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VISUAL SENSATIONS AROUSED BY MAGNETIC FIELDS[1]

HORACE B. BARLOW, HENRY I. KOHN AND E. GEOFFREY WALSH

From the Department of Biology, Massachusetts Institute of Technology, Cambridge, and the Harvard Medical School, Boston, Massachusetts

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Visual sensations aroused by physical stimuli other than light are called phosphenes, and their production by the application of electric currents to the eye has long been known. Electromagnetic fields may also elicit phosphenes; a relatively obscure fact which d'Arsonval (1896) appears to have been the first to record. Thompson (1910) unaware of previous work, rediscovered this effect of magnetic fields using 1,000 Gauss at 50 c.p.s. and described the sensation as a colorless flicker which was brightest in the peripheral parts of the visual field. Dunlap (1911) and Magnusson and Stevens (1912) confirmed this description and made the additional observation that the 25 cycle field was more effective than the 60. For our work we used alternating magnetic fields of variable frequency and compared the properties of the sensations thereby produced with those produced by passing sinusoidal electric currents through the head.

METHODS. The magnet had 397 turns of number 16 copper wire. The dimensions were: internal diameter 10.5 cm., external diameter 20.3 cm., length 7.3 cm. A laminated iron core 5.3 x 2.9 x 37 cm. was placed inside the winding. Current was supplied by a generator, and the strength was adjusted by a variable transformer. The frequency was measured with a calibrated magneto and varied from 10 to 90 c.p.s. The field strength was calculated from the readings of an A.C. voltmeter connected to a small search coil, calibrated in a field of known strength and frequency. All values are in R. M. S. Gauss. Using 20 amperes we were able to obtain up to 900 Gauss. The subject was seated with his temple close to, but not necessarily in contact with, the core of the magnet; under optimal conditions the phosphene could be seen when the temple was several centimeters from the core. The subject fixated steadily on a white spot placed in the center of a dark grey background.

To produce phosphenes by electrical stimulation current from a beat frequency oscillator was applied between an electrode on the side of the forehead and one on the back of the forearm. These electrodes were copper discs 3 cm. in diameter, covered with cloth soaked in saturated sodium chloride solution, and were held in place with adhesive tape. Small changes in inter-electrode resistance should not affect the results since current, not voltage, was measured. The currents used never exceeded 1 milliampere and we were not troubled with pain at the site of the electrode.

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The wave forms of both the magnetic fields and the electric currents were sinusoidal at all frequencies used. Most of the work was done upon ourselves but several others have seen the phosphenes.

RESULTS. The sensations aroused by sinusoidal magnetic and electric stimuli were qualitatively the same at the strengths used by us. At a field strength of 760 Gauss, or a current of 0.3 mA., a stimulus at 60 c.p.s. produced a definite but not very intense shimmering in the periphery of the visual field. This was usually colorless but was occasionally described as faintly tinted with blue or yellow. The phosphene was seen both with the eyes open and shut, and at these intensities lasted only a few seconds, gradually fading until it was no longer perceptible. As the intensity of the stimulus was increased the flickering appeared brighter and persisted for a longer time. It filled a larger part of the visual field, approaching the central part from the periphery, but we have never seen it occupy the point of fixation. The flicker was difficult to detect if the illumination of the field was intense.

The iron core of the magnet concentrated the field in a comparatively small area, and by using a search coil it was found that the field intensity had fallen considerably even a few centimeters away. Therefore, for convenience most experiments were carried out with the temple close to the core. No phosphenes were aroused by placing the coil over the occipital region of the skull even when high field strengths were used. A more localised field was obtained by using a core which came to a point a few millimeters in diameter, and this concentrated the most intense part of the field over a small area of the retina. The sensations thus aroused were referred to the opposite quadrant of the visual field; for example, the flickering was seen medially if the magnet was applied laterally, and above if it was applied below. These relationships suggest that it is the retina itself which is stimulated by the magnetic field rather than the optic nerve.

Firm pressure on the eyeball causes complete but temporary loss of vision in a few seconds. This procedure also renders the eye insensitive not only to electric stimuli (Finkelstein, 1894), but to magnetic stimuli as well, an observation that supports the view that the locus of excitation is within the eyeball.

If the eye is subjected to strong magnetic or electric stimulation a period follows during which excitation is more difficult. This can be shown by subjecting the eye to strong stimuli of 10 to 60 seconds' duration, and measuring the time at which the eye again responds to slightly suprathreshold stimuli, applied every 5 seconds. The threshold was taken as that stimulus strength which produced a visual sensation in half the trials. Threshold determinations were not at all easy; nevertheless as the figures in table 1 show it was evident that a period of subnormality followed the application of strong stimuli and lasted as long as 30 seconds in some instances. The period of subnormality was longer when the fatiguing stimulus was maintained for 60 seconds rather than for 10 seconds, even though the sensation had disappeared within the first ten seconds. When one eye was stimulated maximally with the magnetic field for 60 seconds no change was detected in the threshold of the opposite eye.

In some experiments the duration of the sensation produced by a steadily