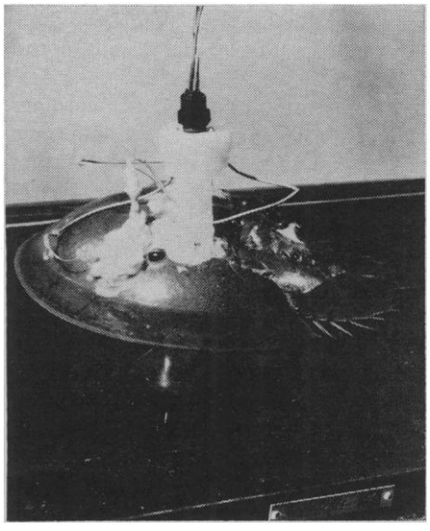

Fig. 2. A *Limulus* with permanently implanted electrodes.

cemented to the anchoring ring. The wound was filled with Gelfoam (Upjohn), sealed with beeswax, and covered with a layer of cement. The beeswax protected the nerve, which is close to the carapace, from the cement.

To obtain recordings of heart rhythms, a 1-mm hole was drilled in the medial ridge of the carapace of the cephalothorax, 2.5 cm from its posterior edge. The electrode was lowered 1 cm below the surface of the carapace and secured by pouring cement around the point of entry of the electrode.

Placement of electrodes in the postbranchial ganglia was the most difficult, mainly because these ganglia are located ventrally. The approach and methods of ensuring electrode stability are depicted in Fig. 1*B*. A hole was cut in the posterior carapace, extending laterally from the midline to the chitinous infoldings, and longitudinally from the third to the fifth pair of entapophyses [see (*4*)]. The pericardial sinus and gut were moved centrally and a teflon tube (0.7 cm in diameter) placed over the cord as shown in Fig. 1*B*. The electrode was then lowered into the cord, piercing the enveloping arterial sheath. The tube prevented the gut and other internal structures from displacing the electrode.

The large dorsal pericardial sinus was the most accessible vessel for cannulation. A hole, slightly smaller than the threaded part of the cannula (*6*), was drilled 1 cm off the midline of the posterior carapace opposite the third pair of entapophyses. The cannula was inserted through the hole and screwed tightly against the carapace, its shaft extending into the sinus.

The reference electrode was placed in the egg masses of the cephalothorax. All electrodes were connected with shielded cable to a seven-pin miniature tube socket. The socket was contained in a teflon bridge attached to the carapace as shown in Fig. 2.

The surgery did not appear to produce any serious changes in behavior, and we found that animals with permanently implanted electrodes could be conditioned. Most animals were kept in a free-living state in an aquarium between recording sessions, and during these periods feeding, mating, and egg-laying were observed.

During recording sessions the animals were placed in a small aquarium containing 3 cm of sea-water, or, if they were unusually active, they were secured in a manner similar to that used by Smith and Baker (*3*). Examples of electrical potentials obtained 12 days after surgery are shown in Fig. 1, *C* through *E*.

To determine whether the cannula was an adequate route for getting an isotope into central nervous-system structures, 50 μc of P^{32} were injected into each of four cannulated animals. In one fraction consisting of ribonucleic acid nucleotides, counts of at least 90 per minute over background have been found per nucleotide. Further details will be published elsewhere.

These findings thus demonstrate the feasibility of permanently implanting electrodes and cannulae in *Limulus* while leaving the animal in a behaviorally unrestricted state.

Table 1. Placements of electrodes and cannulae in eight *Limulus polyphemus*, and the time each survived after surgery. An "X" in any column indicates that the animal received the implantation listed at the top of the column.

Electrodes			Cannula	
Optic nerve	Ventral cord	Heart	Dorsal pericardial sinus	Survival (days)
X	X	X		13
		X	X	18
		X		23
		X	X	36
X	X	X	X	14
			X	78
X				14
X		X	X	57

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References and Notes

1. Specimens may be obtained from W. Taylor, RD 2, Cortez, Fla., or from the Marine Biological Laboratory, Woods Hole, Mass.
2. Artificial sea water was made with Rila marine mix and kept at a *p*H of 7.5 to 8.2.
3. J. C. Smith and H. D. Baker, *J. Comp. Physiol. Psychol.* **53**, 279 (1960).
4. W. Patten and W. A. Redenbaugh, *J. Morphol.* **16**, 1 (1900).
5. H. Grundfest, R. W. Sengstaken, W. H. Oettinger, R. W. Gurry, *Rev. Sci. Instrum.* **21**, 360 (1950).
6. Collison intraventricular cannulae, C. F. Palmer Ltd., London.
7. Supported by NASA grant NSG 475.

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Selective Attentiveness and Cortical Evoked Responses to Visual and Auditory Stimuli

Abstract. *Cortical evoked responses to flashes and clicks were recorded from human subjects performing visual or auditory tasks under three conditions of selective attentiveness. The subjects were required to attend to the flashes and to ignore alternating clicks, or vice versa. Responses to flashes recorded from the occipital area were larger when attention was directed toward visual stimuli, and responses to click stimuli recorded from the temporal area were larger when attention was directed toward auditory stimuli.*

In a previous study (*1*) we demonstrated that the magnitude of visually evoked responses was correlated with fluctuations in attentiveness during a prolonged visual vigilance task. In contrast, the study reported here was concerned with short-term attentiveness to either click or flash stimuli presented alternately. Average evoked potentials were recorded from visual and auditory areas while subjects attended to stimuli within one of the two sense modalities and ignored those in the other. Three methods of inducing and maintaining attentive sets were compared.

Thirteen subjects performed under all three experimental conditions: vigilance, key-pressing, and counting. Un-

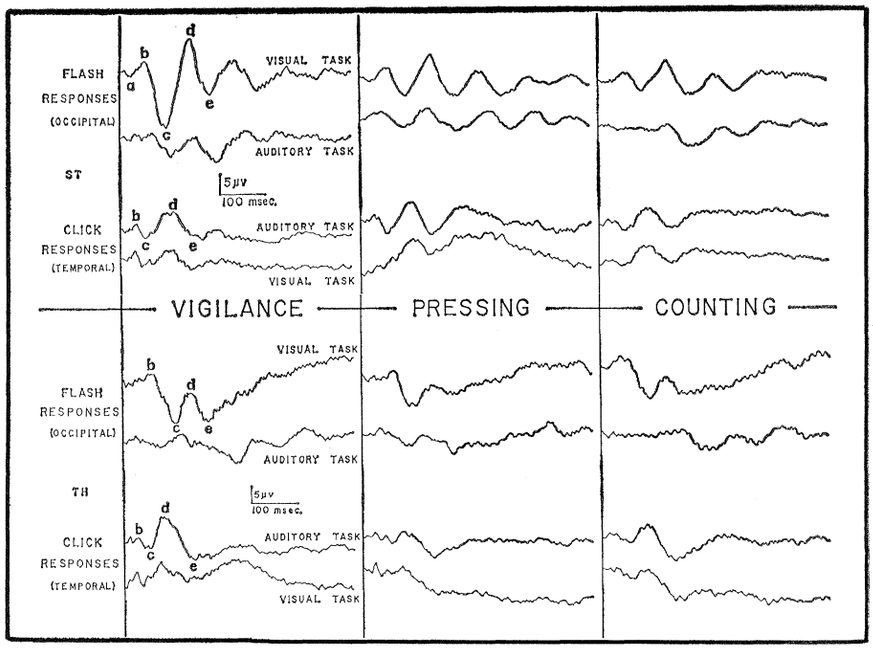

Fig. 1. Computer-averaged cortical evoked potentials obtained from two subjects (ST and TH) in response to flashes and clicks. The potentials were recorded from the occipital and temporal areas while the subjects performed visual and auditory tasks under three experimental conditions: vigilance, key-pressing, and counting. Flashes alternated with clicks throughout. Each trace is the averaged evoked response to 300 stimuli. Analysis time, 500 msec. In the upper left-hand section, the major peaks and troughs of the visual and auditory evoked responses are identified by letters *a* to *e*; the amplitude of the wave defined by *c-d-e* is the principal differentiating criterion. Recordings: right occipital and temporal areas to left ear; negativity upward.

der all conditions, alternating clicks and flashes were presented 1 second apart. For the *vigilance condition*, the subjects were instructed to perform, during one half of the experiment, a vigilance task in one modality, and to ignore stimuli presented in the other modality; they were instructed to reverse the procedure during the other half of the experiment. Thus, when subjects were performing the visual vigilance task, attending to flashes rather than clicks, they received bright flashes (intensity 15 lam) requiring no response, and occasional dim flashes (9 lam) which required the pressing of a key. The purpose of this task was to ensure that attention was paid to all flashes. The clicks which alternated with the flashes during the visual vigilance task were all of the same intensity (400 μbar) and were ignored by the subject. When subjects were performing the auditory vigilance task, attending to clicks rather than flashes, they were required to press a key in response to occasional weak clicks (100 μbar) interspersed among the more numerous louder clicks (400 μbar). Flash stimuli alternating with the clicks during the auditory vigilance task were all of the same intensity (15 lam) and were to be ignored (*2*).

For the *key-pressing condition*, during one-half of the experiment the subjects pressed a key after each stimulus in one sense modality; in the other half they did the reverse. Stimulus intensity was held constant under this condition (flashes, 15 lam; clicks, 400 μbar). For the *counting condition*, the subjects were instructed to attend to either flashes or clicks but were required to count each stimulus in the modality in which they were attending and to press a key after each 50 stimuli. Stimuli in the other sense modality were to be ignored. Stimulus intensity was held constant and was the same as for the key-pressing condition.

In each half of the experiment with subjects under the vigilance condition, 330 flashes and 330 clicks were presented. During the visual vigilance task, 30 of the flashes were dim, and during the auditory task 30 of the clicks were weak. Under each of the other conditions 300 flashes and 300 clicks were presented during each half of the experiment. Each half of an experimental session lasted approximately 10 minutes with a 5-minute rest period between halves. Visual flash stimuli were produced by Grass PS-1 photostimulators and were diffused by means of a 10- by 12-cm flashed-opal glass screen located at the end of a viewing tube 30 cm from the subject's eyes. For bright stimuli one of the photostimulators was set at intensity 4, and for dim stimuli the other was set at intensity 4 with an additional filter. Auditory stimuli were generated by a Grass S-4 stimulator and were relayed to the subject by Permoflux PDR-8 cushioned earphones.

The electroencephalogram was recorded on a Grass model 6 electroencephalograph and an Ampex FR-1300 frequency-modulated tape recorder, from three scalp locations: occipital, temporal, and vertex. The occipital electrode was sited approximately 2.5 cm above the inion and 2.5 cm to the right of the midline at O_2; the temporal electrode, midway between C_6 and T_4; the vertex electrode at C_z. These letter designations are according to the 10-20 electrode system of the International Federation of Electroencephalographic Societies (*3*). In each case the reference electrode was placed on the left earlobe.

Time-averaging of the cortical responses to the 300 flash and 300 click stimuli, presented while the subjects were performing the visual and auditory tasks under each experimental condition, was accomplished by means of a Mnemotron computer of average transients. Responses to flashes and clicks were averaged separately from all three recording sites, but data reported here deal only with flash responses recorded from the occipital area and click responses from the temporal area.

Evoked potentials to flash or click stimuli recorded from the scalps of human subjects over the visual and auditory areas, respectively, consist of a complex sequence of waves. Despite this complexity and a certain amount of variability, there exists within subjects and between subjects a fairly regularly identifiable pattern of waves, the peaks and troughs of which we have identified in Fig. 1 as *a*, *b*, *c*, *d*, and *e*. Of these, the second negative peak (*d*) is usually the most prominent component and has a surprisingly constant latency for a given set of stimulus conditions. The latency of peak (*d*) for a flash stimulus recorded over the visual area is approximately 160 msec; the

latency of peak (*d*) for a click stimulus recorded over the auditory area is approximately 110 msec. In this study, the magnitude of the wave defined as (*c-d-e*) constituted the principal criterion for comparing the evoked potentials elicited under the different experimental conditions. The long latency and diffuse cortical representation of this wave suggests that it is a secondary potential (*4*), perhaps related to the nonspecific sensory system.

Figure 1 presents characteristic data from two of the 13 subjects studied under each of the three experimental conditions. Under the vigilance condition, when subjects were attending to the flash stimuli (visual vigilance task), the amplitude of the visually evoked response (VER) to flashes, recorded from the occipital area, was much greater than when subjects were attending to the click stimuli (auditory vigilance task). Similarly, when subjects were attending to the click stimuli (auditory vigilance task), the amplitude of the auditory evoked response (AER) to clicks recorded from the temporal area, was greater than when subjects were attending to flashes (visual vigilance task). All 13 subjects in the experiment showed VER and AER differences between tasks of the type illustrated in Fig. 1. Basically similar data were obtained when the subjects were under the key-pressing condition: here also the VER and AER amplitudes were greatest when subjects were attending to stimuli in the corresponding sense modality. Thus, when subjects were performing the visual key-pressing task (pressing the key after each flash), the amplitude of the VER's to flashes was greater than when the subjects were pressing the key after each click. Again, all 13 of the subjects showed VER and AER differences between attentive and inattentive conditions of the kind illustrated in Fig. 1. Data obtained with the subjects under the counting condition were equivocal. Six subjects showed differences of the kind found under the other two conditions; three subjects showed no differences; and four subjects showed differences in the opposite direction. As we will explain below, counting may be a task which divides rather than focuses attention.

These data indicate that when attentiveness is effectively manipulated between sense modalities, the amplitude of cortical evoked responses in a given sense modality varies according to whether or not the subject is attending to stimuli in that or another modality. It is important to note that subjects in this experiment were required to be alert for relatively short periods of time (10 minutes). This contrasts with the situation in the experiment we reported previously (*1*), in which subjects performed a vigilance task lasting nearly 2 hours. Attentiveness inevitably fluctuated considerably during performance of that prolonged task, as subjects were usually highly alert at the beginning and much less so at the end. It remained an open question, therefore, whether changes in the cortical evoked responses with changes in attentive state would occur in a continually alert subject. Data obtained under the conditions of the present experiment allow us to state unequivocally that, even in an alert subject, changes in evoked responses occur which are related to the subject's attentive state.

Several other workers have examined the effect of selective attentiveness on cortical evoked responses in humans (*5–9*). Their results have been varied and therefore inconclusive, perhaps because of the varied procedures employed in establishing attentive sets. For example, van Hof *et al.* (*5*) reported that attending to flash stimuli by counting them had no effect on the amplitude of the evoked responses to the flashes. On the other hand, Jouvet (*6*) and Garcia-Austt *et al.* (*7*) reported that counting flash stimuli enhanced the amplitude of the VER. In contrast, Callaway *et al.* (*8*) recently reported that patients showed a decrease in AER amplitude while attending to bursts of tone. The procedures used by the various investigators suggest that the method by which an attentive set was established may have been an important determinant of the findings in a particular experiment. In our experiment, the vigilance and the key-pressing tasks were effective in enhancing cortical evoked responses, whereas the counting task was relatively ineffective. Counting, rather than focusing attention on relevant stimuli, may be distracting because of the necessity of keeping track of the number of stimuli counted. In most of the studies cited above, a counting task was used to elicit attentiveness. The equivocal results obtained may have been because of this.

Our results seem to indicate conclusively that when an attentive set is established by making subjects perform a perceptual discrimination which requires close attention to every stimulus, the amplitude of the cortical evoked responses varies with the attentive set of the subject.

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References and Notes

1. M. Haider, P. Spong, D. B. Lindsley, *Science* **145**, 180 (1964).
2. Flash intensity measured by Spectra Brightness Spot Meter (Photo Research Corporation) at various flash rates and extrapolated; click intensity measured in microbars, a calibrated condenser microphone being used (Brüel and Kjaer type 4134).
3. H. H. Jasper, *Electroencephalog. Clin. Neurophysiol.* **10**, 371 (1958).
4. P. Buser and M. Imbert, in *Sensory Communication*, W. A. Rosenblith, Ed. (Wiley, New York, 1961).
5. M. W. van Hof *et al.*, *Acta Physiol. Pharmacol. Neerl.* **11**, 485 (1962).
6. M. Jouvet, *Psychol. Franc.* **2**, 254 (1957).
7. E. Garcia-Austt, J. Bogacz, A. Vanzulli, *Electroencephalog. Clin. Neurophysiol.* **17**, 136 (1964).
8. E. Callaway, R. T. Jones, R. S. Layne, *Arch. Gen. Psychiat.* **12**, 83 (1965).
9. H. Davis, *Science* **145**, 182 (1964).
10. Supported by NASA contract NsG-623 and NSF grant GB-1844; also aided by ONR, contract Nonr 233(32). One of us (M.H.) was a USPHS international postdoctoral research fellow (FF-534).

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Carotid Sinus and Aortic Reflexes in the Regulation of Circulation during Sleep

Abstract. *In the cat with intact sino-aortic reflexes, episodes of deep sleep are accompanied by marked falls in both systolic and diastolic blood pressure. The falls are much larger after bilateral sino-aortic deafferentation: to such low pressures during deep sleep that episodes of transient cerebral ischemia (electroencephalographic flattening and seizures) sometimes occur.*

It has been known for years that arterial pressure is somewhat decreased during sleep, both in experimental animals and in man (*1*). In cats and dogs (*2*), however, decrease in pressure is only slight during light sleep, when synchronized patterns are present in the electroencephalogram, and when electromyographic activity of the neck indicates persistence of postural tone. A more marked fall, of 20 to 30 and sometimes 40 mm-Hg, occurs only during rhythmically occurring episodes of deeper sleep, signaled by a desynchronized electroencephalogram, a flat elec-