LOCAL RESPONSE OF THE HUMAN ELECTROENCEPHALOGRAM TO LIGHT

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In the human electroencephalogram (EEG), afferent stimulation causes either a depression or an increase in the original activity. In addition to the general changes, there are also local responses to stimulation, which are referred to as evoked responses. It has frequently been shown [4, 6, 8, 12] that, in man, local responses to light, sound, and proprioceptive stimulation may be recorded through the skull from the corresponding projection areas. They evidently correspond to the "primary" responses found in animals, though they do not appear to be the same, on account of the method by which they are recorded. For this reason it is better to refer to them as the "local specific response."

The responses are not easily recorded through the skull because their voltage is small compared with the spontaneous EEG potentials. In order to obtain a specific response to light in the human EEG, most authors have disposed the electrodes sagittally and parasagitally over the occipital protuberance, using bipolar vertical leads [6, 12].

It has frequently been shown [1, 3, 7, 9] that application of stimuli to different sensory modalities in addition to producing the specific response causes also a response which is best shown in the vertex region and which may take the form of either a rapid oscillation, a slow wave, or a series of oscillations (vertex complex). Many authors have associated this nonspecific local response with the activity of the thalamic reticular formation. Both the amplitude and the latent period of the nonspecific response are greater than those of the specific response.

The present investigation represents an attempt to determine the conditions under which a well-marked specific response to light may occur in the human EEG, as recorded on an ink-writing electroencephalogram.

A comparison was made of the specific and the nonspecific responses to light, because in many cases when extraneous stimuli have been used the nonspecific effect has been much better shown and more widely distributed than the specific.

METHOD

The observations were carried out on 21 healthy human subjects between 18 and 36 years old and on three older individuals; in all, 35 records were made. In many cases, other studies were made of patients with local brain damage, the EEG being recorded on an ink-writing electroencephalogram. Electrodes made by the firm Al'var were used. Light flashes were supplied by a Kaiser photostimulator, or by a Soviet FFS-1 instrument. The subjects were seated and their eyes were open; the stimulus lamp was placed level with the eyes at 50-70 cm distance.

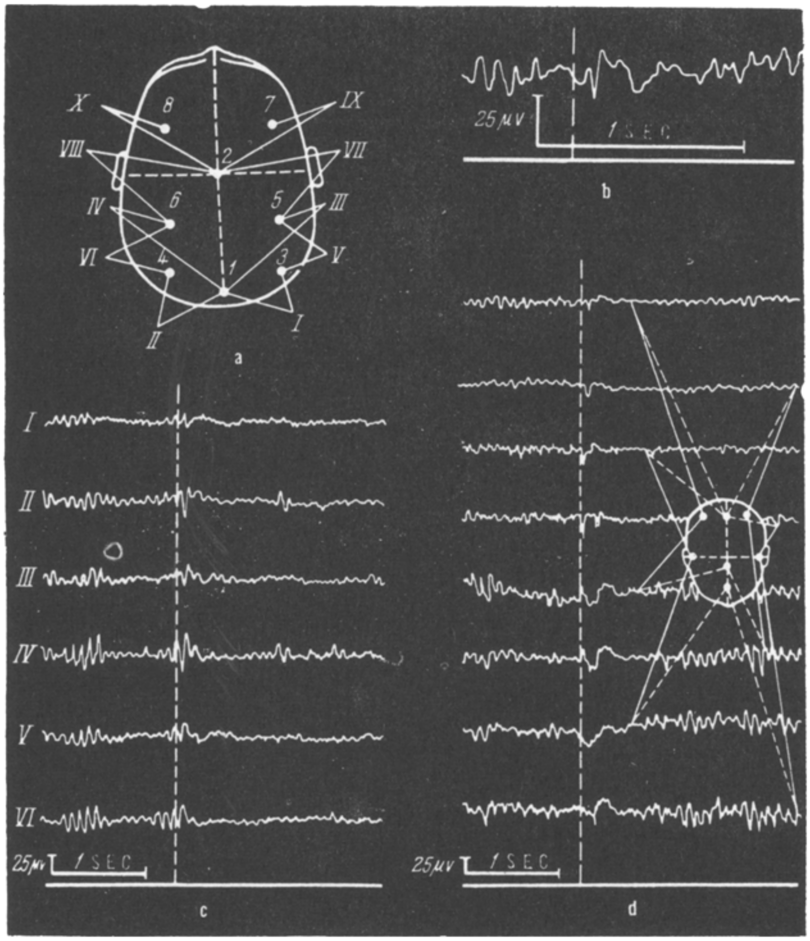

Fig. 1. Arrangement for obtaining the nonspecific response to light in the human electroencephalogram. a) Diagram of the leads. Disposition of the electrodes: sagittal electrodes: 1) over the occipital protuberance; 2) over the vertex; 3, 4) occipital leads; 5, 6) posterior parental electrodes; 7, 8) posterior frontal electrodes. b) A specific response to a single flash of light; c) well-shown specific effect to light in different leads from the occipital region; d) distribution of the specific and nonspecific responses to light according to areas.

The position of the electrodes is shown in Figs. 1, 2, and 3.

For the specific response to light leads I-II, III-IV, and V-VI were used, and for the nonspecific response leads VII-VIII and IX-X. In many of the investigations, there were very small deviations from the disposition of the electrodes illustrated.

RESULTS

The response to a single flash of light takes the form of rapid oscillation followed by alpha-like waves (Fig. 1b). It is best shown in the leads I-II, III-IV (Fig. 1c). As can be seen from the curves of the vertex leads V-VI, it is absent or less well developed in the first two leads. However, it is just this arrangement of leads which is most often used by other investigators. Sometimes the specific response to light spreads to the bordering anterior areas, but it was always best shown in the sagittal lead I, and the effect is evidently due to the disposition of the visual fields on the medial surface of the hemispheres.

When there is also a nonspecific response to light its distribution according to areas is clearly seen (Fig. 1d). In the curve given, the specific response to light takes the form of a rapid oscillation, while the nonspecific effect

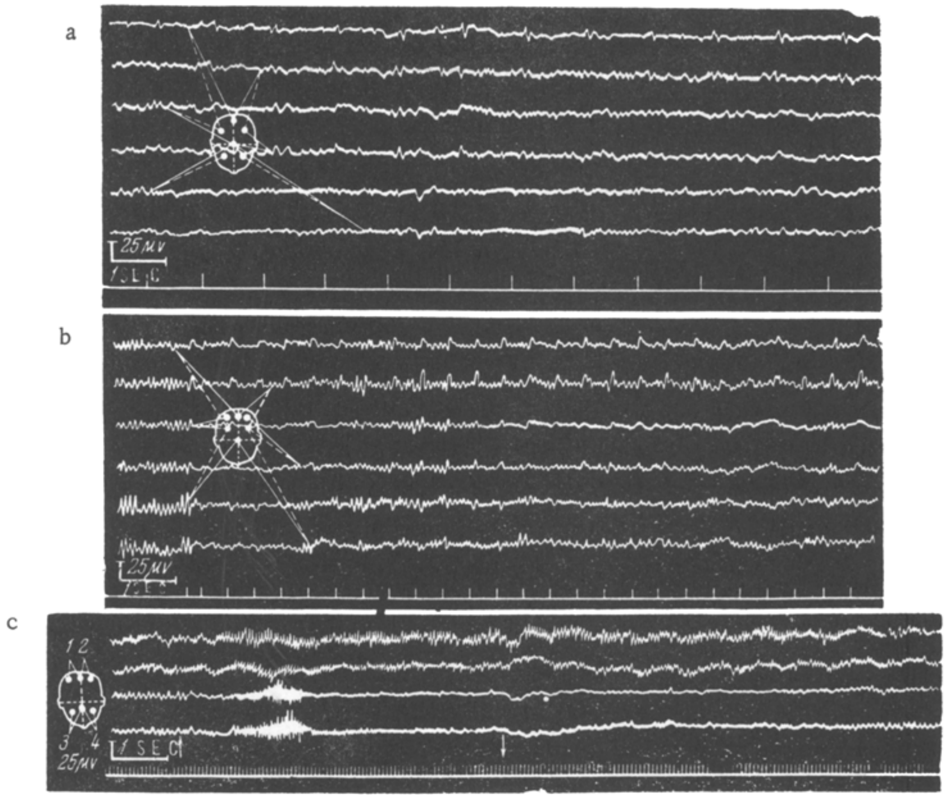

Fig. 2. Specific and nonspecific responses in the human electroencephalogram. a) Extinction of the nonspecific response to light by rhythmical stimulation, with preservation of the specific effect; b) increase of the specific response to light during stimulation; c) increase in the specific response to light during clenching fist in a patient with a tumor of the frontal bone.

is represented by a slow biphasic wave. In leads I-IV a specific effect is shown, and in leads V-VI there is also a specific effect followed by a nonspecific response. In leads VII-VIII, there is a nonspecific response only.

The specific and nonspecific responses differ not only in the latent period, shape, and in the region from which they are recorded, but they differ also when rhythmic stimuli are applied. It can be seen from the curves of Fig. 2a that at a flicker frequency of 1 per second, the nonspecific component disappears after 6 seconds. At a higher frequency the nonspecific effect develops only in response to the first flash. However, the specific effect to rhythmic light stimulation does not die out. Further, as the stimulation is continued, the specific response to light increases in amplitude and becomes more regular (Fig. 2b).

An increase in the not very clearly shown response to light can also be observed when other afferent stimuli are produced by sound, or by tightly squeezing the fist. In some cases of local cerebral damage, this increase was very marked. For instance, Fig. 2c shows the EEG of a patient with a tumor of the frontal bone which extended intracranially and compressed the frontal lobe. When rhythmic light stimuli were applied, there was a specific response to light in leads I-II, which followed the stimulus rhythm. In leads III-IV the Rolandic rhythm was recorded, and it did not change when light stimuli were applied. When the patient closed his fist more tightly, the Rolandic rhythm was depressed, and there was an increase in the light response in leads I-II. When the fingers of the fist were relaxed, the Rolandic rhythm gradually recovered, and at the same time the response to light became less marked.

In many cases, when the specific response to light was well shown, it became reduced when the afferent stimulation was continued.

A factor which increases the specific response to light is a general illumination during the investigation.

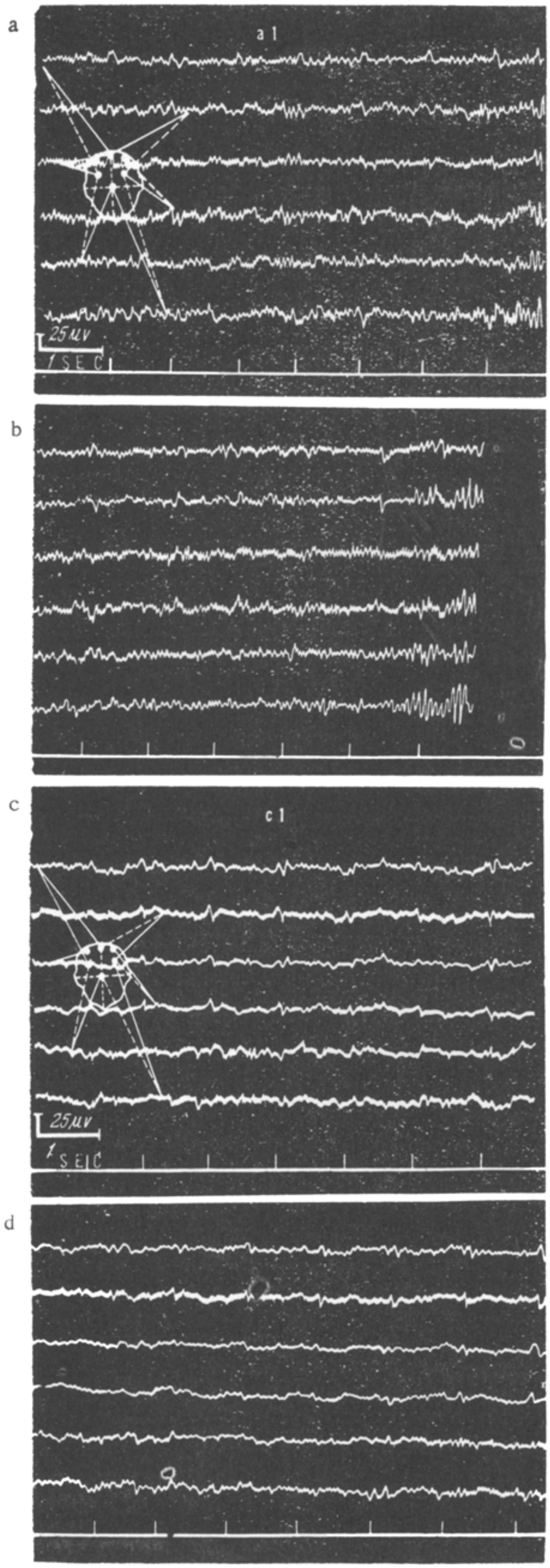

Fig. 3. The specific response to light in darkness and in general illumination in the same subject. Key: a1) In the dark; c1) with a light background.

Figure 3 shows EEGs recorded from the same subject in the dark, and in general illumination. The response to rhythmic light stimulation at a frequency of 1-2 per second in darkness is poorly shown both at the beginning (Fig. 3a) and at the end (Fig. 3b) of the investigation. The response to stimulation at the same frequency obtained in general illumination is well shown at the beginning (Fig. 3c), and at the end (Fig. 3d). With general illumination the specific response to light can as a rule be recorded over a wider region, and in particular in leads VII-VIII.

The results obtained on the increase in the amplitude of the specific response to light when additional afferent stimulation of the auditory or proprioceptive receptors is given during general illumination in man agrees with the results obtained in animal experiments.

Chang [5] showed that the electrical response of the visual cortex to stimulation of the lateral geniculate body and the response of the auditory cortex to stimulation of the medial geniculate body are increased in amplitude by illumination of the retina; the threshold of the responses is also reduced. However, a very bright light may suppress the responses. Gellhorn [10] found that in the cat under dial anesthesia, the primary responses of the visual and auditory areas were increased in amplitude during painful stimulation, and became more regular and extended over a greater area of the cortex. Other results have been obtained which are the reverse of those described above. Thus, in animal experiments, S. P. Narikashvili [2] found that when the preparation was in good condition and when the strength of the stimuli was appropriately chosen, sound stimulation might exert a depressive effect on the primary response of the visual area, and light stimulation might similarly depress the response of the auditory area.

Studies on man have been made by Jasper and Cruishank [11]. They studied the response of the human EEG to light, and found that the response was maximal in amplitude and most regular in cases when the muscles were relaxed and the eyes were closed.

The reason for these contradictions was evidently due to the different conditions under which the experiments were carried out and the different kinds of strength of stimuli used.

All the facts we have considered show that a current of nervous impulses passing along one afferent pathway will affect the activity of another system, will reflect the excitability of the brain and in so doing will establish a background on which the activity of any other afferent system will be manifested. Evidently the change in excitability concerns not only the cortical neurons, but the whole afferent system. Chang [5] has shown that when the whole of the grey matter of the brain is removed, the effect of the increase of the primary response to illumination of the retina is preserved. Probably such effects are mediated through the nonspecific projection system.

SUMMARY

A study was made of the local specific response to light in the human EEG, registered by bipolar recording with a sagittal occipital electrode. It was found that background illumination combined with additional sound or proprioceptive stimulation caused the amplitude of the response to increase, to become more regular, and to spread to adjacent areas.

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