

Research Report

LOOMING RESPONSES TO OBSTACLES AND APERTURES: The Role of Accretion and Deletion of Background Texture

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Abstract—Successful navigation in the world requires differentiating an obstacle in one's path from an aperture through which one could pass. An approaching obstacle is specified by texture expansion within the obstacle's contour and the deletion of background texture outside the object. In contrast, an approaching aperture contains texture expansion within the aperture's frame and accretion of background texture within the aperture's contour. This study investigated 3- to 5-month-old infants' discrimination of obstacles from apertures, examining eyeblink responses to the movement of both kinds of objects against backgrounds varying in salience. Obstacles produced stronger looming reactions than apertures, and the salience of the background influenced responses to apertures but not obstacles. These findings imply that infants differentiate obstacles from apertures based on their relative patterns of accretion versus deletion of background texture, and suggest that infants recognize the functional consequences of contact with these objects.

A critical component of visually guided locomotion (e.g., Cutting, Vishton, & Braren, 1995; E.J. Gibson & Schmuckler, 1989; Schmuckler, 1993, 1995, 1996; Schmuckler & Gibson, 1989) involves differentiating obstacles in one's path from apertures through which one could pass. Looming information (J.J. Gibson, 1958, 1966, 1979; Schiff, 1965; Schiff, Caviness, & Gibson, 1962) underlies the perception of impending collision and consists of the symmetrical expansion of a contour as the object approaches. Additionally, a looming object produces occlusion of background texture outside of the object (J.J. Gibson, 1979). In contrast, an approaching aperture, though also containing an expanding contour, provides accretion of background texture inside this contour. Thus, "as you come up to the obstacle it hides more and more of the vista, and as you come up to the opening it reveals more and more of the vista. Deletion outside the occluding edge and accretion inside the occluding edge will distinguish the two" (J.J. Gibson, 1979, p. 230).

Experimental work has demonstrated that humans and animals react to looming information (Schiff, 1965; Schiff et al., 1962). Human infants respond with backward head movements, eyeblinks, and raising of the arms (Ball & Tronick, 1971; Bower, Broughton, & Moore, 1970; Peiper, 1963). Although subsequent work has challenged whether such responses truly represent defensive reactions (see Yonas & Granrud, 1985), the finding remains that approaching objects produce consistent responses in infants (Ball & Tronick, 1971; Bower et al., 1970; Carroll & Gibson, 1981; Nández, 1988; Pettersen, Yonas, & Fisch, 1980).

Although some research has examined the developmental use of accretion and deletion information in the perception of surfaces and objects (e.g., Granrud et al., 1984; Kaufman-Hayoz, Kaufman, & Stucki,

1986), Carroll and Gibson (1981; see E.J. Gibson, 1982) provided the only study of the use of such information for perceiving object looming. In this work, analyses of 3-month-old infants' reactions to the approach of obstacles and apertures revealed significant backward head withdrawal, with obstacles producing stronger responses than apertures. Moreover, infants exhibited additional defensive behaviors such as eye blinking and head turning to avoid contact in response to obstacles, and nondefensive behaviors such as head turning to track the object in response to apertures. Carroll and Gibson suggested that the occlusion of the background produced by an obstacle specified an object to be avoided, whereas the disocclusion of the background produced by an aperture specified an opening through which one could pass. Thus, infants' differential response to obstacles and apertures implied an understanding of the consequences of contact with these objects.

If infants do use the relative occlusion versus disocclusion of background texture in this situation, then manipulating the salience of the background should differentially influence looming responses. Because an obstacle always provides information for collision, it should produce equivalent reactions irrespective of the background. The salience of the background should influence reactions to an aperture, however. Backgrounds of low salience will produce little disocclusion information, though still producing texture expansion in the aperture's frame; accordingly, apertures looming against low-salience backgrounds should produce strong defensive reactions. Increasing background salience emphasizes the aperture's disocclusion information, thereby highlighting the possibility of passage. Hence, apertures looming against highly salient backgrounds should produce weaker defensive reactions. This study tested this prediction.

METHOD

Subjects

The final sample consisted of 28 infants (13 female) between 3 and 5 months old ($M = 17.3$ weeks). The data from an additional 19 infants were not analyzed because of the infants' fussiness ($n = 12$) or experimental error ($n = 5$), or because we learned they were born more than 4 weeks prematurely ($n = 2$). All infants were recruited from the Scarborough, Ontario, community.

Apparatus and Stimuli

The experiment was conducted in a room 1.52 m long, 1.22 m wide, and 1.62 m high. Covering the front end of this room was a piece of black cloth, either an intact cloth or a cloth with a rectangular hole (40 cm \times 28 cm) in its center. A 20-in. Panasonic CT-1920M color video monitor was positioned so its screen appeared in this rectangular hole. The monitor was connected to a JVC BR8600U professional editing video cassette recorder.

Infants sat in an infant seat positioned 1.2 m back from the front end of the room; the front wall subtended a visual angle of $68.0^\circ \times 54.0^\circ$.

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The infant seat was attached to a force platform, which measured movement in lateral and fore-aft dimensions. Located 24 cm in front of this seat were two poles supporting a Plexiglas barrier 93 cm wide by 33 cm high. The barrier eliminated any air pressure changes resulting from movement of the looming objects.

Two looming objects were created. The *obstacle* was a 24-cm wooden square, 2 cm thick, covered with a red-and-black checkerboard pattern; the *aperture* was a similarly dimensioned and patterned wooden frame with an interior hole measuring 20 cm by 20 cm. Both objects were hung with their centers at eye level for a seated infant.

Along the ceiling was a track and roller for moving the objects up and down the room. The objects were moved manually, with the 90-cm distance from front wall to barrier requiring approximately 1.2 s to be traversed. A Sony CT-TR30 video camera, positioned 60 cm away from the infant and 45° to the right of the line of sight, recorded the infant's face.

Experimental Design and Procedure

The first experimental manipulation involved the stimulus object, which was either the obstacle or the aperture. The second manipulation involved the background behind these objects. The *untextured* background was the intact black cloth. The *stationary* background was a color picture of the cartoon character Garfield, showing through the black cloth with the hole. The *moving* background contained a Garfield cartoon. Both objects appeared against all backgrounds. Half the infants received the obstacle conditions first, and the background order was randomized across infants.

The third manipulation involved the objects' direction of movement. In *approach* trials, the object loomed toward the infant, whereas in *withdrawal* trials, the object moved away from the infant. The visual angles for the outer contours of the objects were 10.4° × 10.4° near the background and 53.1° × 53.1° near the barrier. The visual angles of the aperture's interior contour were 9.5° × 9.5° and 45.2° × 45.2°, respectively.

Infants received multiple, alternating presentations of approach and withdrawal trials, with half of the infants receiving an approach trial first. Overall, infants received 11 to 25 trials per object and background condition. In the obstacle conditions, there were, on average, 14.8, 14.7, and 14.1 trials for untextured, stationary, and moving backgrounds; the aperture conditions had, on average, 14.2, 14.1, and 13.4 trials for untextured, stationary, and moving backgrounds. The entire visit to the laboratory lasted 30 to 45 min.

DATA REDUCTION

This experiment produced two dependent measures. The first involved eyeblinks in response to the object's movement, whereas the second involved changes in the infant's fore-aft movement in response to the object's movement. A series of analyses revealed that fore-aft movement was uninformative; hence, analyses focused on the eyeblink measure. Eyeblinks have been found to index perceived looming reliably, with such reactions becoming fully established by 3 months of age (e.g., Nájuez, 1988; Peiper, 1963; Yonas & Granrud, 1985).

Infants' reactions when the stimulus objects were close to their faces (i.e., approximately the last 1/2 s of approach trials and approximately the first 1/2 s of withdrawal trials) were coded as "blinking," "no response," or "not attending." Not-attending trials accounted for 1.9% of trials, with no difference in the number of these trials by object type, $F(1, 27) = 1.9$,

$MSE = 72.3$, n.s., or background texture, $F(2, 54) = 1.2$, $MSE = 33.7$, n.s. Not-attending trials were not considered further in subsequent analyses.

Subsequent to this initial coding, a second observer (blind to the background condition and experimental hypotheses) provided reliability assessments. Cohen's (1960) Kappa of agreement, which reflects percentage of agreement correcting for chance, was calculated for each subject. These Kappa values had a mean of .87, $SD = .09$, with a range from .68 to 1.00. Although there are no significance tests for Kappa, values between .60 and .75 represent good reliability, whereas values over .75 reflect excellent reliability (Fleiss, 1981).

RESULTS

Percentage of blinking responses (number of blinking responses/total number of usable trials) was examined in a five-way analysis of variance (ANOVA), with the three within-subjects factors of object (obstacle vs. aperture), background (untextured vs. stationary vs. moving), and direction (approach vs. withdrawal), and the two between-subjects factors of object order (obstacle first vs. aperture first) and direction order (approach first vs. withdrawal first). This analysis revealed main effects for object, $F(1, 24) = 41.2$, $MSE = 0.03$, $p < .001$; background, $F(2, 48) = 3.8$, $MSE = 0.03$, $p < .05$; and direction, $F(1, 24) = 228.6$, $MSE = 0.15$, $p < .001$. All of the two-way interactions among object, direction, and background were also significant. Most critically, the three-way interaction among these factors was reliable, $F(2, 48) = 3.7$, $MSE = 0.02$, $p < .05$. The two order variables were not involved in any significant effects.

Subsequent analyses examined blinking responses for approach and withdrawal trials separately, using two-way ANOVAs. Figure 1

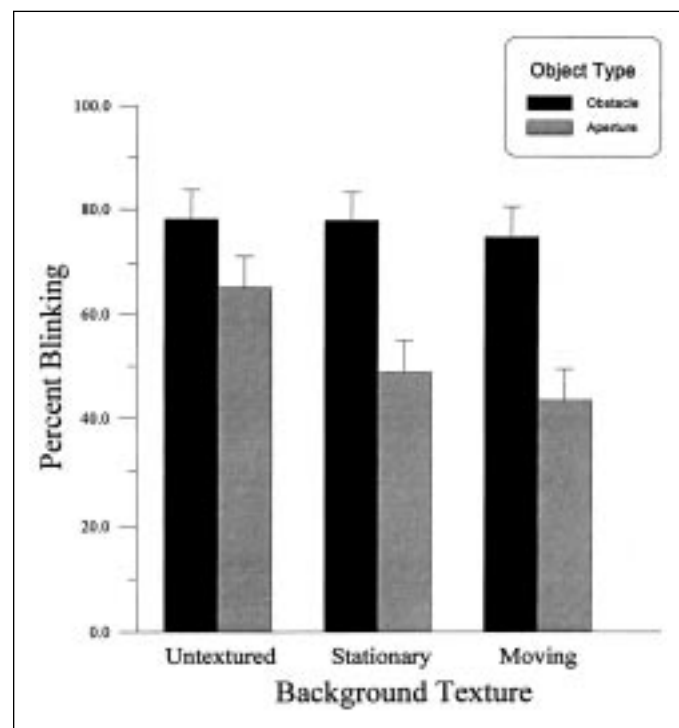


Fig. 1. Mean percentage of blinking responses (with standard error bars) as a function of object type (obstacle vs. aperture) and background texture (untextured vs. stationary vs. moving) for approach trials.

shows the mean percentage of blinking responses as a function of object and background for approach trials. Overall, there was more blinking to obstacles than to apertures, with a main effect for object, $F(1, 27) = 45.5$, $MSE = 0.1$, $p < .001$. There was also a main effect of background, with the most blinking responses to untextured backgrounds, followed by stationary backgrounds, and then moving backgrounds, $F(2, 54) = 4.6$, $MSE = 0.05$, $p < .05$. Most important, the interaction between object and background was significant, $F(2, 54) = 3.5$, $MSE = 0.04$, $p < .05$, revealing that background influenced blinking to apertures but not obstacles.

Single-degree-of-freedom polynomial contrasts revealed a linear trend across backgrounds, $F(1, 27) = 7.09$, $MSE = 0.1$, $p < .05$, and an object-by-background interaction for this trend, $F(1, 27) = 9.2$, $MSE = 0.03$, $p < .006$, with the linear trend characterizing responses to the aperture. Post hoc comparisons, using Bonferroni corrections, revealed lower blinking rates for apertures than obstacles for stationary and moving backgrounds, and a marginal difference for untextured backgrounds; this difference for untextured backgrounds was significant before correcting for multiple comparisons.

Withdrawal trials rarely produced responses in infants, with an overall blinking rate of less than 1% (mean response across conditions = 0.84%). The ANOVA on the blinking responses for withdrawal trials failed to uncover differences as a function of object, $F(1, 27) = 1.1$, $MSE = 0.001$, n.s.; or background, $F(2, 54) = 0.5$, $MSE = 0.001$, n.s.; nor any interaction between the two, $F(2, 54) = 1.2$, $MSE = 0.001$, n.s.

DISCUSSION

Overall, these results confirmed our predictions concerning infants' perceptions of looming obstacles versus apertures. Specifically, infants responded more to looming obstacles than to apertures (replicating Carroll & Gibson, 1981), with the reaction to looming apertures, but not obstacles, varying as a function of the salience of the background. This compelling replication of the unpublished work of Carroll and Gibson is especially persuasive given that this experiment differed from theirs in numerous ways. One critical difference is that Carroll and Gibson's aperture was a large wall with a window in its center, whereas this experiment's aperture had the same outer dimensions as the obstacle. Thus, in this study, the outer contour of the looming information was equivalent for the two objects. A second difference is that the primary dependent measure of this study involved eyeblinks, whereas Carroll and Gibson measured backward head pressure resulting from head withdrawal. This distinction is important given that Yonas and colleagues (Yonas et al., 1977; Yonas, Pettersen, & Lockman, 1979) suggested that head withdrawal could result from nondefensive tracking of the rising upper contour of the object. Thus, replicating Carroll and Gibson's findings using a different measure is warranted given the principle of converging operations (Garner, Hake, & Eriksen, 1956; Proffitt & Bertenthal, 1990).

More generally, this study speaks to the controversy concerning whether or not such responses actually reflect defensive reactions produced by recognizing impending collision. Early work (Ball & Tronick, 1971; Bower et al., 1970) assumed that infants' responses to looming indicated the perception of imminent contact, based on the finding that infants responded more to information specifying contact (symmetrical expansion) than to information specifying no contact (asymmetrical expansion). Thus, it was assumed that infants dissociated the implications of these visual patterns (hits vs. misses) and responded appropriately.

One concern with this interpretation is that this dissociation is based on very different patterns of looming. Thus, the consequences for contact with these objects are confounded with differences in the visual information. The current study, along with Carroll and Gibson's (1981), addressed this confound by using two objects that provided similar looming information but nevertheless elicited differential responding because of the consequences of contact with them. Thus, although both objects loomed, the obstacle specified collision, whereas the aperture specified passage.

The current study moves beyond Carroll and Gibson's (1981) work in two important ways. First, as already mentioned, Carroll and Gibson compared looming responses to a small closed contour and a large open contour; unfortunately, it is unclear how such size differences affect looming. In this study, however, the objects contained the same expansion patterns in their outer contours, while being distinguished by the relative deletion and accretion patterns in their centers. Second, this experiment demonstrated differences in defensive responses to the aperture using equivalent looming information across background conditions. In this case, variation in looming responses resulted from highlighting the properties of the looming aperture, without altering the looming information itself. Generally, variations in looming responses produced solely by modifying the consequences of contact with the objects provide compelling evidence that infants do recognize objects on a collision course.

One theoretical characterization of this finding that infants are aware of these functional consequences involves the perception of the *affordances* of objects. The concept of affordances, originally developed by J.J. Gibson (1979), and subsequently explicated by E.J. Gibson and other investigators (E.J. Gibson, 1982; see Adolph, Eppler, & Gibson, 1993, for a review), refers to the potential for action arising from the interrelation between an actor and environmental properties supporting action. In this situation, the obstacle and aperture present infants with the affordances of collision and passage, and the infants' behavior is then related to these differing possibilities. A great deal of recent research attests to the viability of this characterization of perception-action coupling (Schmuckler, 1996), and these results fit well into this general framework.

In sum, the current study explored infants' differentiation of obstacles and apertures. Within a broader framework, this research speaks to the growth of perceptual-motor abilities underlying movement through the world and to the perception of three-dimensional depth relations. Accordingly, this work sheds light on the growth of visual perception abilities and infants' developing skill in coordinating vision with action.

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