative meaning may well be reflected in the neuroelectric activity elicited by semantic stimuli.

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