Perception & Psychophysics
1985, 37, 459-466

Infants' sensitivity to familiar size: The effect of memory on spatial perception

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Two experiments investigated infants' sensitivity to familiar size as information for the distances of objects with which they had had only brief experience. Each experiment had two phases: a familiarization phase and a test phase. During the familiarization phase, the infant played with a pair of different-sized objects for 10 min. During the test phase, a pair of objects, identical to those seen in the familiarization phase but now equal in size, were presented to the infant at a fixed distance under monocular or binocular viewing conditions. In the test phase of Experiment 1, 7-month-old infants viewing the objects monocularly showed a significant preference to reach for the object that resembled the smaller object in the familiarization phase. Seven-month-old infants in the binocular viewing condition reached equally to the two test phase objects. These results indicate that, in the monocular condition, the 7-month-olds used knowledge about the objects' sizes, acquired during the familiarization phase, to perceive distance from the test objects' visual angles, and that they reached preferentially for the apparently nearer object. The lack of a reaching preference in the binocular condition rules out interpretations of the results not based on the objects' perceived distances. The results, therefore, indicate that 7-month-old infants can use memory to mediate spatial perception. The implications of this finding for the debate between direct and indirect theories of visual perception are discussed. In the test phase of Experiment 2, 5-month-old infants viewing the objects monocularly showed no reaching preference. These infants, therefore, showed no evidence of sensitivity to familiar size as distance information.

An important issue that differentiates theories of visual perception is whether perception is viewed as direct or indirect. Indirect, or constructivist, theories maintain that sensory stimulation is less than fully informative and that the perceptual world is constructed through processes, such as unconscious inferences, that mediate or enrich the sensory input (e.g., Helmholtz, 1890/1962; Rock, 1977, 1983). In contrast, the theory of direct perception claims that visual perception is determined directly by the information present in the light reaching the eye, and is not mediated or enriched by inferences, assumptions, computations, or memory (J. J. Gibson, 1966, 1979). Despite considerable debate in recent years between proponents of direct and constructivist theories (e.g., Fodor & Pylyshyn, 1981; Turvey, Shaw, Reed, & Mace, 1981; Ullman, 1980), little progress has been made toward resolving this issue. This lack of progress can be attributed largely to the difficulty of conducting empirical tests of either theory. The depth cue of familiar size is particularly relevant to this debate because its effectiveness could be accounted for only by a constructivist theory.

This research was supported by National Institute of Child Health and Human Development Grants HD-05027 and R01-HD-16924-01. The authors thank Isabel Smith for her assistance in conducting the study and Bill Merriman, Herb Pick, Richard Aslin, Walter Gogel, and Carolyn Palmer for their helpful comments on the paper. Correspondence concerning the article and requests for reprints should be sent to Carl E. Granrud, Department of Psychology, Carnegie-Mellon University, Pittsburgh, PA 15213.

The depth cue of familiar size is based on the relationship between an object's distance from an observer and the visual angle subtended by the object at the point of observation. Because visual angle is determined jointly by an object's size and its distance from the observer, visual angle alone cannot specify distance. If an object's physical size were known, however, this knowledge could potentially be used to recover information for distance, since visual angle would then vary only as a function of distance. Perception of distance from familiar size, by definition, would involve enrichment of uninformative visual input by information stored in memory, in contradiction to the claims of the theory of direct perception (J. J. Gibson, 1966, 1979; J. J. Gibson & E. J. Gibson, 1955). The present study had two related goals. The first was to discover whether familiar size is an effective cue for perceiving objects' distances. The second was to conduct a test of Gibson's theory of direct perception. If familiar size is an effective depth cue, it would indicate that the theory of direct perception cannot account for all aspects of spatial perception.

Despite considerable research investigating depth perception from familiar size, it has remained unknown whether or not familiar size is an effective cue for perceiving objects' distances. Although a number of studies have demonstrated convincingly that familiar size influences adult subjects' judgments of object distance (Baird, 1963; Dinnerstein, 1967; Epstein, 1963, 1965; Epstein & Baratz, 1964; Eriksson & Zetterberg, 1975; Fitzpatrick, Pasnak, & Tyer, 1982; Gogel, 1968, 1969; Gogel & Mertens, 1968; Ittelson, 1951a, 1951b; Newman, 1972; Ono, 1969), one important criticism of these studies has not been adequately addressed. In a critique of Ittelson's (1951a) study, Hochberg and Hochberg (1953) argued that Ittleson's subjects might not have perceived the stimulus objects to be at the distances they reported; instead, they may have consciously inferred the distances at which familiar objects would project various visual angles. Thus, it is unclear whether familiar size determines perceived distance or only allows subjects to make conscious estimates of distance. This criticism, which can apply to all familiar-size studies in which adult subjects make distance judgments, is particularly important in light of a number of studies showing that adult subjects' distance judgments are influenced by such variables as instructions, viewing attitude, and suggested, rather than familiar, size of target objects (Baird, 1963; Coltheart, 1969, 1970; Gogel, 1981; Hastorf, 1950; Higashiyama, 1984; Park & Michaelson, 1974). The findings of these studies are consistent with the view that adults' distance judgments in familiar-size experiments may be influenced by factors other than the perceived distances of the stimulus objects.

To minimize the intrusion of nonperceptual factors, Mershon and Gogel (1975) and Gogel (1976) have attempted to evaluate the effectiveness of familiar size by using less direct methods than asking subjects to judge the distances of familiar objects. Mershon and Gogel (1975) asked whether familiar size could provide a metric for the perception of spatial extent within a visual display; they found no clear effect of familiar size. Gogel (1976) investigated whether subjects' perceptions of an object's apparent motions would be influenced by the object's apparent distance as specified by familiar size. He found some evidence that familiar size influences perceived distance, but his results also suggested that adults' responses to familiar size might be primarily nonperceptual.

In a recent study, Yonas, Pettersen, and Granrud (1982) used a different strategy to investigate the effectiveness of familiar size independently of nonperceptual factors. They asked whether 5- and 7-month-old infants' reaching behavior might be influenced by objects' apparent distances as specified by familiar size. Infants viewed, one at a time, larger-than-life-size and smaller-than-life-size photographs of adult female faces (a familiar class of objects). The 7-month-old infants responded to distance specified by familiar size. They reached significantly more for the large faces than for the small faces, suggesting that they perceived the large faces to be nearer than the small faces. The results from two control conditions ruled out the possibility that the infants preferred to reach for large faces or for large objects without regard to apparent distance. Because infants', and even young children's, problem solving abilities appear to be very limited (e.g., see Harris, 1983; Klahr & Robinson, 1981; Siegler, 1978), it is likely that the 7-month-old infants' reaching was guided by the perceived distances of the faces and not by conscious estimates of the faces' distances. The Yonas et al. (1982) findings, therefore, suggest that familiar size is an effective determinant of perceived distance, and that, by 7 months of age, spatial perception can be mediated by knowledge about objects acquired through experience and stored in memory. In contrast to the 7-month-olds, the 5-month-olds did not respond to distance specified by familiar size.

The conclusion that 7-month-old infants' spatial perception can be mediated by memory must be made cautiously, however. It has been hypothesized that infants may have an innate schema for faces. If this is correct, the Yonas et al. (1982) results may not demonstrate an effect of experience or memory on infant spatial perception. Although this hypothesis is not supported by the existing data on infants' face perception, the issue remains unsettled (see Cohen, DeLoache, & Strauss, 1979). The present study attempted to find unambiguous evidence that knowledge about specific objects, acquired through experience and stored in memory, can mediate infants' spatial perception. Five- and 7-month-old infants were tested for sensitivity to familiar size as information for the distances of objects whose sizes could be learned only from experience. There were two phases in the experiment: a familiarization phase and a test phase. During the 10-min familiarization phase, the infant played with a pair of different-sized objects, either pair A or pair B pictured in Figure 1. During the test phase, two objects, identical to those seen in the familiarization phase but now equal in size (pair C in Figure 1), were presented to the infants side by side at a fixed distance. It was predicted that if infants could remember the sizes of the familiarization objects and could use familiar size to perceive object distance, they would perceive the two test-phase objects as being at different distances. Because the test-phase objects subtended equal visual angles, the object with the smaller known size (the object resembling the smaller object in the familiarization pair) would be perceived as nearer. Reaching was used as the dependent measure. Based on Granrud, Yonas, and Pettersen's (1984) finding that 5- and 7-month-old infants reach preferentially for the nearer of two objects, a reaching preference for the test-phase object resembling the smaller object of the familiarization pair might indicate sensitivity to familiar size as information for relative distance.

A reaching preference in the test phase would not necessarily indicate sensitivity to familiar size, however. Two alternative accounts are possible. First, during the familiarization phase, infants could acquire a preference for the smaller object because this object might be more easily grasped, held, and put into the mouth than the larger

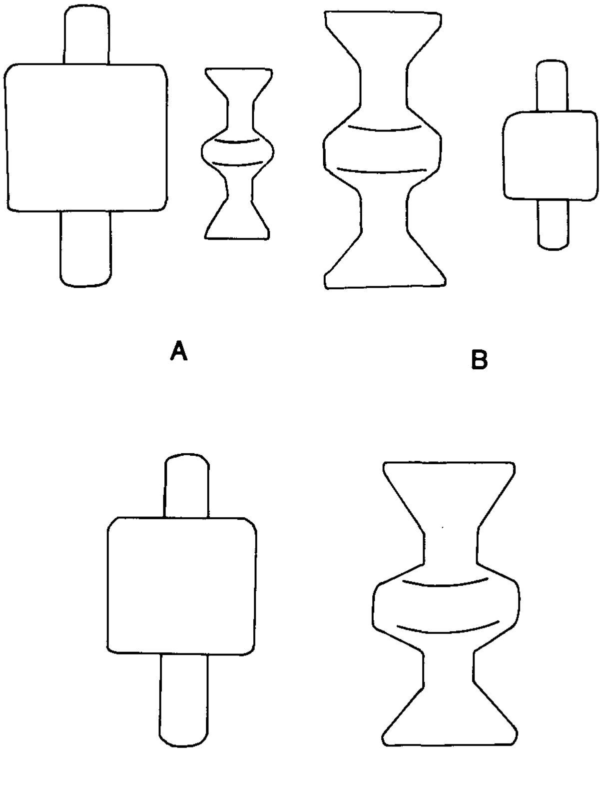

Figure 1. Objects used in Experiments 1 and 2. Infants were presented with either pair A or pair B during the familiarization phase. Pair C was presented during the test phase.

object. In the test phase, this preference might generalize to the object in the test pair which more closely resembles this preferred object. Second, one test-phase object was identical to the larger object in the familiarization pair whereas the other test phase object was not seen during the familiarization phase. It is possible that infants might lose interest in the objects during the familiarization phase and, therefore, reach preferentially for the novel object in the test phase, not because it appears to be nearer, but simply because it is novel.

In order to control for the possibility that either an acquired preference or a preference based on novelty might account for the infants' reaching behavior in the test phase, two groups of infants were tested in the experiment. One group viewed the test-phase objects binocularly; the other group viewed the test-phase objects monocularly (infants in the monocular group wore an eyepatch over one eye). All other aspects of the procedure were identical. If the infants' reaching behavior is determined by the perceived relative distances of the objects on the basis of familiar size, a reaching preference should be found only in the monocular condition; in the binocular condition, binocular information specifying the actual equidistance of the objects should override the effects of familiar size and result in no reaching preference (several studies have found that conflicting binocular information overrides the effects of pictorial information for 7-month-old infants: Granrud, Yonas, & Opland, 1985; Yonas, Cleaves, & Pettersen, 1978; Yonas, Granrud, & Pettersen, 1985; Yonas et al., 1982). Conversely, if infants acquire a preference during the familiarization phase or if they prefer to reach for the novel object in the test phase, we should observe a reaching preference in both the monocular and binocular conditions, since patching one eye should not influence these preferences.

Prior to testing infants, we conducted an initial experiment with adult subjects to determine whether a familiar size effect could be induced through brief experience with novel objects. Subjects viewed and handled either pair A or pair B, pictured in Figure 1, for 1 min. Following this familiarization period, the subjects placed a patch over the left eye and viewed the test objects, pair C in Figure 1, from a distance of 50 cm. The subjects were asked to report whether the objects appeared to be equidistant or at different distances. If a subject reported that the objects were at different distances, he or she was asked to report which object appeared to be nearer and to specify, in inches, how much nearer than the other object it appeared to be. Each subject was given four trials; the left-right positions of the objects were alternated on each trial. The results indicated that the subjects responded to familiar size in judging the objects' relative distances. They judged the test object resembling the smaller familiarization object to be a mean of .86 in. (2.18 cm) nearer than the other test object. This mean distance was significantly greater than zero [$t(12) = 2.21$, $p < .05$]. Thus, with adult subjects, a familiar size effect can be induced through brief experience. Although subjects' distance judgments did not conform to the absolute distances predicted by the familiar-size hypothesis [if familiar size had perfectly determined perceived distance, the apparently nearer object would have appeared to be half as distant as the other object, i.e., about 9.8 in. (25 cm) nearer], it is impressive that familiar size influenced these distance judgments despite the presence of conflicting motion parallax (generated by the subjects' head movements) and accommodation information and the subjects' belief that they were being presented with an illusion. Of course, these judgments may have been based on conscious problem solving rather than perceived distance. By asking whether 7-month-old infants, subjects whose responses are very unlikely to be influenced by conscious problem solving, could perceive distance from familiar size, Experiment 1 attempted to discover whether familiar size is an effective perceptual cue.

EXPERIMENT 1

Method

Subjects. Infants were recruited from birth announcements published in local newspapers, and were brought to the laboratory by a parent who gave informed consent. Forty-three 7-month-old infants participated in Experiment 1. Twenty-five infants began the monocular condition, but 7 infants were excluded due to failure to meet the criterion of at least six trials with reaches. Thus, 18 infants (10 females, 8 males, mean age = 194.8 days, range = 188-200 days) constituted the monocular sample. All 18 infants in the binocular group (11 females, 7 males, mean age = 199.1 days, range = 190-206 days) surpassed the criterion of six trials with reaches.

Apparatus. During the familiarization phase, the infant sat or lay on a plastic-covered foam cushion that covered a 175-cm-long and 75-cm-wide table, and played with one of the pairs of familiarization objects shown in Figures 1A and 1B. The objects were made of wood and were painted with nontoxic acrylic paint. Familiarization pair A (Figure 1A) consisted of a blue, green, and orange large object measuring 14 × 5 × 5 cm and a red, yellow, and white small object measuring 7 × 3 × 3 cm. Familiarization pair B (Figure 1B) consisted of a red, yellow, and white large object (14 × 6 × 6 cm) and a blue, green, and orange small object (7 × 2.5 × 2.5 cm). (Measurements were made at the objects' longest, widest, and deepest points.)

In the test phase, infants viewed the pair of objects pictured in Figure 1C while sitting in a self-supporting Gerry-brand infant carrier. This pair consisted of the two larger objects from the familiarization pairs. The objects were mounted on wooden dowels (which were occluded from the infants' viewpoint by the objects), which suspended them side by side (as shown in Figure 1) 6 cm apart (at their nearest points) and 6 cm in front of a vertical gray background (102 × 76 cm), which stood at one end of the table. The distance between the infant and the objects was adjusted slightly for each infant, averaging approximately 25 cm between the objects and the infant's forehead. The visual angle subtended by both objects at 25 cm was 29.2° (measured vertically).

The experiment was recorded with a TV camera positioned directly overhead and connected to a video tape recorder. Both phases of the experiment were conducted in normal room light.

Procedure. The experiment consisted of two parts: the familiarization phase and the test phase. During the familiarization phase, the parent played with the infant, who sat or lay on the table, with one of the pairs of objects pictured in Figure 1A or Figure 1B. The pair used for familiarization was chosen randomly. For the purpose of data analysis, infants familiarized to pair A were designated as Group A and those familiarized to pair B were designated as Group B. The only instruction the parent received was to see that the infant had approximately equal amounts of experience with each toy. Familiarization lasted approximately 10 min. During the familiarization phase, the infants viewed the objects binocularly and saw them at various distances and in various orientations. The infants typically handled, mouthed, dropped, picked up, pounded, and threw the objects.

To determine whether the infants had acquired a preference for one of the objects during the familiarization phase, the infants were tested for a reaching preference three times during this phase: at the beginning of the phase, after 5 min, and after 10 min. The two objects were placed side by side on the table at equal distances (approximately 15 cm) in front of the infant. Four trials were given. A trial lasted either 30 sec or until the infant touched one of the objects. The initial left-right positions of the objects were chosen randomly, and position was alternated on each subsequent trial. The familiarization-phase preference tests were scored by the experimenter at the time of the experiment. After the third preference test, the familiarization phase ended. The infant was removed from the table and the foam pad was replaced with the infant carrier. The infant was then seated in the infant carrier and the test phase began. The interval between the familiarization and test phases lasted approximately 1 to 2 min.

There were two viewing conditions in the test phase: a binocular viewing condition and a monocular viewing condition. Each infant was tested in only one viewing condition; infants were alternately assigned to the two viewing conditions. For each infant in the monocular group, an adhesive eyepatch was placed over one eye (determined randomly).

During the test phase, the experimenter and the parent stood behind the infant, and the parent was requested not to speak to the infant. The test objects were occluded prior to the beginning of the test phase by a cardboard screen held by the experimenter. The experimenter drew the infant's attention toward the objects by tapping on the screen, then lifted the screen to reveal the objects. The initial left-right positions of the objects were chosen randomly, and left-right positions were alternated on each subsequent trial. The trial was terminated and the objects were again occluded immediately after the infant touched one of the objects. If no reach occurred, the trial was terminated 60 sec after the infant's first fixation of the objects. If the infant looked away during a trial, the experimenter attempted to attract the infant's attention back to the objects by tapping on the center of the background screen above the objects. After a trial was terminated, there was a brief interval (approximately 5 sec) during which the objects were occluded and their positions were changed; then another trial began. This procedure was repeated until the infant stopped reaching for the objects or became too fussy to continue. At least six trials with reaches were required for inclusion of an infant's data in the analysis.

Reaches in the test phase were scored from the videotape record of the experiment. To ensure that there could be no experimenter bias in scoring, scorers did not know which set of familiarization objects each infant had received prior to testing. Only the first reach in each trial was scored. Reaches were scored as "left" if the infant's hand first touched the object on the left, "right" if the infant's hand first touched the object on the right, or as "both" if the infant touched both objects simultaneously. Trials in which no reach occurred were scored as "no reach." Infants' reaches were later converted to reaches for the object corresponding to the large or small object in the familiarization phase. Very few trials were scored as "both" or "no reach" (2% and 6%, respectively, in the monocular condition and 4% and 5% in the binocular condition); these categories were excluded from the data analysis. The percentages of reaches for the two test-phase objects, therefore, summed to 100. Each infant's reaching was scored from the videotape independently by the experimenter and by a research assistant who was unfamiliar with the hypotheses of the experiment. The correlation between the two observers' scores was .99.

The dependent variable in the test phase was the mean percentage of the infants' reaches that first contacted the object resembling the smaller object in the familiarization phase (henceforth, the test-phase object resembling the smaller familiarization-phase object will be referred to as the "apparently nearer" object, since familiar size would specify that it was the nearer object in the test phase).

Results and Discussion

In the reaching preference tests conducted during the familiarization phase, a mean of 48.0% (SD = 15.0) of the monocular group's reaches and a mean of 45.2% (SD = 16.4) of the binocular group's reaches were for the smaller object (the percentages of reaches for the small and large objects summed to 100). Neither group showed a significant object preference in these tests.

Table 1 presents the mean number of reaches scored in the test phase of the experiment and the mean percentage of these reaches that first contacted the "apparently nearer" object. Percentages of reaches to the "apparently nearer" object were analyzed in a 2 × 2 analysis of variance with condition (monocular and binocular) and familiarization group (Groups A and B) as factors. The analysis revealed a significant main effect for condition [$F(1,32) = 8.10$, $p < .01$], no main effect for familiarization group [$F(1,32) = 1.27$, $p > .05$], and no condition × familiarization group interaction [$F(1,32) = 0.37$, $p > .05$]. The main effect for condition indicates that the infants in the monocular condition reached significantly

Table 1
Results from Experiment 1: 7-Month-Olds

Group	Number of Reaches		Percentage of Reaches to "Apparently Nearer" Object	
	Mean	SD	Mean	SD
	Monocular Condition			
A	12.77	5.93	63.91	16.57
B	12.38	4.27	56.25	16.71
Combined	12.59	5.06	60.51	16.60
	Binocular Condition			
A	12.44	4.13	48.71	9.75
B	13.44	4.95	46.32	7.70
Combined	12.94	4.45	47.52	8.61

more consistently for the "apparently nearer" object than did the infants in the binocular condition. Since there was no main effect for familiarization group and no interaction, the means from the two familiarization groups in each condition were combined. Tukey post hoc comparisons were performed to compare these means with chance (50%). The infants' tendency to reach for the "apparently nearer" object was significantly greater than chance in the monocular condition ($p < .05$), but did not differ from chance in the binocular condition ($p > .05$).

The results indicate that in the monocular condition the infants reached preferentially for the object in the test phase that resembled the smaller object in the familiarization phase, that is, the "apparently nearer" object. This reaching preference suggests that the infants perceived this object to be the nearer of the two test objects. The infants apparently remembered the objects' physical sizes from the familiarization phase and used familiar size to extract information for distance from the test objects' visual angles. The finding of no reaching preference in the binocular condition indicates that the infants' reaching preference in the monocular condition cannot be accounted for either by a preference acquired during the familiarization phase or by a preference to reach for the novel object in the test pair. Had either of these variables influenced the results, their effects should have been observed in the binocular condition.

These findings suggest that familiar size is an effective source of information for perceiving object distance. It is not plausible that the infants' reaching preference resulted from conscious reasoning about the objects' distances (cf. Hochberg & Hochberg, 1953). In light of findings by Klahr and Robinson (1981) and Siegler (1978), suggesting that even 3- to 4-year-old children have very limited problem solving abilities, it would be extremely surprising if 7-month-old infants could consciously infer that one object must be nearer than another based on the objects' equal visual angles and different known sizes. The most plausible interpretation of the results from this experiment is that the infants perceived the test objects as being at different distances and that this percept guided their reaching.

Walter Gogel (personal communication) has suggested, however, that infants could make a cognitive response to familiar size without engaging in sophisticated reasoning about objects' distances. Gogel (1969) and Gogel and Newton (1969) have found that when adult subjects are presented with various-size stimuli resembling familiar objects, they typically do not perceive the stimuli as normal in size and located at the precise distance specified by familiar size and visual angle. Instead, subjects report that the objects appear to be nonnormal in size, or "off-size." Gogel (1969, 1976, 1981) argues that subjects often modify their reports of apparent distance on the basis of these off-size perceptions. If the stimulus object looks larger than normal, subjects report that it is nearer than it actually appears to be; if the stimulus object looks smaller than normal, subjects report that it is more distant than it appears to be. Gogel (1976) suggests that this cognitive modification of reported distance is based on adults' expectation that an object at a far distance appears to be smaller than the same object at a near distance. Gogel (personal communication) further suggests that if infants have less than perfect size constancy, a nearby object might appear to them to be slightly larger than the same object farther away. As a result, infants could form an association between apparent size and nearness or graspability. In the present study, infants might perceive the "apparently nearer" test-phase object to be larger than its expected size. They might then associate this off-size perception with nearness and, consequently, they might reach preferentially for this object, despite their perception that the objects are equidistant.

Gogel's account may be correct. However, it depends on two assumptions that we find implausible. First, it assumes that familiar size can influence perceived size without influencing perceived distance. We find it more plausible to assume that familiar size either influences both perceived size and perceived distance or that the effects of familiar size on both size and distance judgments are nonperceptual. Second, this account assumes that the infants perceived the two test-phase objects to be at the same distance, but that they ignored this perception and instead based their reaching on a judgment about distance. Although instructions to estimate the distances of stimulus objects could motivate adults to report distance judgments different from the objects' actual perceived distances, in an attempt to give the "correct" answer, it is difficult to imagine what would motivate infants to ignore their perceptions of objects' distances and rely instead on nonperceptual judgments. We find it far more plausible to suppose that infants base their reaching behavior on the perceived, not judged, distances of objects.

EXPERIMENT 2

Experiment 2 used the same method as Experiment 1 to investigate 5-month-old infants' perception of distance from familiar size. Although Yonas et al. (1982) found no evidence of sensitivity to familiar size in 5-month-olds, their findings do not demonstrate that these infants are insensitive to familiar size. It is possible that 5-month-olds can perceive distance from familiar size, but that the method employed by Yonas et al. (1982) was inadequate to reveal this sensitivity. The method used in the present study may provide a better measure of 5-month-olds' sensitivity to familiar size. In the Yonas et al. study, infants viewed the stimulus objects one at a time; in the present study, infants viewed the two stimulus objects simultaneously. It is possible that small differences in perceived distance lead to a significant reaching preference when objects are presented simultaneously but not when they are presented sequentially.

Method

Subjects. Twenty-three infants participated in Experiment 2. Eighteen infants were included in the sample (9 females, 9 males, mean age = 151.9 days, range = 147-157 days). Five infants failed to meet the criterion of six trials with reaches and were therefore excluded from the sample.

Apparatus. The apparatus in Experiment 2 was the same as in Experiment 1.

Procedure. The procedure in Experiment 2 was the same as in Experiment 1, with one exception. Only one group of infants participated in Experiment 2; these infants viewed the objects in the test phase monocularly.

Results and Discussion

In the reaching preference tests conducted during the familiarization phase, a mean of 43.9% (SD = 20.9) of the infants' reaches were for the small object. The infants showed no significant object preference in these tests.

Table 2 presents the mean number of reaches scored in the test phase and the mean percentage of these reaches that first contacted the "apparently nearer" object. Because the two familiarization groups' tendencies to reach for the "apparently nearer" object were not signficantly different [$t(16) = .23$, $p > .05$], the results from the two groups were combined. The combined mean percentage of the infants' reaches for the "apparently nearer" object did not differ significantly from chance [$t(17) = -0.70$, $p > .05$].

Unlike the 7-month-olds, the 5-month-olds showed no preference to reach for the "apparently nearer" object in the test phase of the experiment. Thus, these infants gave no evidence of sensitivity to familiar size as depth information. A binocular viewing condition would be necessary only to control for the possibility that a reaching preference observed in the monocular condition was due to some variable other than the perceived relative distances of the test objects. Because the infants in the monocular viewing condition showed no reaching preference, no binocular control condition was needed.

These findings are consistent with a number of studies indicating that the ability to perceive the spatial information specified by pictorial depth cues, such as interposition, shading, relative size, and familiar size, may first appear between 5 and 7 months of age (Granrud & Yonas, 1984; Granrud, Yonas, & Opland, 1985; Kaufmann, Maland, & Yonas, 1981; Yonas et al., 1978; Yonas, Granrud, & Pettersen, 1985; Yonas, et al., 1982; for a review of these studies, see Yonas & Granrud, 1985). We cannot be certain, however, that 5-month-olds are insensitive to familiar size. There are several possible reasons for the 5-month-olds' failure to demonstrate sensitivity to familiar size in this experiment. For example, it is possible that the 5-month-olds perceived the objects' distances as specified by familiar size and that their failure to show evidence of this perception resulted from the inadequacy of reaching as a dependent measure. This is unlikely, however. Reaching has been used successfully as a dependent measure in studies demonstrating 5-month-olds' sensitivity to accretion and deletion of texture (Granrud, Yonas, Smith, Arterberry, Glicksman, & Sorknes, 1984) and a variety of other depth cues (Gordon & Yonas, 1976; Granrud, 1985; Granrud, Yonas, & Pettersen, 1984; Yonas, Cleaves, & Pettersen, 1978).

The 5-month-olds' lack of a reaching preference may also have been due to the presence of conflicting motion parallax (generated by the infants' head movement) in the test phase of the experiment. For 5-month-olds, motion parallax may be a more effective and dominant source of depth information than familiar size; thus, the infants may have responded to motion parallax specifying the objects' equal distances. A more sensitive test of 5-month-olds' sensitivity to familiar size might be achieved if conflicting motion parallax could be eliminated.

One additional possibility is that 10 min of familiarization may have been insufficient for 5-month-old infants to learn the objects' sizes; more familiarization might have resulted in familiar size's effectively influencing perceived depth. This is a question for future research. We might note, however, that in some tasks 5-month-olds show recognition memory for objects after less than 30 sec of study time (e.g., Cornell, 1979; Fagan, 1974), and that 5-month-olds showed no evidence of sensitivity to familiar size in the Yonas et al. (1982) study, in which the stimulus objects were human faces, a class of objects with which 5-month-olds have had a great deal of experience.

Table 2
Results from Experiment 2: 5-Month-Olds, Monocular Condition

Group	Number of Reaches		Percentage of Reaches to "Apparently Nearer" Object	
	Mean	SD	Mean	SD
A	7.33	1.32	47.17	14.91
B	7.22	1.92	48.64	10.24
Combined	7.28	1.60	47.91	12.40

GENERAL DISCUSSION

In Experiment 1, 7-month-olds showed clear evidence of sensitivity to familiar size. Infants in the monocular viewing condition showed a reliable preference to reach for the "apparently nearer" object in the test phase of the experiment. In contrast, infants in the binocular viewing condition showed no reaching preference, indicating that the reaching preference observed in the monocular condition resulted from the perceived relative distances of the test objects and not from a preference acquired during the familiarization phase or from a preference to reach for the novel object in the test phase. The finding that 7-month-old infants can perceive object distance from familiar size suggests that familiar size is an effective perceptual cue, and that familiar size does not merely enable subjects to make conscious inferences about distance (cf. Hochberg & Hochberg, 1953). In Experiment 2, 5-month-olds showed no evidence of sensitivity to familiar size. They did not reach preferentially for the "apparently nearer" object under monocular viewing conditions. Although we cannot be certain from these results that 5-month-olds are insensitive to familiar size, they are consistent with a number of studies that have failed to find sensitivity to pictorial depth information in 5-month-olds.

The finding that 7-month-old infants can use familiar size to perceive distance lends credence to constructivist theories of visual perception and points to limitations in the Gibsons' theory of direct perception. Although the Gibsons emphasized the effect of experience on perception, they argued that the result of perceptual learning was not enrichment of inadequate sensory input by memory, but increased sensitivity to, or differentiation of, information in the sensory stimulation (J. J. Gibson, 1966; J. J. Gibson & E. J. Gibson, 1955). Although considerable evidence exists indicating that perceptual learning can result in such increased sensitivity (E. J. Gibson, 1966; J. J. Gibson & E. J. Gibson, 1955), perception of distance from familiar size can only be a case of enrichment, or indirect perception, in which the perceiver uses knowledge stored in memory to extract information from otherwise uninformative visual input. In the test phase of Experiment 1, no information present in the optic array specified that the two objects were at different distances. Perception of a difference in distance could have resulted only if the visual input was enriched by memory for the objects' sizes. The results of this study therefore indicate that 7-month-old infants are capable of indirect perception, and that a purely direct perception theory cannot fully account for infants' spatial perception. Moreover, the effectiveness of familiar size at such an early age suggests that enrichment of visual stimulation by memory may be a fundamental aspect of spatial perception.

We should note that J. J. Gibson (1966, chap. 14) acknowledged that in the absence of perceptual information the perceiver can make inferences and guesses about the distal state of affairs. One way to interpret Gibson is that these inferences and guesses are the result of conscious reasoning. We have argued that such reasoning is unlikely in 7-month-old infants. Alternatively, Gibson could be interpreted as claiming that perception can involve unconscious inferences (like those posited by Helmholtz, 1890/1962, and Rock, 1977), but that these inferential processes occur only when no perceptual information is available. Following this view, proponents of the theory of direct perception might argue that the information available in the monocular condition of the present study was artificially degraded because infants had one eye patched, and that the indirect perceptual processes involved in perceiving distance from familiar size are used only in such "ecologically invalid" situations. However, a considerable amount of information specifying the distances of the test-phase objects was available. Because the infants' heads were unrestrained, head movements generated motion parallax specifying the equal distances of the objects. Findings by Granrud, Yonas, and Pettersen (1984) and Yonas, Sorknes, and Smith (1983) clearly show that, for 7-month-olds, the motion parallax and accommodation information available in a similar situation is sufficient for perceiving the relative distances of two objects separated by as little as 2 cm. That familiar size overrides conflicting motion parallax suggests that the use of familiar size is not restricted to situations in which no other information is available. Furthermore, familiar size may be an important cue for perceiving distance in natural environments, because it can specify the absolute distances of objects beyond the distances at which binocular disparity, motion parallax, convergence, and accommodation are effective.

To conclude, the results of this study indicate that, by 7 months of age, infants can use memory to mediate spatial perception. This finding suggests that a purely direct perception theory cannot account for all aspects of spatial perception. An adequate theory must include indirect perceptual processes to account for the full range of perceptual phenomena.

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(Manuscript received July 19, 1984;
revision accepted for publication April 26, 1985.)