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The Effects of Stimulus Expectancy on Evoked Brain Potentials

BERNICE PORJESZ AND HENRI BEGLEITER
Department of Psychiatry, State University of New York, Downstate Medical Center, Brooklyn

ABSTRACT

The effects of self-generated expectancy of stimulus content on the visual evoked potential to physically identical stimuli were studied in college students. The subject set up his own internal expectancy by choosing to see either a bright or dim flash. When a bright or dim flash was anticipated, the potentials evoked by a medium stimulus intensity resembled the responses elicited by an actual bright or dim flash, respectively. Significant differences in visual evoked potential amplitude were obtained between identical medium intensity stimuli depending on the stimulus intensity expected, despite the constant physical properties of the stimulus. The results suggest that a subject's expectancy of certain physical parameters of a stimulus are as important in determining the resultant visual evoked potential as the actual physical features of the stimulus.

DESCRIPTORS: Visual evoked potentials, Stimulus expectancy.

Many investigators have observed that certain aspects of the evoked potential reflect previous experiences of the organism. Numerous human studies have shown that an electrical brain event occurs to an expected but physically absent stimulus. Barlow, Morrell, and Morrell (1967) reported small electrophysiological responses to the omission of an expected light flash. These responses occurred at about the same latency as the response to the actual light stimulus. Sutton, Tueting, Zubin, and John (1967) observed that the absence of an external event or passage of time can act as an endogenous stimulus. They reported that the latency of a positive deflection was a function of the point in time at which a click might have occurred, but did not occur. Klinke, Fruhstorfer, and Finkenzeller (1968) presented a fast periodic stimulus sequence; irregularly, single stimuli were purposely omitted. The stimulus omission elicited a typical cerebral response which was somewhat different in waveform from the potential normally evoked by the regular stimulus. Weinberg, Walter, and Crow (1970) substantiated the presence of a cerebral electrical event which is emitted when an external stimulus is expected but does not occur. They reported that the emitted potentials resembled those evoked when real stimuli were actually presented.

The aforementioned experiments were primarily concerned with the presence of an electrical event to an expected but absent stimulus. The relationship between visual evoked potentials and the expectation of a specific stimulus characteristic has been recently investigated (Begleiter, Porjesz, Yerre, & Kissin, 1973). It was reported that potentials evoked by the same physical stimulus undergo a modification leading to the emergence of markedly different waveshapes in trials in which the occurrence of a different stimulus is signalled. When a stimulus of medium intensity is preceded by a signal indicating the occurrence of a bright flash, the resulting evoked potential is more similar in amplitude to the visual evoked potential obtained to the actual bright flash. The potentials evoked by the medium flash when a dim flash is expected closely resemble the potentials evoked when the dim flash is actually presented.

Buchsbaum, Coppola, and Bittker (1974) report very similar results to ours, in experiments carried out independently. Subjects were presented with a sequence of flashes of specific intensities and learned to expect the occurrence of that sequence. When the sequence of flashes was changed, subjects produced visual evoked potentials characteristic

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Address requests for reprints to: Bernice Porjesz, Department of Psychiatry, State University of New York, Downstate Medical Center, Brooklyn, New York 11203.

of the flash intensity they expected to see, not consistent with the actual stimulus presentation. These results are in keeping with our own findings.

In the previous experiment (Begleiter et al., 1973), different external stimuli were used to signal the occurrence of a bright or dim flash. It was assumed that the subject's expectation would be consistent with the delivery of our differential signals. In the present experiment, the effects of self-generated stimulus expectancy on evoked potentials are investigated by asking the subject to request the stimulus he wishes to see.

Method

Subjects

Subjects consisted of 24 college students with a mean age of 21. All *S*s were paid volunteers.

Electrodes

Monopolar recordings were obtained with Beckman biopotential skin electrodes secured to the scalp with collodion. The active lead was placed at vertex (C_Z, according to the 10-20 International System), and the reference was located on the right earlobe. The left earlobe lead served as ground. Resistances were maintained below 5000 ohms.

Apparatus

Each *S* was seated in sound-attenuated, electrically shielded enclosure, with his head resting on an adjustable chin rest, so that he was looking directly into a viewing hood, which was flushed against the one-way mirror of the enclosure. A Grass PS-2 photostimulator was mounted on the other side of the glass, 50 cm from the *S*'s eyes, and was set at a No. 2 intensity.

The visual stimuli were 5 cm squares placed in a random access projector in front of the photostimulator, such that they subtended the central 20° of the visual field. Each square was a different neutral density filter which reduced the amount of light being transmitted by a fixed proportion. Three different filters were used: 80%, 20%, and 50% transmittance, corresponding to the bright (B), dim (D), and medium (M) stimulus intensities respectively.

Visual evoked potentials (VEPs) were recorded by means of a Grass wide-band AC polygraph; the low-frequency cutoff filter was set at 0.3 Hz, and the high frequency cutoff filter was set at 100 Hz, with a gain setting of 5μV/mm. The VEPs were summated in a Hewlett Packard Signal Analyzer for a 500 msec epoch, and were written out on a Hewlett Packard XY Recorder.

Three latency measures were obtained: at the time of occurrence after the stimulus (in msec) of the first positive peak (P1-100 msec), first negative peak (N1-140 msec), and second positive peak (P2-200 msec). Two amplitudes were measured in terms of the perpendicular distance (in μV) between successive peaks (P1-N1; N1-P2).

Experimental Procedure

Training. Initially the *S* was trained to discriminate between the bright and dim flashes. He was instructed to press one of two microswitches after each stimulus to indicate whether he had seen a bright or dim flash. The training procedure was terminated when *S* reached the criterion of 30 consecutive correct discriminations, which took an average of 52 trials.

Run 1 (Baseline). Baseline VEP recordings were then obtained to the bright and dim flashes. They were presented in random order for a total of 20 times each, at a random rate of 2-5 sec apart, and the *S* was again instructed to press the bright or dim button after each flash.

Run 2. In the next run the *S* was told that he could select his own stimulus (either bright or dim flash), by pressing the appropriate button, but to ensure an approximately equal number of each. Initially, he was able to totally manipulate which stimulus he received by pressing the corresponding microswitch. However, after the first 5 stimuli of each intensity had been presented upon request, the flash of medium intensity was introduced, and was interspersed among the actual bright and dim flashes 50% of the time, regardless of which button he pressed. Thereafter, whenever he pressed the bright button he had an equal chance of receiving either the bright (B) or medium (Mb) intensity flash; when he selected the dim button he received either the dim (D) or medium (Md) flash. This procedure was continued until a total of 20 Mb and 20 Md stimuli were presented and stored on separate channels; 25 B and 25 D stimuli were also accumulated in separate channels. Immediately following the run, the *S* was interviewed about his perception of the flashes.

Run 3. The instructions to the *S* in the last run were identical to that of the previous run. However, now whenever he requested the bright (B) flash he received the flash of medium intensity (Mb), and whenever he chose the dim (D) flash, he was likewise presented with the identical medium flash (Md). No actual bright or dim flashes were used in this run; regardless of which microswitch *S* pressed, he received the same medium stimulus. The VEPs to this medium stimulus were stored in separate channels depending on which button he pushed, for a total of 20 Mb and 20 Md responses. Again, at the end of the run the *S* was interviewed regarding his perception.

Results

The differences in mean amplitudes (P1-N1; N1-P2) and latencies (P1; N1; P2) of the VEPs obtained during the 3 experimental runs were evaluated by paired *t*-tests for correlated samples. The .05 rejection region was adopted.

In the baseline run, where only the bright (B) and dim (D) flashes were presented in a discrimination task, a statistically significant amplitude difference was obtained between the two stimuli at N1-P2, $t=2.77$. In this run latencies P1 and N1 also yielded statistically significant differences between B and D flashes, $t=5.32$ and 2.25, respectively. No significant difference was obtained between B and D for amplitude P1-N1 or latency P2.

Fig. 1 shows the evoked potentials of 4 typical *S*s during the second run, where *S* selected to see either a bright or dim flash. VEP amplitude N1-P2 was significantly different between B and D flashes, $t=5.33$. The difference between potentials evoked by interspersed medium flashes expected as bright

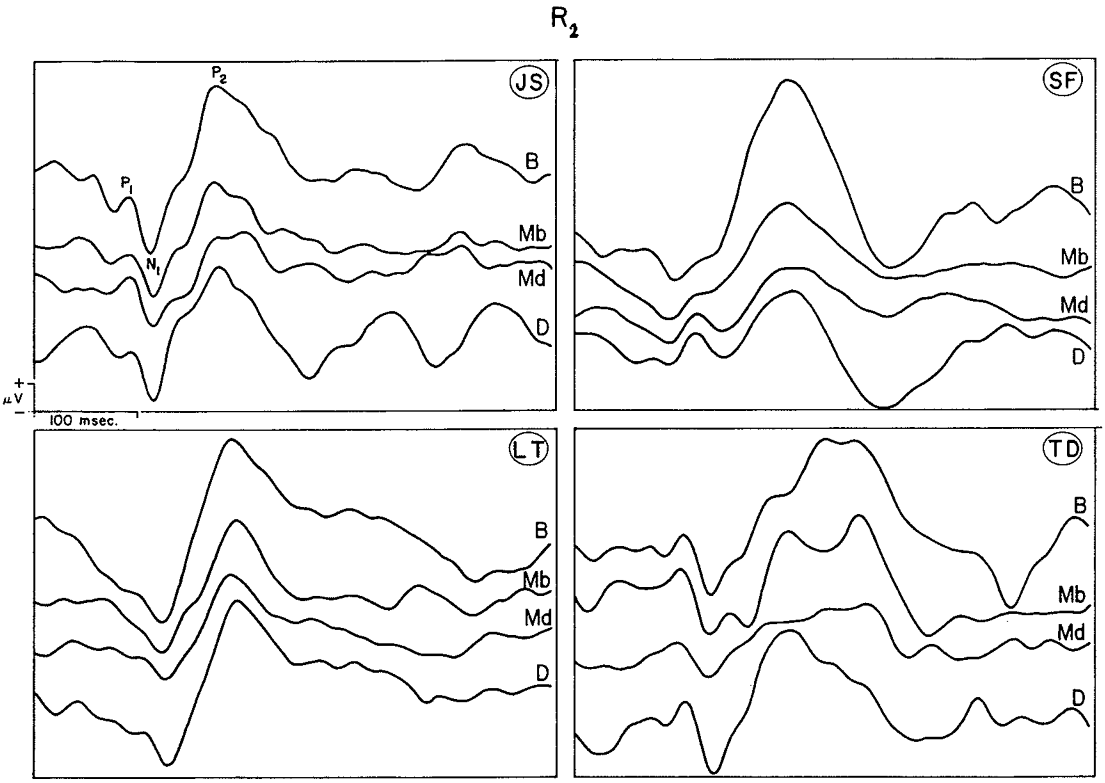

Fig. 1. Visual evoked potentials obtained at C_Z for 4 typical *S*s during Run 2, where medium intensity flashes were interspersed among actual bright (B) and dim (D) stimuli. The B and D traces shown above are an average of 25 responses to each stimulus. The Mb trace is the average of 20 evoked responses to a medium intensity stimulus when bright was expected, while the Md recording is the average of 20 responses to the same medium intensity stimulus when dim was expected. The calibration pulse is 5 µV for the Mb and Md stimuli, and is 3.7 µV for B and D stimuli.

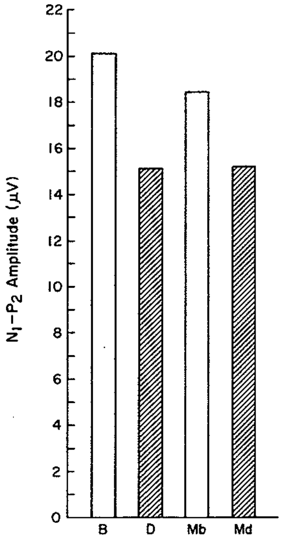

Fig. 2. Mean VEP amplitude N1-P2 for each stimulus during Run 2, where medium intensity flashes were interspersed among actual bright (B) and dim (D) stimuli. Differences in amplitude are evident as a function of the *S*'s expectancy (bright □ or dim ▨). Amplitude differences to the same medium stimulus are apparent depending on whether a bright (Mb) or dim (Md) stimulus is expected.

(Mb) and those expected as dim (Md) was also statistically significant for amplitude N1-P2, t=2.92. (Fig. 2) Paired t-tests between B and Mb, and D and Md VEPs, did not yield statistical significance for any of the amplitudes or latencies measured. Furthermore, statistical significance was not reached between B and D, or Mb and Md traces for amplitude P1-N1 or any of the three latencies.

In the third run, only medium flashes were presented to the *S* when he requested either a bright or dim stimulus. Typical records from the same 4 *S*s for this run can be seen in Fig. 3. Amplitude N1-P2 of the evoked potential to the same physical stimulus yielded a statistically significant difference, t=3.7, depending on whether the *S* requested to be presented with a bright (Mb) or a dim (Md) flash. (Fig. 4) There were no significant differences in latencies or in amplitude P1-N1.

In order to compare the amplitude differences obtained between the bright and dim flashes during the first run and the differences obtained between Mb and Md during the second and third runs, a one-way analysis of var-

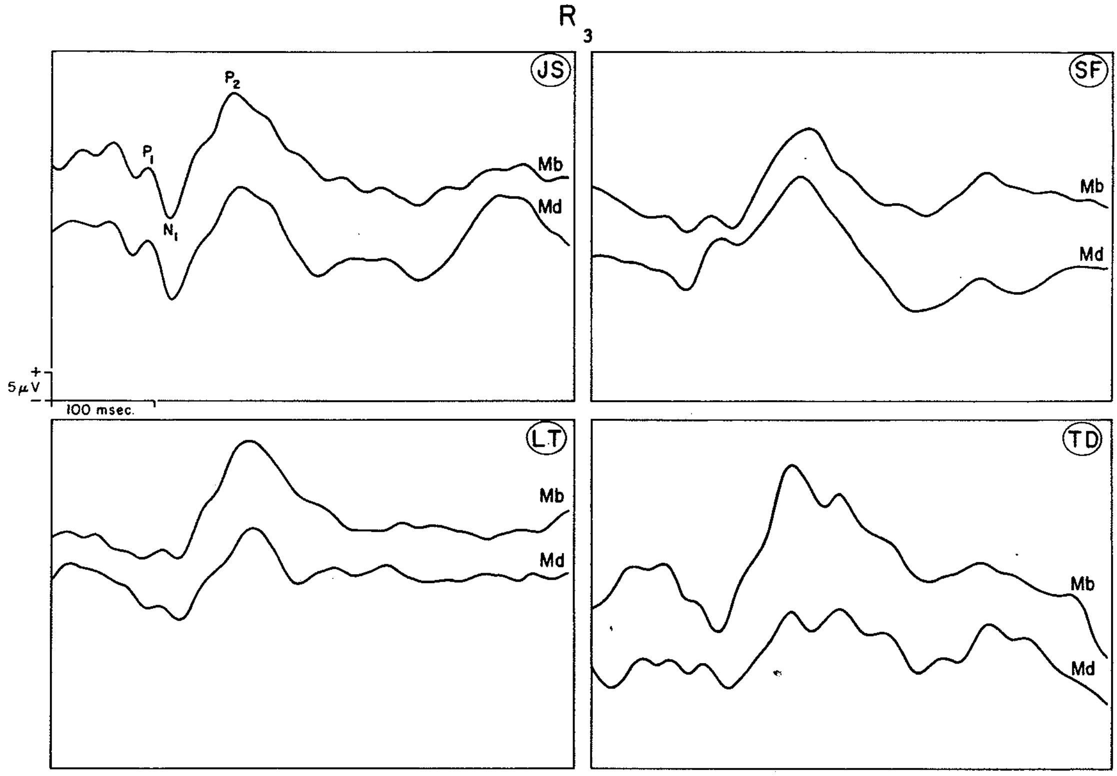

Fig. 3. Visual evoked potentials for the same 4 typical *S*s during Run 3 where only medium intensity flashes were presented. The top trace is the potential recorded when a bright flash was expected, and the bottom trace is the response obtained to the identical medium stimulus when a dim flash was anticipated. Each recording is an average of 20 evoked responses.

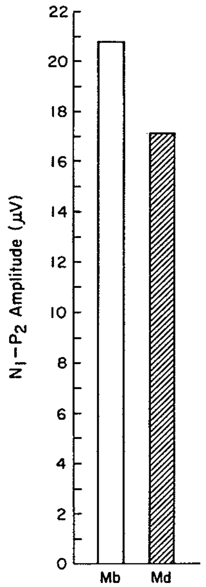

Fig. 4. Mean VEP amplitude N1-P2 for all *S*s during Run 3, when only medium intensity flashes were present. Differences in amplitude to the same medium stimulus are apparent depending on whether a bright (Mb) or dim (Md) stimulus is expected.

iance was performed using the difference scores for the three runs. The analysis of variance was not statistically significant.

Discussion

The present results confirm the findings of the previous experiment (Begleiter et al., 1973) of VEP waveshape modification determined by expectancy, and further indicate that self-generated expectancy alters the response at the vertex to a physically identical stimulus. In the earlier study the *S*'s set was controlled externally by presenting different cues. However, it could not be established that the *S*'s expectancy was consonant with what was signalled. In the present experiment, the *S* set up his own internal expectancy to an identical medium intensity stimulus: he could opt to see either a bright or dim flash. Interviews with the *S* at the conclusion of each run revealed that they perceived the intensity requested, indicating that their perception was consonant with their expectation. If a flash of medium intensity replaced a bright flash when *S* requested to see "bright," it was perceived as bright; similarly, the same medium flash was perceived as dim when a dim flash was expected. The VEP also reflected this false anticipation: if a bright flash was anticipated (Mb), the VEP waveform resembled that evoked by a bright flash, while if a dim flash was expected (Md), the VEP waveshape was similar to that of the dim flash. Furthermore, significant differences in VEP amplitude were obtained between the identical Mb and Md flash, despite the constant physical properties of the stimulus.

Similar results have been reported by Buchsbaum et al. (1974), who found that the *S*'s internal model of expectancy influences his evoked potential to a greater degree than the physical properties of the stimulus. However, the effect was obtained in the early (P100-N140) component, while the present one is in a later component (N140-P200). This difference might possibly be explained by the use of a different stimulus duration in our experiment. Buchsbaum et al. (1974) used a stimulus lasting 500 msec whereas our stimulus lasted only 10 msec. It is quite reasonable to assume that a stimulus of short duration evokes both an "on" response and an "off" response. Use of a stimulus lasting the length of the total recorded epoch precludes the recording of "off" responses.

Another experiment showing alterations in VEPs by expectancy has been reported by Lelord (1973). With the use of classical conditioning techniques, he obtained evoked potentials to auditory stimuli that resembled those normally evoked by light. This result provides further evidence that a *S*'s expectancy is a critical factor determining the neuroelectric response of an external stimulus.

Experiments dealing with the relationship between VEP and expectancy have typically focused on the temporal occurrence or nonoccurrence of an expected stimulus, rather than on its qualitative characteristics (Barlow et al., 1967; Klinke et al., 1968; Weinberg et al., 1970). In the present experiment expectancy about stimulus content rather than its temporality was manipulated and it was found that VEP amplitude is also sensitive to this phenomenon.

The present findings indicate that the electrical activity evoked by a sensory stimulus is not solely determined by the physical attributes of the stimulus itself but may be taken to reflect the activation of endogenous neurophysiological processes related to the past experience and present state of the organism. In recent years, John (1967) has demonstrated that in cats, certain aspects of the evoked potential do reflect previous experiences rather than responses to an afferent stimulus, and are in that sense released from memory rather than evoked. In a differential generalization paradigm, he found that the same physical stimulus could elicit different evoked potential waveshapes depending on the behavioral outcomes. Those differences were attributed to the activation of specific memories.

It appears unlikely that in man, the central nervous system should only be responsive to the physical characteristics of the environment without the ability to modulate the nature and amount of input. It seems reasonable to expect that sensory data should be analyzed in terms of an organization which takes into account the effects of inherent constitution of the organism, long-term learning, and the immediately preceding situation. Input of new data against such a background means inevitably that, as Bartlett (1932) noted, the final analyzed result will be a compromise between the incoming data and the pre-existing organization.

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