Gibson (*10, 11*) pointed out that the features to which physiologists have found responses in mammalian visual systems—such as disks, lines, and edges moving on homogeneous screens—are highly ambiguous for perception. An edge in the optic array can specify the edge of an object in the environment, but it can also signal a shadow, a change in contour, or many other things. Useful structure in the ambient optic array comes not from differences in brightness, but from stabilities in optical patterns over time and the lawful transformations of these patterns.

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Object Distance as a Determinant of Visual Fixation in Early Infancy

Abstract. *Data from two experiments show that the duration of visual fixation of solid objects by infants aged 6 to 20 weeks varies as a function of object distance between 30 and 90 centimeters. There was no characteristic habituation of fixation of an object at 90 centimeters but there was a marked increase in fixation time when objects were advanced to 30 centimeters (experiment 1). A linear decline in fixation times occurred as the object distance increased from 30 to 90 centimeters with the real size and the angular size of the object held constant (experiment 2). No evidence for visual size constancy in young infants was obtained by this method.*

During the course of a series of experiments designed to investigate visual size constancy in early infancy, we obtained evidence strongly suggesting that object distance is a critical determinant of the duration of visual fixation, regardless of the object's actual or retinal size. Further investigation confirmed this suggestion, showing that infants between 6 and 20 weeks of age pay little regard to objects located at more than about 1 m away. These results bear closely on theories of the development of space perception and have obvious implications for experiments on infant perception in which visual fixation serves as an index of discrimination. When objects of the same actual or retinal size are presented repeatedly at different distances, infants respond to the variation in object distance rather than to the constancy of actual or retinal size. We report here the results received in our two experiments.

In the first experiment the degree of recovery from habituation (*1*) of visual fixation was used as an index of the apparent size of white cubes. After ten 10-second trials (5-second intervals between trials) with an 18-cm (visual angle, 11°26′) cube at a distance of 90 cm, the same (18-cm) or a different (6-cm) cube was presented for two 10-second test trials at either 90 cm or 30 cm. Thus the four test conditions were as follows: 18-cm object at 90 cm, 18-cm object at 30 cm, 6-cm object at 90 cm, and 6-cm object at 30 cm. These conditions essentially replicate those used by Bower (*2*) but with smaller objects at shorter distances. It was our original intention that the degree of recovery (increments in fixation time) under these four conditions would indicate whether the apparent size is determined mainly by the object's real size irrespective of distance (perceptual constancy) or by the angle subtended by the object at the eye (visual angle). Thus minimum recovery when the same (18-cm) cube was presented at 30 cm would have suggested constancy, whereas minimum recovery when the 6-cm cube was presented at 30 cm would have suggested visual angle. It was assumed that the magnitude of recovery would reflect the magnitude of the perceived change.

A group of 32 healthy, full-term infants viewed the suspended white cubes in an observation chamber 140 cm long, 76 cm wide, and sloping from 64 cm high at the viewing end to 98 cm at the other. The interior was dark blue to provide high contrast with the cubes, the surfaces of which were of different reflectances to give constant luminance when illuminated by two 20-watt fluorescent tubes mounted in the corners behind the infant. Black crosses 18 mm wide for the large cube and 6 mm wide for the small cube were taped on the surfaces facing the subject. The infant was deemed to be fixating on the cube when the center of the corneal reflection of the cross was centered in the pupil as observed from a 7-mm aperture in the side of the chamber in front of, and to the right of, the subject (*3*). Fixation was manually timed by means of a switch which operated a printout timer. Separate groups of eight infants, four boys and four girls in each group, were assigned to each test condition. In each group there were two age levels, 6 to 12 weeks and 13 to 20 weeks, equally distributed between the sexes.

The mean fixation times for each group during the ten habituation trials and the two test trials are shown in Fig. 1A. Appropriate tests of trend (*4*) over habituation trials showed no significant overall decline in fixation time and no differences in trend between the four groups or the two age levels. Contrary to expectation, there was no habituation of fixation over ten trials with an 18-cm object at 90 cm. Using an analysis of variance that took into account groups, age, and sex (*5*), we examined the change in fixation time in the test phase by comparing the mean fixation time of the last two habituation trials with the fixation time during the first test trial. There were significant main effects for groups and for trials ($P < .01$ in both instances), and a significant interaction between groups and trials ($P < .05$). There was no significant increase in fixation time for the two test conditions in which the 18-cm or 6-cm object remained at 90 cm, but a large and significant increase occurred for both conditions in which the 18-cm and 6-cm objects were presented at 30 cm. Despite the difference in visual angle, there was no difference in fixation time for these latter two conditions. Neither age nor sex proved to be significant variables.

Thus with a large object at 90 cm there was no habituation of fixation over ten trials (*6*) and no change in fixation time when a smaller object was presented at that distance. However, a marked increase occurred when either the large or small object was presented at 30 cm. These data strongly suggest that fixation time depends in large part on the distance of the object.

In a second experiment we compared the effect of distance on fixation time between two conditions: (i) retinal size constant over distance (that is, actual size proportional to distance) and (ii) actual size constant over distance (that is, retinal size inversely proportional to distance).

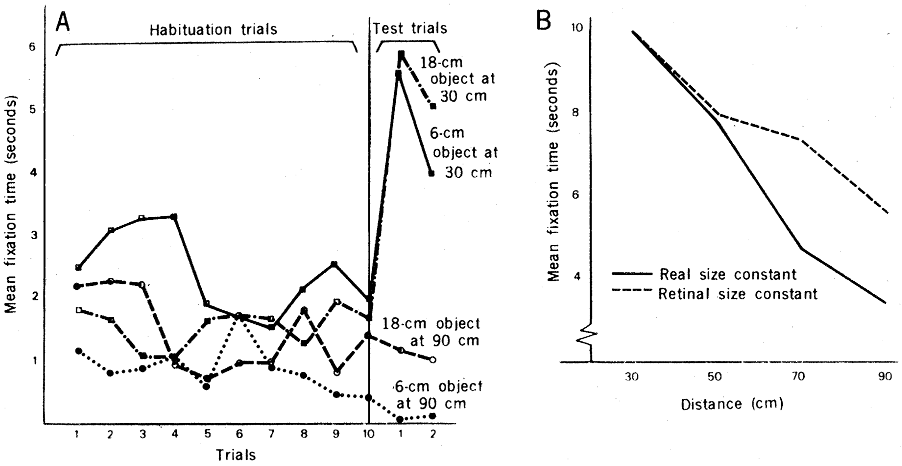

Fig. 1. (A) Mean fixation times of three-dimensional patterned cubes during ten 10-second habituation trials and two 10-second test trials for each of four test trial conditions. (B) Mean fixation times for three-dimensional patterned cubes at four distances (30, 50, 70, and 90 cm) with the real size and the retinal size of the cube held constant.

Two groups of 16 infants each were presented with white cubes of constant actual or angular size with their near surfaces at distances of 30, 50, 70, and 90 cm. The surface luminance was constant, and black crosses with widths proportional to cube size were taped on near surfaces. For one group the cubes were 18 cm on a side at all distances and for the other a constant angular size of 11°26′ was maintained with cubes 6, 10, 14, and 18 cm on a side. The viewing chamber and the observation and recording procedures were essentially the same as in the first experiment. There were eight boys and eight girls in each group and two age levels, 6 to 12 weeks and 13 to 20 weeks, equally distributed between the sexes. The objects were presented twice at each distance for 20 seconds with four orders of presentation of the eight trials. In each group four infants balanced for age and sex were assigned to each order. Controls for decline in attention over the eight trials and for the effects of variation in surface reflectance necessary to maintain constant luminance were introduced. We monitored the attention of the infants by presenting a cube with an irregular yellow and black pattern for 20 seconds either after the eight trials for half the subjects or before and after for the other half. Any progressive change in level of attention would have been clear from the time of fixation to this novel and interesting object. A separate control group of eight subjects with the same representation of sex and age viewed an 18-cm white cube at the four distances so that, while its reflectance remained constant, its illuminance declined with distance from the light source.

The mean fixation times based on the two trials at each distance are plotted in Fig. 1B for the two groups. Analysis of variance showed that the effect on fixation time of distance was significant ($P < .001$) and that age was a significant variable ($P < .01$), with the younger infants looking longer (9.0 seconds) than the older (5.2 seconds). The analysis revealed no significant effect due to groups or sex and no significant interaction of these factors with any other variable. A trend analysis (*4*) over distance showed a significant linear component only ($P < .001$) and no difference in trend due to group, age, or their interaction. However, a similar analysis revealed no reliable trends associated with successive trials irrespective of distance. A linear decline in fixation time with distance occurred also in the control group in which luminance varied ($P <$ .001) but here again there was no reliable decline over successive trials irrespective of distance. Finally, consideration of fixation times for the yellow and black patterned cubes indicated that the level of attention was high at the beginning of a session and did not decline noticeably during it.

In summary, the data from the first experiment show that there was no habituation of visual fixation of an object at 90 cm and a marked increase in fixation when this object, or a smaller one projecting the same visual angle, was moved to 30 cm. The results of the second experiment show a steady decline in fixation with increasing distances of objects of constant real and angular size. Taken together, the results from the two experiments clearly show that the duration of visual fixation of three-dimensional patterned objects is dependent on object distance. This conclusion is strongly supported by the relationship which obtained between fixation times and distances under conditions in which the real size, angular size, and luminance of the object were controlled.

That young infants have a preferred distance of regard which increases with age was noted by Ling (*7*) and by Gesell *et al.* (*8*). This preference for near objects cannot be attributed solely to lack of accommodative ability. Haynes *et al.* (*9*) observed that the ability to bring an image into focus on the retina improves rapidly within the age range of our subjects, with mature performance by 4 months. If accommodative blur were a determinant of fixation time, it should have affected our two age groups differentially. However, no interaction of age and distance factors was observed in our experiments.

Our results do not support the hypothesis of visual size constancy in young infants. Repetitive stimulation over eight trials with object size constant and distance randomly varying did not lead to response decrement (experiment 2), and thus did not show that young infants attend solely or even mainly to real size rather than to distance or retinal size. The possibility remains, however, that an appreciation of perceptual constancies cannot be demonstrated by habituation methods with the use of an unlearned response which entails no external reinforcement. If operant training methods as used by Bower (*2*) permit size discrimination at distances well beyond the preferred range, they must also alter the relative salience of stimulus properties.

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Visual Input to the Pontine Nuclei

Abstract. *Visual input to the pons was studied by anatomical and physiological methods. Cortical area 18 sends a dense projection to the rostral pons. Pontine cells respond best to targets moving in a preferred direction over a large receptive field, which usually includes the center of gaze. The results suggest a role for pontocerebellar pathways in visual control of movement.*

The pons is one of the major targets for fibers that leave the cerebral cortex. Cells in the pontine nuclei, in turn, send their axons to the cerebellum. These anatomical facts are well established, but the function of the corticopontocerebellar pathway is not at all clear. We hoped that we could throw light on cerebellar mechanisms by studying connections to the pons of the cat's visual cortex, for which the response properties of neurons are well described (*1*). We first did an anatomical study to find the terminations of corticopontine fibers, and then recorded the type of information that is relayed to the cerebellum via the pontine nuclei (*2*).

We hoped our experiments would help us to understand another problem. In the cat the lateral geniculate nucleus sends parallel representations of the visual field to areas 17 and 18 (*3*). Since areas 17 and 18 receive independent visual maps, they may have different functions. Differences in the pattern of efferent projections from these two cortical areas might give a clue to what these functions might be.

We made lesions either by subpial suction or by stripping pia from the surface of the visual cortex in 11 cats. In one animal this was a large lesion which included almost all of areas 17, 18, and 19 on one side, in order to define the overall pattern of fiber projections from the visual cortex to the pons. Smaller lesions were placed in area 18 in six animals, and in area 17 in four others. The lesions were placed in the areas of the visual cortex that receive projections from the center of the visual fields. The animals were allowed to survive from 11 to 14 days. Eight brains were sectioned in a sagittal plane, three in a transverse plane. We stained the brains by a Nauta-Laidlaw method (*4*) to locate degenerating fibers, and determined the nature and extent of the cortical lesions with a Nissl stain.

We then recorded from pontine cells that responded to visual stimuli in 20 normal, unlesioned cats. Nembutal or Pentothal anesthesia was initially administered intraperitoneally, and the animal was maintained intravenously at a light anesthetic level throughout the experiment. There was no difference in results obtained with the two types of anesthetic. With the animal in a supine position we removed the larynx completely and drilled through the occipital bone between tympanic bullae, exposing the ventral surface of the pons. Tungsten microelectrodes with impedances between 1 and 5 megohms at 1000 hertz were then advanced into the pontine nuclei.

At the conclusion of each experiment the cats were perfused with saline followed by 10 percent formalin. The brain was removed, embedded, sectioned, and stained for reconstruction of electrode tracks. In some experiments the electrode was left in place during perfusion and fixation to make sure that we could find an important track.

In all the cats in which we destroyed a part of area 18 of the cortex we found a clear-cut focus of degenerating fibers among a group of cells of the pontine nuclei. Figure 1 illustrates the location of degenerating fiber terminals in the pons in two such cases. In all of these animals the lesion was largely confined to the cortex of area 18 on the dorsal surface of the lateral gyrus, sparing all of the posterolateral gyrus. In cat A the lesion was made by subpial suction, and the underlying white matter was slightly damaged. In cat B the lesion was made by stripping pia from the same area of the lateral gyrus, and there was only minimal invasion of white matter. In both cats degenerating preterminal fibers were found in the anterior portion of the pontine protuberance. Degenerating fibers began at about the midpoint of the pontine protuberance, extended anteriorly for about 2 mm, and were found laterally between 1 and 3 mm. Degeneration was found in the same general area of the pons in all animals in which lesions were made in area 18.

The projection from the visual cortex appeared to be entirely ipsilateral; we found degenerating fibers near pontine cells only on the same side of the brain. We have not yet studied the topographic organization of the corticopontine projection. All of our lesions were rather large for this purpose. We saw few, if any, degenerating fibers in the pons when the lesion was confined to area 17, but our lesions were restricted to the region of area 17 that receives an input from the center of the visual field.

In the physiological experiments we found a total of 42 pontine cells that were responsive to visual stimuli. These cells were in the same small rostral pontine region in which we had found degenerating fibers after lesions in area 18. Some of these cells could be activated about 25 msec after a bright flash, although moving targets were more effective. When we lowered the intensity of the flash there was an orderly increase in response latency.

All the pontine visual cells which we tested responded to an input from