Reports

Moon Illusion and Emmert's Law

Abstract. The perceived size of an afterimage varies with the part of the sky to which it is projected in a manner predictable from Emmert's Law and the appearance of the sky as a flattened dome. This effect is directly analogous to the moon illusion.

The fact that the moon looks larger near the horizon than at its zenith, although the size of the retinal image does not vary, has long been noted. Among early commentators, Ptolemy (*1*) proposed that the sky appears as a flattened dome, the moon's perceived size varying with the perceived distance of the surface to which it is attached, as shown in Fig. 1.

Holway and Boring (*2*) proposed that the moon illusion is caused by changes of the position of the eyes in the head as the angle of elevation of the moon changes. Kaufman and Rock (*3*), however, were able to show that the position of the eyes in the head does not influence the perceived size of the moon. Since, in their experiments, factors such as terrain and cloud formations were important, they decided in favor of the Ptolemaic hypothesis, emphasizing visual perspective.

Recently, Gruber, King, and Link (*4*) have tested the same approach in a laboratory setting. Artificial moons of the same retinal size were presented at different angles of elevation against a luminous ceiling: the "horizon moon" looked larger than the "zenith moon." Control subjects who viewed the moons in a dark room saw them as being the same size. For some subjects an *imaginary* ceiling was induced by first showing them the luminous ceiling and then removing it before introducing the artificial moons. The moon illusion was obtained with the artificial moons seen against this imaginary ceiling.

The present experiment is a demonstration of a new phenomenon analogous to the moon illusion. Emmert's Law states that the apparent size of an afterimage is "directly proportional to its apparent distance from the observer" (*5*); it is usually demonstrated by measuring the apparent size of afterimages projected onto real surfaces. If, however, the sky is perceived as the surface of a flattened dome, with the surface near the horizon further from the observer than the surface at the zenith, then it follows from Emmert's Law that an afterimage viewed against the sky near the horizon should look larger than an afterimage viewed against the sky at the zenith. Figure 1, therefore, applies as well to an afterimage as it does to the retinal image produced by the moon.

In this experiment, the subjects developed an afterimage and then viewed it against different parts of the sky. The stimulus for the afterimage was a 2-inch square of highly saturated blue paper on a yellow background. The fixation point was the subject's own eye, viewed in a 0.5-inch diameter mirror, the near edge of which was 0.125 inch from the blue square. When fixated for 30 seconds at a distance of 2 feet this stimulus gave a distinct yellow-green afterimage that lasted long enough for the subject to make several judgments of its size against different parts of the sky.

The subject was first instructed on how to produce afterimages and on how to make a size-ratio judgment of two squares by using the lengths of the sides. He was then given practice in moving his head from one viewing position to another so that he could view the afterimage against the prescribed part of the sky without markedly changing the position of the eyes with respect to the head. On each trial, the subject was required to develop an afterimage, then to fixate two different parts of the sky successively, closing his eye between fixations, and finally to give a judgment of the size-ratio of the two afterimages. The subject was encouraged to move back and forth between the two positions several times before making his judgment, and all subjects took advantage of this technique. One eye was covered throughout the experiment.

Three parts of the sky were used as "viewing surfaces": near the horizon, 45° elevation, and 90° elevation. Each subject made four size-ratio judgments: two judgments comparing afterimages at the horizon and 45°, and two judgments comparing afterimages at the horizon and 90°. When inspecting the afterimage near the horizon, the subject was instructed to choose a fixation point such that the entire image would be seen against the sky, and none of it against the ground. The order of judgments was counterbalanced between subjects to obviate serial effects.

The experiment was conducted on a rooftop from which a clear view of the horizon could be obtained. The terrain under the sky was flat, with no large obstructions. To avoid having the subject gaze at an uncomfortably bright sky, all observations were made with the sun at his back. Judgments were made under a variety of cloud conditions. Of 16 subjects, eight were tested with a cloudless sky, five were tested with a sky having a few wisps of cloud but permitting inspection of all afterimages against blue sky, and three were

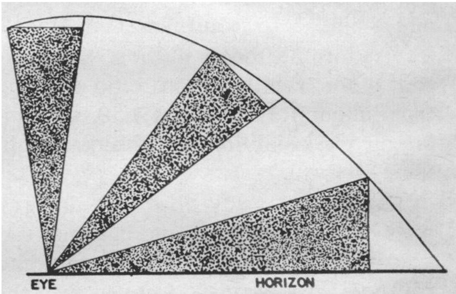

Fig. 1. The moon illusion and Emmert's Law. The three cones subtend equal angles, indicating the way in which a retinal image of a given size would produce an object of varying perceived size, depending on the part of a dome-like sky in which it is seen.

Instructions for preparing reports. Begin the report with an abstract of from 45 to 55 words. The abstract should *not* repeat phrases employed in the title. It should work with the title to give the reader a summary of the results presented in the report proper.

Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to contributors" [*Science* 125, 16 (1957)].

tested with an overcast sky. Since these differences in cloud conditions had no apparent effect, results for all subjects have been grouped together.

For five subjects the correct positioning of the head was determined by a headboard preset by the experimenter; for 11 subjects it was determined by the subject's own estimate. Since this factor had no effect on the results, all 16 subjects have been combined below.

The subjects experienced some initial difficulty in assuming the correct head positions and in fixating a point on the "surface" of the sky. For this reason, the first two trials for each subject are considered as practice, and results are reported only for the last two trials. It should be noted, however, that the results for the practice trials were very similar to the results for the final trials.

Of the 16 subjects, 14 saw the horizon afterimage as larger than the 90° afterimage; 13 saw the horizon image as larger than the 45° image. The two subjects who did not report the effect described above both experienced extreme difficulty in following the instruction to fixate a point on the "surface" of the sky. It will be remembered that all judgments in the main experiment were monocular; after the monocular trials, both of these subjects were given a binocular trial, whereupon they reported the horizon image larger than the zenith image. Omitting these two subjects, the mean size-ratio for the horizon/90° comparison was 1.625, with S.D.=.252. For the horizon/45° comparison, the mean size-ratio was 1.50, with S.D.=.266. Thus it can be seen that the perceived size of the afterimage varies in a manner predictable from Emmert's Law and the reported appearance of the sky as a flattened dome.

It is interesting to note that the magnitude of the effect reported above is quite similar to Kaufman and Rock's results for the moon illusion, the horizon moon/zenith moon ratio varying from about 1.35 to about 1.50, depending on the conditions of observation in their study.

The present study illustrates the way in which sensory inputs become significant objects as they are mapped into psychological spaces. Conversely, the object can be used as a probe for investigating the nature of these spaces.

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References and Notes

1. For a discussion of this hypothesis see *Helmholtz's Physiological Optics*, J. P. C. Southall, Ed. (Optical Society of America, 1925), vol. 3, pp. 290 ff.
2. A. H. Holway and E. G. Boring, *Am. J. Psychol.* 53, 109 (1940).
3. L. Kaufman and I. Rock, paper presented at the meeting of the Eastern Psychological Association, New York, Apr. 1960.
4. H. Gruber, W. King, S. Link, paper presented at the meeting of the Western Psychological Association, Seattle, Wash., June 1961.
5. E. G. Boring, *Sensation and Perception in the History of Experimental Psychology* (Appleton-Century, New York, 1942), p. 292.

19 October 1961

Drug Administration to Cerebral Cortex of Freely Moving Dogs

Abstract. A method is described to implant a permanent indwelling polyethylene tube venting to the surface of the cerebral cortex of the dog. Morphine, amobarbital, or imipramine was administered through the tube, and behavioral changes were observed in unanesthetized and unrestrained animals. The results are different from those occurring after intraventricular injection.

Other workers have described the effect of topical application of drugs to the cerebral cortex. In their experiments, the animal was anesthetized or immobilized, and usually a large area of the cortex was exposed (*1*). This report, however, describes a new technique for administering drugs to the cortex in conscious and unrestrained dogs, permitting the observation of behavioral changes. By this technique, the drugs were injected into the arachnoid space (*2*) overlying the cerebral cortex, through a polyethylene tube permanently implanted in the skull (intra-arachnoid injection over cerebral hemisphere).

In this study employing the intra-arachnoid injection over cerebral hemisphere, three drugs were given. The results from the intra-arachnoid injection were compared with those from intraventricular injection of the drug through a permanently implanted cannula, in order to study the site of action of drugs.

To install the tube, a midline incision of about 5 cm was made near the vertex of the head of the dog under pentobarbital anesthesia. The surface of the skull was exposed and a hole 4.5 mm in diameter was drilled through the skull directly above the lateral ventricle (*3*). In this hole either a polyethylene tube for intra-arachnoid injection or a metal cannula for intraventricular injection was implanted. The location of the hole was carefully determined in order to permit the intraventricular implantation. The determination was done without the use of stereotaxic apparatus which produces deafness. Using the external occipital protuberance as the center of a circle, I drew an arc intersecting the midline close to the vertex of the skull. The radius of the arc was half the distance between the supraorbital process of the frontal bone and the external occipital protuberance. The hole was drilled at a point 6 mm lateral to this midline intersection. The hole was perpendicular to the Frankfort horizontal plane, as determined by the external meatus of each ear and the lower edge of the ocular orbits.

To implant the tube an incision was made in the dura mater through the hole. The polyethylene tube (Intramedic; PE 10; I.D. 0.011 inch; O.D. 0.024 inch) connected to a sawed-off hypodermic needle was inserted 2 to 3

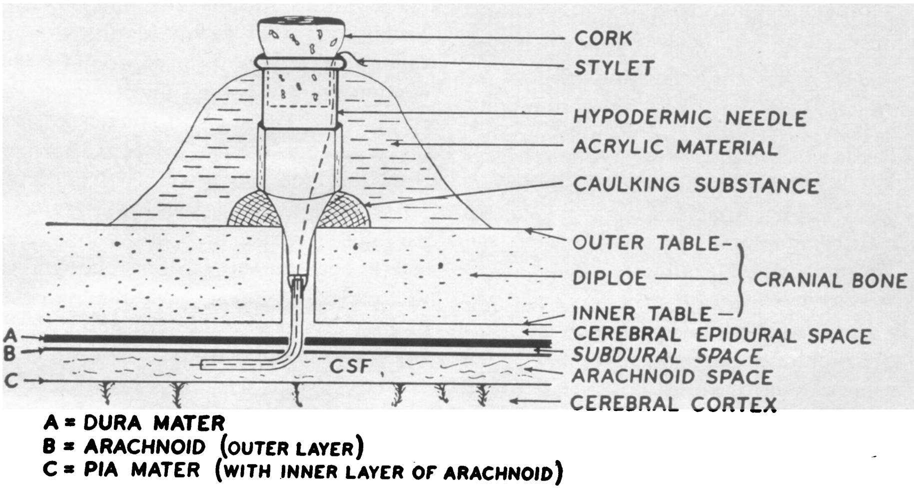

Fig. 1. Schematic representation of setup for permanent indwelling polyethylene tube into the arachnoid space.