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Infant Perception of the Invariant Size of Approaching and Receding Objects

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After habituation of looking at an object that repeatedly approached and receded through 50 cm along the medial axis, infants of about 18 weeks of age were presented with both the same moving object and one of a different size falling within the same range of visual angles as those projected during habituation. The starting point for movement varied widely from trial to trial to "desensitize" subjects to a range of changing distances and visual angles. Recovery from habituation of looking was greater for the moving object of a different size than for the same object, indicating that the infants perceived an object's invariant size with changing visual angle (i.e., that visual size constancy was operative). A secondary finding was that following habituation to the smaller object there was a markedly greater recovery with the larger object than with the smaller, but following habituation with the larger there was no difference between recovery for the two. These outcomes were attributed to the additive effects of object salience and recovery from habituation.

When the distance of an object varies, the representation of its size at the eye is transformed. Nevertheless, under normal viewing conditions its perceived size remains relatively unchanged. A recent series of experiments (McKenzie, Tootell, & Day, 1980) has shown that such perceptual constancy in the face of image transformations at the eye is operative at least from the end of the first half year of infancy. In this study the infants were aged between 18 and 33 weeks. Following habituation of visual fixation under one of four stimulus conditions, recovery from habituation was observed under a standard condition that represented a change in size, a change in distance, a change in size and distance, or no change at all. The pattern of recovery scores across the four groups in each experiment indicated that visual size constancy is clearly present from about 26 weeks. For infants of 18 weeks the results were less clear. For these younger subjects the recovery scores indicated nonselective perception of each change in stimulus conditions. More detailed analysis, however, showed that subjects with low variance relative to the median exhibited a pattern of recovery scores similar to that of older infants, whereas those with high variance did not. In the latter case, recovery scores were more or less the same across the various conditions of stimulus change. It was concluded that although some infants at 18 weeks may perceive the invariant size of an object when its visual image is transformed by a change in distance, others do not. In short, for the conditions of this earlier experiment, although visual size constancy was clearly present at 26 weeks, it was not unequivocally so at 18 weeks.

Two considerations suggest that visual size constancy might be more fully developed at 18 weeks than the conditions of these experiments have indicated. First, the stimulus objects located at 30 or 60 cm were always stationary. Stationary objects and patterns are notably lower in salience at this age than are moving ones (McKenzie & Day, 1976; Volkmann & Dobson, 1976; Wilcox & Clay-

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ton, 1968; Silfen & Ames, Note 1). It is conceivable, therefore, that size constancy is more fully established at 18 weeks for moving than for stationary objects. In this regard there has been little research on the development of the perception of invariant properties of objects when the objects are subjected to continuous transformations. Among the few researchers to use changing displays are Gibson and her co-workers (1978, 1979) in their studies of the perception of substance and shape. Second, Caron, Caron, and Carlson (1979) and Caron, Caron, Carlson, and Cobb (1979), also using habituation-recovery procedures, convincingly demonstrated that visual shape constancy is operative at 12 weeks. Although there is no a priori reason for supposing that shape constancy should not precede size constancy, given that both rest on the utilization of information for depth, a difference of about 14 weeks in their time of onset intuitively seems excessive.

In the experiment by Caron, Caron, and Carlson (1979), subjects were "desensitized" to slant during habituation by varying slant over a wide range. Thus responsiveness to constant shape in the recovery phase could be assessed largely independently of the accompanying change in slant. On the other hand, in the experiment by McKenzie, Tootell, and Day (1980), subjects were not familiarized to distance changes during habituation. Rather, four groups were habituated to a particular size at a particular distance, and the degrees of recovery in a standard test condition were compared. Because with the former procedure recovery in the test trials is far less likely to be due to stimulus dimensions other than real shape or size, it is likely that the method results in a more sensitive test of perceptual constancy. For this reason the "desensitization" procedure was used in the experiment reported here.

The general procedure and logic of the experiment were as follows. The subjects were presented during habituation trials with an object that continuously approached and receded through a fixed extent. Approach and recession began from one of four distances from the subject. These distances varied from subject to subject so that the infants were exposed to a range of changing visual angles as the object moved. After habituation of looking to a predetermined criterion, the same moving object and one of a different size (either larger or smaller) were presented in two test trials. These objects began moving from a point that was different from the previous starting points but such that the objects' changing visual angles fell within the range of those for the habituation trials. A difference in the extent of recovery of looking at the two objects during the test trials could not be attributed to the novel distance but could more likely be attributed to their difference in size. In particular, a greater recovery for the different-sized object could be taken as an index of size constancy for approaching and receding objects.

Another aspect of experimental design that deserves comment is the direction of the size relationship between the stimulus objects presented during the habituation and test phases. For infants in the age range studied (16–20 weeks), a large object is perceptually more salient than is a smaller one (Fantz, Fagan, & Miranda, 1975). Thus if a small object were presented during habituation trials, greater recovery with the large object would be attributable to both dishabituation and increased attention to the more salient object. In contrast, relatively slight recovery with the small object after habituation to the large one would be attributable to both dishabituation and decreased attention. In order to unconfound the effects of these two factors, one group of infants was presented with the large stimulus object during habituation trials and another with the small object. In the test trials the objects were presented in a balanced order to both groups.

Method

Subjects

There were 30 healthy, alert subjects, 15 girls and 15 boys, in the age range 16.1–19.6 weeks. The mean age was 17.9 weeks. An additional 11 infants were tested, but the results were not included because of failure to achieve the habituation criterion (7), crying or fussing

(3), or equipment malfunctioning (1). The subjects were brought to the laboratory by their mothers, who were present throughout the experimental session.

Apparatus

The experimental arrangement is shown in Figure 1. The subjects were supported in an infant seat facing a carriage consisting of two frontoparallel screens that could be moved silently on rails toward and away from the infant. The near screen was 116-cm wide and 116-cm high with a midgray matte surface. The far screen was the same width and 164-cm high. Its visible upper part was patterned with red, blue, and white vertical stripes, each about 2-cm wide. The stimulus objects were presented above the upper edge of the lower near screen and were viewed against the striped background of the far screen. The experimenter stood hidden behind the far screen and observed the subject through a .8-cm aperture while pushing and pulling the carriage through a fixed extent of 50 cm. There was a similar aperture to the right and to the left of the stimulus object. The starting and finishing points of the fixed 50-cm extent could be varied by adjusting and fixing an arrangement of stops along the rails. Thus the experimenter could move the carriage so that it repeatedly approached and receded from the infant through a fixed distance while at the same time observing the direction in which the infants looked. Another two screens, each 183 cm × 157 cm, were arranged on either side of the subject. They were patterned in the same way as the far, frontoparallel screen. Each was placed laterally about 112 cm from the subject but angled inward at about 45° so that the carriage and two side screens formed a partially enclosed chamber. Information on the distance of the object was provided by the striped pattern of the enclosing screens on either side.

A television camera was mounted on an overhead support 45 cm above and 80 cm in front of the infant. By angling the camera downward, a clear view of the subject was presented on a video monitor concealed behind the carriage. During the experiment the stimulus objects were exposed by lowering a roller blind that was fixed just below the upper edge of the near screen (see Figure 1). The experimenter could observe the subject on the monitor when the raised blind prevented direct viewing through the aperture.

Stimulus Objects

There were three stimulus objects: a large and a small model female head used in habituation and test trials and an irregularly colored ball for assessing attention before and after the habituation-test sequence. The model heads have been described already (McKenzie, Tootell, & Day, 1980). They were used in this experiment because of their demonstrated attractiveness for 4-month-old infants and in the interests of comparing results between this and the earlier experiments. The large head was about life-size and the smaller head half-size. The ball was patterned in green and red. Each stimulus object was mounted on a steel rod 1-cm thick. The three rods radiated from a hub that rotated on an axle projecting from the far side of the near frontoparallel screen. By means of this arrangement an object could be brought quickly and silently into view just above the upper edge of the near screen and locked into position.

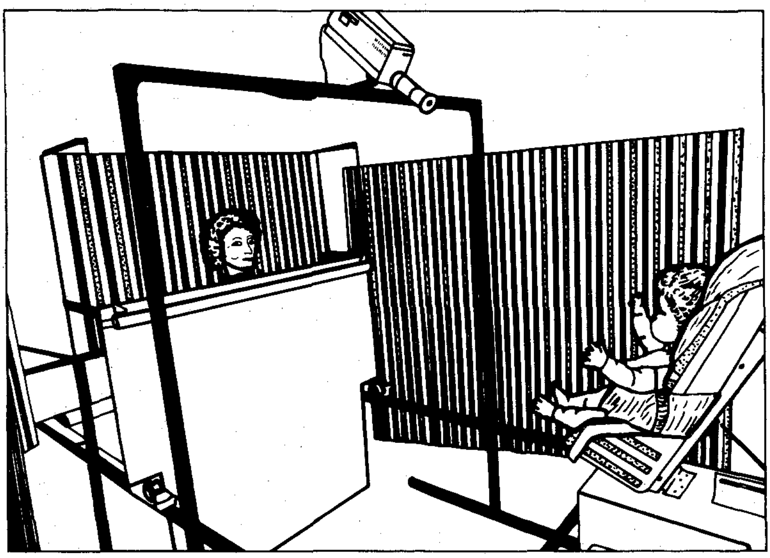

Figure 1. Experimental arrangement.

Experimental Design and Procedure

The measure of attention throughout was the time for which the subject looked at the stimulus object. This was indicated by the direction of gaze, which was observed and recorded directly by one of the experimenters. The velocity of movement of the object was about 22 cm/sec. A trial extended from the moment the subject first looked at the object until the first look-away interval of at least 2 sec.

The infants were allocated randomly to one of two groups. Subjects in one group were presented with the large head during habituation trials, and those in the other were presented with the small head. All subjects were presented with the large head for one test trial and the small head for the other with the order of presentation counterbalanced.

An experimental session consisted of two trials with the colored ball, one before the first habituation trial and one immediately after the last test trial, a number of habituation trials to criterion or to a limit of 18, and two test trials. The results of subjects who did not achieve the habituation criterion by 18 trials were not included in the analysis. The criterion for habituation was two consecutive trials with a mean looking time that was less than half the mean of the first four habituation trials. The attainment of this criterion and the termination of each trial were signaled to the experimenter by a computer through a headphone using different tones.

There were in all six different starting points for the initiation of forward and backward movement: 80, 105, 130, 155, 217, and 236 cm. The object was moved forward 50 cm and then backward 50 cm. This movement continued until the infant looked away for at least 2 sec. The combination of four starting points was different for each subject, although some of the individual points were common for two or more subjects. The starting points for the two test trials were selected between the limits of 80 and 236 cm so that the visual angle of the stimulus objects fell within the range of visual angles for the habituation trials. The starting point was 105, 130, or 155 cm depending on the particular combination of starting points selected for the habituation sequence. An example will clarify this point. A subject may have undergone habituation trials with the large head moving from the starting positions of 80, 155, 236, and 105 cm with this sequence being repeated until the criterion was achieved. For the test trials, the large and the small heads may have moved from the starting position of 130 cm. Thus both objects would move through the same extent at the same distance from the subject while projecting visual angles within the range of those for the habituation trials.

A trial began when the experimenter judged from the monitor that the infant was looking straight ahead. The blind was then lowered to expose the stimulus object against its patterned ground, and forward (toward the subject) and backward (away from the subject) movement of the carriage was initiated. The experimenter observed the subject's direction of regard through the aperture and recorded looking time by pressing a hand-held button that was coupled to the computer. The blind was raised as soon as the signal for trial termination was received. Between trials the sliding stops defining the starting and finishing points of the new 50 cm extent were adjusted. The intertrial interval varied from about 5 to 30 sec.

Reliability

It has been noted that the procedure used in this experiment, where the duration of fixation defines the trial length, presents particular difficulties for the measurement of interobserver agreement (Ames, Hunter, Black, Lithgow, & Newman, 1978). The usual measure of percentage agreement on overall looking time is unsuitable because it is not quantifiable for the case in which the observer controlling trial termination has judged that fixation has ceased and the other observer has not. We have therefore developed a procedure that permits the calculation of reliability measures for termination of trials, the number of trials to reach the habituation criterion, and the final criterion level.

For eight subjects randomly selected from the two groups, there were two observers whose judgments of initiation and termination of fixation were independently recorded by the computer. During these trials one observer was aware of the stimulus object presented to the subject during habituation and test phases, whereas the other was not. On each trial, three separate measures of fixation were entered in the results: those for Observer A (Channel A), those for Observer B (Channel B), and those obtained from the union of these two data sets (Channel AUB). For example, if on a particular trial Observer A indicated that the latency to fixation was 1 sec and the duration of fixation was 5 sec and Observer B indicated a latency of 2 sec and a fixation duration of 5.5 sec, then the fixation duration for Channel AUB was recorded as 6.5 sec. Each trial was terminated only after both observers had indicated that the infant had not been fixating for 2 sec. This resulted in three types of trials: normal, discrepant, and aborted, as illustrated in Figure 2. In the normal trials, recording ceased after the identical fixation on all three channels; in the discrepant trials, there was a new fixation on Channels B and AUB after Channel A had ceased recording; and in the aborted trials, no fixations were recorded on Channel B when recording on channels A and AUB had ceased. In this latter type of trial where there was no overlap between the judged fixation time between the two observers, the trial was aborted, and the results from this trial were not included in any calculations. Out of 103 trials for the eight subjects, 3 were aborted, 23 were discrepant, and 77 were normal.

Three separate criteria of habituation were calculated from the data sets obtained from Channels A, B, and AUB. Habituation trials were continued until all three criteria had been reached. To assess the reliability of number of trials to criterion and that of the final criterion level, the data obtained for the two observers were compared. There were two occasions when the criterion was indicated by one observer prior to the other. The

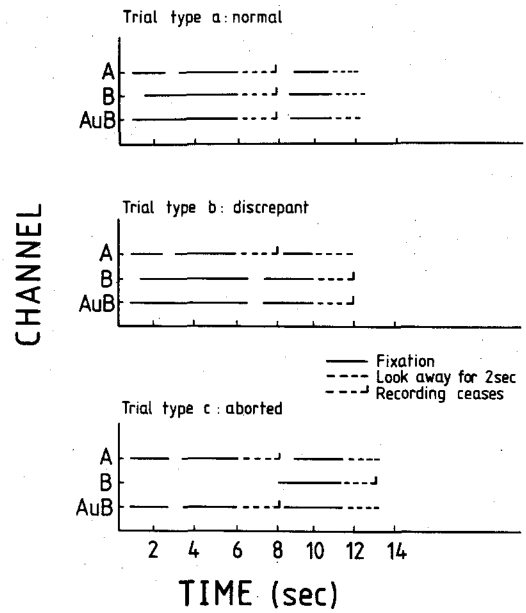

Figure 2. Representation of "normal," "discrepant," and "aborted" trials considered in the assessment of reliability.

differences in the number of trials to criterion on these two occasions were 6 and 1, respectively. The mean difference in the value of the habituation criterion for the two observers was 1.2 sec with a standard deviation of 1.77. Thus overall it appears that an acceptable degree of reliability was achieved, and there was no evidence of experimenter bias.

On the test trials the percentage agreement (seconds of agreement/seconds of agreement + seconds of disagreement) between the two observers was 92.5. This value was also regarded as acceptable.

Results

The data have been analyzed primarily to establish the relative levels of attention before and after the habituation-test sequence, the similarity of the two groups before habituation trials, and the similarity of the groups in terms of rate and final level of habituation. The mean looking times and number of trials relevant to these analyses are shown with their standard deviations in Table 1.

The mean looking times with the moving colored ball before the habituation trials (2.4 sec) and after the test trials (5.0 sec) were compared in a two-way analysis of variance, with the trials before and after the habituation-test sequence as a within-subjects vari-

Table 1
Means and Standard Deviations for Looking Times (in seconds) and for Number of Trials to Criterion

Score	Ball		Large head		Small head	
	M	*SD*	*M*	*SD*	*M*	*SD*
Looking time						
Before habituation	2.4	1.4	—		—	
After habituation	5.0	3.6	—		—	
For habituation trials 1–4	—		2.31	12.4	11.2	10.6
For last two habituation trials	—		6.1	4.0	3.1	2.2
Number of trials to criterion	—		6.9	.6	9.1	3.8

able and groups as a between-subjects variable. The effect due to trials was significant, $F(1, 28) = 19.23, p < .01$, whereas that due to groups was not, $F(1, 28) = 1.57, p > .05$. The interaction between trials and groups also failed to achieve significance. It can be concluded, therefore, that there was no nonspecific decline in attention following the experimental treatment. In point of fact, increased looking at the colored ball suggests that after the intervention of habituation trials with a model head, the ball itself was perceived as a novel object.

In order to compare the attention levels of the two groups before habituation, the mean looking times over the first four habituation trials (23.1 sec and 11.2 sec) were compared by means of a t test. The difference between the means was significant, $t(28) = 2.74, p < .01$. This outcome indicates that the larger object was more potent in holding attention in the early trials.

The mean number of trials to reach the habituation criterion for the two groups and the final levels reached were also compared. The mean number of trials to criterion with the large head (6.9) was significantly different from that with the small head (9.1) according to a t test, $t(28) = 2.32, p < .05$. Thus habituation occurred readily for both groups despite the wide range in changing visual angles. The mean looking time for the last two habituation trials with the large head (6.1 sec) was also significantly different from that with the small head (3.1 sec), $t(28) = 2.53, p < .01$. In summary, initial looking time, rate of habituation, and final looking time were greater with the large head. These outcomes may reasonably be attributed to the greater saliency of the larger of the two moving stimulus objects.

It was expected that if perception of the invariant physical size of a moving object occurred, recovery from habituation in the trial with a moving object that was different from that in the habituation trials would be greater than that in the trial with a moving object of the same size. This expectation was tested by comparing the two test trial recovery scores, each expressed as a proportion of the mean score for the last two habituation trials. These proportional recovery scores were first transformed using an arc sine transformation and then compared in a 2×2 analysis of variance in which the factors were Relative Size (same and different from habituation object) and Groups (large and small object in habituation trials).

Table 2
Means and Standard Deviations for Looking Times (in seconds) and for Transformed Proportional Recovery Scores

	Large head		Small head	
Score	*M*	*SD*	*M*	*SD*
Following habituation to the small object				
Looking time	13.2	14.6	2.9	2.4
Transformed proportional recovery score	.83	.51	.39	.11
Following habituation to the large object				
Looking time	12.9	20.9	8.4	8.2
Transformed proportional recovery score	.45	.21	.51	.37

The means and standard deviations of the looking times on the test trials and the transformed proportional recovery scores are given in Table 2.

The mean transformed proportional recovery scores for the group habituated with the large model head were .45 when no size change in the test object occurred and .51 when it did, and for the group habituated to a small head, .39 and .83, respectively. The main effect of Relative Size was significant, $F(1, 28) = 5.37, p < .05$, but that of Groups was not, $F(1, 28) = 1.98, p > .05$. The Relative Size $\times$ Groups interaction, however, proved to be significant, $F(1, 28) = 9.11, p < .01$. These outcomes indicate that recovery from habituation with an object that is different in size from that of the habituation trials was reliably greater than with an object of the same size. Furthermore, the significant interaction between the two factors indicates that the degree of recovery is dependent on the direction of change in size from habituation to test trials. Recovery when the test object was larger than the habituation object was greater than when it was smaller.

Discussion

Allowing for the interaction between object size and novelty in the test phase, the outcomes of this experiment warrant the conclusion that at about 18 weeks of age infants perceive the invariant size of an approaching and receding object. That is, for objects of this type, visual size constancy obtains. Whether or not failure clearly to demonstrate perception of invariant size in the earlier experiment with 18-week-old infants (McKenzie, Tootell, & Day, 1980) was due to the objects being stationary or to a less sensitive procedure is uncertain. Whatever the reason, the main point is that the infant at 18 weeks of age perceives the invariant real size of an object as it moves along a medial path. Of course, it is possible that with the same stimulus conditions and procedure as described here, perception of invariant real size might be revealed even earlier in infancy. This possibility is a matter for further experimentation.

The large modeled head elicited greater attention than did the small head both at the beginning and at the end of the habituation phase. After habituation to the small head, this difference in attention to the two objects was enhanced due presumably to the joint effects of the salience of the large head and recovery from habituation to it. For all subjects the proportional recovery score for the large object was greater than that for the small. After habituation to the large object, however, this difference in attention in the test phase was no longer observable. The transformed proportional recovery score for the large head was not significantly different from that for the small head. In 9 of the 15 subjects, the proportional recovery score for the small object was greater than that for the large. It appears that the salience of the larger stimulus object was counteracted by recovery from habituation with the smaller. Taken together these outcomes indicate that recovery from habituation to an object of a different size is greater than that to one of the same size. It therefore seems that size constancy obtains for both large and small objects.

One further point should be made. It could be argued that because the large and small objects started movement from the same position, the former would have subtended greater visual angles. This might have resulted in longer looking times as a consequence of the greater time required to explore the large object. The fact that looking time was not directly related to projected retinal extent in either the habituation or the test phase, however, disconfirms this interpretation.

The use of different starting points during the familiarization phase renders this experiment similar to those referred to by Cohen (1979) as concept studies. In such studies, infants are shown a variety of stimulus objects belonging to the same class and then tested for generalization of habituation with a new member of the class and a nonmember. It should be noted that infants habituated readily during the familiarization phase, despite the wide range of visual angles projected by the objects both within and between trials. Clearly fixation time was not directly related to similarity in retinal extent. The results reported here show that infants of about 18 weeks generalize habituation to a moving object of a given size at a novel distance but do not do so to an object of a different size. That is, they have perceived size-at-a-distance and discriminated differences in absolute size even though the visual angles projected by the familiar and the novel object fall within the same range.

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