Evoked Brain Potentials as Indicators of Decision-Making

Abstract. *The effects of decision-making processes on evoked brain potentials recorded at the vertex were studied in human subjects. Significantly different visual evoked potentials to the same physical stimulus were obtained in trials that resulted in different behavioral decisions. The results suggest that certain characteristics of evoked potentials may perhaps be used as indicators of specific behavioral outcomes.*

Certain components of the evoked potential (EP) may reflect previous experiences rather than responses to an afferent stimulus (*1*). We reported that when a flash of medium intensity is preceded by a signal indicating the occurrence of a bright flash, the resulting EP is similar to that obtained to a bright flash; the EP's to the medium flash when a dim flash is signaled resemble those elicited by the dim flash (*2*). We studied the effects of self-generated expectancy of stimulus content on the EP's to physically identical stimuli. Significant differences in EP amplitude were obtained between identical stimuli of medium intensity depending on the stimulus intensity expected (*3*). Similar results were obtained by Buchsbaum *et al.* (*4*), who demonstrated that a subject's expectancy of the physical properties of a stimulus are important in determining the characteristics of the EP to that stimulus.

In the present experiment we found that EP's to physically identical stimuli differed in trials resulting in different behavioral decisions. Data were derived from monopolar scalp recordings with the active electrode located on the midline at Cz (vertex) and the reference electrode at the left earlobe, while that at the right earlobe served as ground. Evoked potentials were recorded by means of a Grass model 78 wide-band a-c polygraph, whose low-frequency cutoff filter was set at 0.3 hertz; the high-frequency cutoff filter of the driver amplifier was set at 100 hertz, and the gain at 5 μv/mm. The EP's were summed by a Hewlett-Packard signal analyzer (5480-B) and were written out on a Hewlett-Packard X-Y plotter.

Subjects consisted of 18 college students, 9 of each sex. Each subject was seated in an acoustically shielded enclosure so that he looked directly into a viewing hood that was flush against the one-way mirror of the enclosure. On the other side of the glass window, a Grass PS-2 photostimulator was mounted and set at No. 2 intensity. The stimuli were presented in front of the photostimulator, 50 cm from the subject's eyes, and subtended the central 20° of the visual field.

The visual stimuli were flashes transmitted through three different neutral density filters that reduced the light intensity of the photostimulator by a definite ratio. The transmittance of the filter for the dim stimulus was 20 percent, that for the bright stimulus was 80 percent, and that for the stimulus of medium intensity was 50 percent. The filters were 5-cm squares placed in a random access projector.

Before the first experimental run, the subjects were told that they would be presented repeatedly with bright and dim flashes. They were instructed to press one of two microswitches after each stimulus to indicate whether they had seen a bright or dim flash. Sixteen bright and 16 dim flashes were presented randomly, with an interstimulus interval of 3 to 6 seconds.

Before the second run, the subjects were informed that a bright flash would be presented on 50 percent of the trials and a dim flash on the other 50 percent. They were told that the discrimination between bright and dim flashes would be somewhat more difficult than before. In addition, they were told that 5¢ would be paid for every correct discrimination and that 20¢ would be deducted for every incorrect discrimination. Incorrect discriminations of bright and dim flashes were signaled by a 1500-hertz tone; there were no signals for medium flashes.

In actuality, the subject was randomly presented with 32 bright flashes, 32 dim flashes, and a minimum of 32 medium flashes. Medium flashes were presented until each subject had judged 16 medium flashes to be "bright" and another 16 to be "dim."

Since all data were recorded on tape, we were able to average the EP's to the medium stimuli in terms of the decision made about each ("bright" or "dim"), as well as in terms of the preceding stimulus on

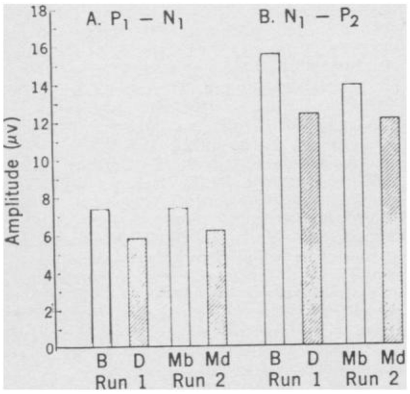

Fig. 1. Mean amplitude of evoked potentials for correctly detected bright (*B*) and dim (*D*) flashes in run 1 and for medium flashes detected as "bright" (*Mb*) and "dim" (*Md*) in run 2. Potentials were recorded at the vertex. Data in (A) are for amplitude P_1-N_1 (which appears at 100 to 140 msec) and those in (B) are for N_1-P_2 (140 to 200 msec).

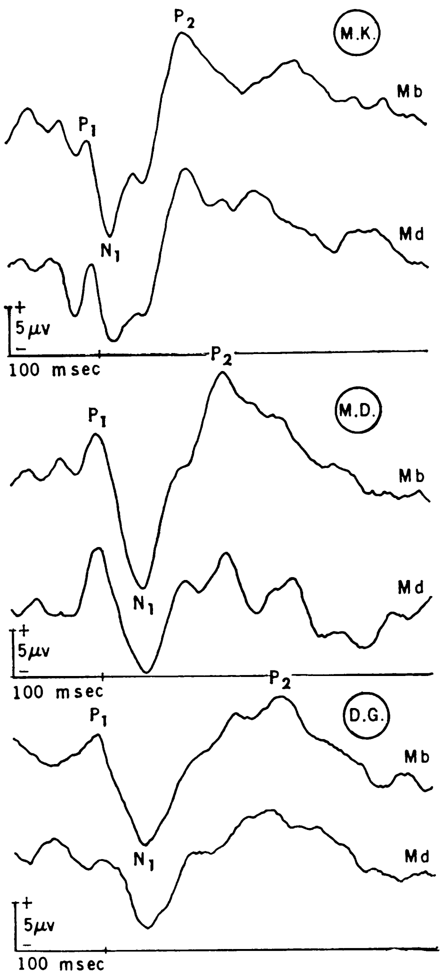

Fig. 2. Visual evoked potentials, recorded at the vertex, for three typical subjects in response to identical stimuli of medium intensity that resulted in different behavioral decisions. The top trace (*Mb*) for each subject is the average of 16 EP's to medium stimuli that the subject decided were "bright," while the bottom recording (*Md*) is the average of 16 EP's to identical sitmuli that the subject decided were "dim."

each decision. Changes in the EP's were assessed by measurement of the peak-to-peak P_1-N_1 amplitude (which appears at 100 to 140 msec) and N_1-P_2 amplitude (140 to 200 msec). Statistical comparisons of the data obtained during each run were made on each amplitude with paired *t*-tests for correlated samples.

In the first (baseline) run, when only the bright and dim flashes were presented, statistically significant differences were obtained between the two stimuli for P_1-N_1 ($t = 3.54$, $P < .01$) and at N_1-P_2 ($t = 4.15$, $P < .001$).

Figure 1 also indicates the difference between EP's to identical medium flashes that were judged to be either "bright" or "dim," and were interspersed among real bright and dim flashes during the second run. Statistically significant differences to these identical medium stimuli were obtained depending on the subject's decision about the physical properties of the stimulus for both amplitudes investigated (P_1-N_1: $t = 2.80$, $P < .02$; N_1-P_2: $t = 2.94$, $P < .01$). The subject's decisions about the intensity of the medium flash were not related to the preceding stimulus, as an approximately equal number of bright and dim flashes preceded each type of decision.

Figure 2 shows the EP's of three typical subjects during the second run. The EP's to the same physical stimulus are markedly different in trials resulting in different decisions.

When a subject is presented with a stimulus of medium intensity and decides that it is "bright," the EP to that stimulus is quite different from the EP elicited by an identical stimulus that he decides is "dim." This effect cannot be explained in terms of contrast, fatigue, or recovery, because it is independent of the preceding stimulus. We explored the possibility that EP differences might be due to a specific type of instrumental behavior, such as the pressing of a particular button. Nine of the 18 subjects were asked to look at another visual stimulus and subsequently press either of two buttons on each trial. The EP's were retrieved in terms of the subject's presses. There were no differences in the two averaged EP's. Therefore, we believe that our results demonstrate a relationship between specific components of the EP to a sensory stimulus and a cognitive decision about the physical attributes of that stimulus. The findings suggest that these patterns of neural activity might reflect the activation of memory traces about a specific experience.

The release of endogenous patterns of activity appropriate to subsequent behavioral response rather than to the actual physical stimulus has been observed in animals. John (*5*) reported on the use of a differential generalization paradigm in which animals were trained to emit two different responses, each appropriate to one of two stimulus frequencies. He studied the electrical and behavioral responses to a third stimulus at a frequency midway between the original stimuli, and observed that the same physical stimulus could elicit different EP wave shapes depending on the behavioral outcomes. He concluded that certain aspects of the EP may reflect previous experiences rather than responses to an afferent stimulus, and are in that sense released from memory rather than evoked. Our present data are consistent with those results and suggest that the EP recorded at the vertex might reflect decision-making processes in humans.

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References and Notes

1. H. Begleiter and A. Platz, *Science* **166**, 769 (1969); H. Weinberg, W. Grey-Walter, H. J. Crow, *Electroencephalogr. Clin. Neurophysiol.* **29**, 1 (1970); S. Sutton, M. Braren, J. Zubin, E. R. John, *Science* **150**, 1187 (1965); H. Begleiter, M. M. Gross, B. Kissin, *Psychophysiology* **3**, 336 (1967).
2. H. Begleiter, B. Porjesz, C. Yerre, B. Kissin, *Science* **179**, 814 (1973).
3. B. Porjesz and H. Begleiter, *Psychophysiology*, in press.
4. M. Buchsbaum, R. Coppola, T. E. Bittker, *Neuropsychologia*, in press.
5. E. R. John, *Mechanisms of Memory* (Academic Press, New York, 1967).
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Primate Predation: Interim Report on the Development of a Tradition in a Troop of Olive Baboons

Abstract. *A troop of olive baboons,* Papio anubis, *has developed systematic predation, which includes hunting and sharing of meat. Although meat-eating among nonhuman primates—baboons and chimpanzees especially—had been discovered in earlier field studies, systematic predation had been reported for chimpanzees and humans only. Starting as an adult male activity in the olive baboon troop, this tradition rapidly expanded to include capture and consumption of prey by adult females and juveniles of all ages and both sexes. Infants eat but have not been observed to capture prey.*

Although there are isolated reports of meat-eating in nonhuman primates, systematic predation has been observed only recently (*1, 2*). Meat-eating by baboons and chimpanzees appears to be restricted to limited populations. The present study provides evidence concerning the way in which a tradition of predation can develop within a group of nonhuman primates.

From December 1972 until January 1974 I conducted a field study of the social behavior of a troop of free-ranging olive baboons (*Papio anubis*) near Gilgil, Kenya. This troop had been studied by Harding (*3*) in 1970 to 1971 and by 1973 averaged 7 adult males, 21 adult females, and 38 immatures. Harding observed 47 cases of baboon predation on small animals in 1032 hours of observation, the highest rate of predation reported for any primate other than man. The prey were Cape hares (*Lepus capensis*), birds of various species, and the young of diverse antelopes: Thomson's gazelles (*Gazella thomsoni*), dik-dik (*Rhyncotragus kirki*), steinbok (*Raphicerus campestris*), and impala (*Aepyceros melampus*). All but three cases of predation were the result of adult male activity; in all but one case, adult males were the only consumers of the meat.

Although the primary focus of my study was intratroop social dynamics, I observed 100 cases of predation by baboons in 1200 hours of observation. In addition to this increased predatory rate, important changes in the pattern of predation had also taken place (*4*).

With minor exceptions the list of species preyed upon by the baboons remained the same as in the earlier study period, although prey preferences were different (Table 1). The propor-