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ABSTRACT

A looming paradigm was used to determine what depth information infants process in addition to that provided by the expansion of a single, closed contour of an object. A total of 18 male and 15 female infants aged 22-48 days watched a film in which the circular elements and inter-element spaces of the projected image alternately expanded and contracted. A display containing 800 black circles elicited significantly more head responses directed away from the screen than displays having either one or three circles of the same size. The differences were only found in the expansion trials. Infants thus processed depth information provided by the expanding spaces between elements or movement of the elements toward the peripheral visual field. The results were in agreement with Gibson's (1966, 1968) description of the adequate stimulus for perceived movement in depth. (Author/BRT)

Infant Processing of Depth Information
In Expanding Dot Patterns

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Abstract

A looming paradigm was used to determine what depth information infants process in addition to that provided by the expansion of a single, closed contour of an object. A total of 18 male and 15 female infants aged 22-48 days watched a film in which the circular elements and inter-element spaces of the projected image alternately expanded and contracted. A display containing 800 black circles elicited significantly more head responses directed away from the screen than displays having either one or three circles of the same size. The differences were only found in the expansion trials. Infants thus processed depth information provided by the expanding spaces between elements or movement of the elements toward the peripheral visual field. The results were in agreement with Gibson's (1966, 1968) description of the adequate stimulus for perceived movement in depth.

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Young infants probably perceive movement of an object in depth well before they are able to locomote or manipulate objects systematically. Recent work casts doubt on the "action" hypothesis that the capacity to see a change in the distance between the observer and the observed depends on tactile-kinesthetic experience. Bower, Broughton, and Moore (1970) found that even 6-day-old infants reacted to an approaching object by moving their heads back and bringing their arms between their faces and the object. Furthermore, a purely visual stimulus, the symmetrical expansion of a shadow on a translucent screen, also released the avoidance response. Simply increasing the air pressure on the infants' faces did not result in the same response, the subjects merely slumping farther into their seat. Ball and Tronick (1971) replicated the observations of Bower et al. (1970) and extended them in showing that the head and arms reactions were specific to movement of the object directed toward the subject. A real object passing off to the side of the subject and its optical equivalent, the asymmetrical expansion of a shadow, rarely elicited the head back response. Subjects generally tracked the object or shadow to the side without bringing their heads back.

It should be noted that movement of an object away from the subject and the optical equivalent of this displacement, contraction of a shadow, did not result in the combined head and arm responses. Thus, the reactions were specific both to the approach of an object toward the observer and the purely optical transformation corresponding to approach, the symmetrical expansion of a closed contour. As implied by Gibson (1966), Hay (1966), and Johansson (1964), the expansion (or contraction) of a closed contour provides information to young infants that allows them to perceive movement of an object in depth together with its path of approach. Given the age of the subjects (as young as 6 days), the ability to process this optical depth information probably did not stem from tactile-kinesthetic experience.

Research concerning the infant's ability to perceive movement in depth has so far involved a single type of stimulus: the transformation of an isolated shadow or the approach of a single object. But visual information about movement in depth is not limited to that provided by the transformation of an isolated element in the visual field. Gibson (1958, 1966, & 1968) argued that optical transformations such as the expansion of the inter-element distances of a stimulus could provide depth information concerning the observer's own displacements or the movement of a textured surface. For example, when an observer moves toward a textured wall, the relationship between the elements of the visual field undergoes a transformation: The visual angle of the distance between any two elements increases at the same time as the visual angles of the elements themselves. Braunstein (1962a, 1962b, 1966, & 1968) in fact found that adult subjects perceived a change in the distance between themselves and a two-dimensional dot pattern when the pattern underwent expansion or contraction. The subjects actually viewed a film so that the real distance from the stimulus remained constant. Expansion or contraction of the inter-element spaces favored the perception of approach or withdrawal of a surface.

The origin of the infant's capacity to process the depth information provided by the expansion and contraction of a multi-element pattern remains unknown. Nothing indicates at present that the young infant takes into account all the information available during the simultaneous expansion of several elements in the visual field. The present research is designed to demonstrate that infants under two months old can process and use appropriately the depth information contained in the transformation of a complex stimulus.

If the expansion of a multi-element visual stimulus corresponded for the infant to a change in depth, the transformation of a two-dimensional pattern of small circles might release the head and arms avoidance response. It is predicted that transformation of a purely optical stimulus can, in certain conditions, result in avoidance responses not caused solely by the expansion of a single element of the display. More specifically, the expansion pattern of a stimulus containing 800 elements should result in a greater frequency of head and arm responses than the magnification of a single element of appropriate size. The effectiveness of the 800 elements condition might conceivably result from the expansion of a relatively small subset of its constituents. Therefore, a condition involving the expansion of only three elements will be used, but no specific hypotheses concerning its relative effectiveness in releasing the response will be made. It is important to note that contraction of the elements in the visual field should not yield the avoidance response as frequently as their expansion if the response were specific to conditions of approach.

Method

Subjects

A total of 33 infants ranging in age from 22 to 48 days was divided into three groups, each group corresponding to a particular order of the three experimental conditions. The average ages of Group 1, Group 2, and Group 3 were, respectively, 33.2 days, 34.2 days, and 35.8 days. The 18 male and 15 female subjects came from a predominantly middle-class, urban environment.

Material and stimuli

The experiment took place in a small room (2.4 m x 2.4 m) next to the waiting room of a well-baby clinic. A plastic rear projection screen (160 cm x 160 cm) divided the area into two parts: A 16 mm movie projector was placed on one side of the screen and an infant seat on the other. A video tape machine behind the infant chair and a television camera situated 50 cm to the right of the seat allowed a complete recording of all responses during the experimental session. Light from a 200 w lamp directed toward the rear wall of the room allowed efficient operation of the video machine without impairing the clarity of the image on the projection screen. On the side of the chair oriented towards the camera was placed a small 12 v bulb (invisible to the subject), which signaled the beginning and end of a stimulus transformation. The television monitor was located on the same side of the screen as the movie projector.

The experimental displays were filmed with 16 mm black and white Kodak 4-X movie film (400 ASA) at 24 frames per second. A zoom lens operated by a motor, in turn controlled electronically, produced expansions and contractions of the filmed elements of the following three conditions: 1) 800 circles on a white background (75 cm x 51 cm) such that the density of the elements was constant in all areas of the display, 2) 3 circles arranged in the form of a triangle with one vertex down and 3) 1 circle located in the center of the white background. Each individual element had the form of a black circle with a diameter of .9 cm once projected on the screen. The distance between any two elements was at least equal to the diameter of an element.

The film began with 10 sec of leader frames. The first stimulus was then presented for 15 sec without undergoing any transformation. Next, all the elements in the visual display as well as the inter-element distances underwent a a five-fold expansion such that the size of an element on the screen went in 6 sec from .9 cm to 4.5 cm. At 25-30 cm from the screen, the visual angle of an element centered on the subject thus went from roughly 1.8°-2.06° to about 9.0°-10.30°.

The set of three elements went from a minimum width of 8.0°-8.52° to about 39.0°-40.6° visual angle. After 10 sec without further transformation, a contraction of the elements of the display during 6 sec occurred that was the exact inverse of the expansion trial. Following another 10 sec without transformation, a new expansion took place. At the end of three such "expansion-contraction" cycles, there were 10 sec of an empty but illuminated screen. Now a different stimulus was presented during three expansion-contraction cycles. Another 10 sec of blank screen separated the second from the third stimulus, the latter also undergoing three expansion-contraction cycles. The first expansion of any given stimulus was always preceded by 15 sec of the display without transformation to assure proper orientation of the subject to the new stimulus elements.

The frame size of the projected image remained constant at 75 cm x 51 cm (about 113° x 90° visual angle). Thus, after the expansion of the 800 element condition, only 37 circles remained in the visual field. In the cases of the 3 and 1 element conditions, the number of circles visible remained constant during the transformations.

It should be noted that before a transformation one experimenter suspended an object such that its inverted V-shaped shadow (the visual angle remaining constant at 7°) was projected on the screen. Movement of the shadow served to maintain visual orientation of the subject toward the center of the stimulus between transformations.

Procedure

Each subject viewed all stimuli in an order determined by a Latin Square. Thus there were three groups of 11 subjects: 1) Group 1: 800-Circles-3-Circles-1 Circle, 2) Group 2: 1 Circle-800 Circles-3 Circles, and 3) Group 3: 3 Circles-1 Circle-800-Circles.

Subjects were carried by a parent to the experimental space where they were seated in an infant chair about 25-30 cm from the projection screen. A subject was held in the seat by a belt passed around the thighs with the lower region of the back supported by a cushion. The experimenter holding the subject started the video tape recorder. Once the infant was oriented toward the screen, another experimenter began the film. The baby's head was supported during the 3 min 19 sec of the film in order to prevent gross side to side head movements. Despite the head support, the arms and the head were free to move in any direction; the role of the experimenter was to preserve the subject's head orientation to the stimulus at the beginning of a transformation.

Results

Two response measures were defined: 1) head movements directed away from the screen with respect to an arbitrary point of departure and 2) arm movements consisting of the raising of one or two arms such that the hands finished at about face level. Each response or combination of both head and arm movements was counted as present or absent during each of the three expansions and three contractions of a stimulus. For example, a subject could have made a maximum of three head movements, three arm movements, and three combined head and arm movements during the three expansion trials of the stimulus "1 Circle." The results of the expansion and contraction trials considered separately were examined using an analysis of variance for a 3 x 3 Latin Square (Winer, 1970) as well as the Scheffe test (Hays, 1963). Comparisons of expansion and contraction trials were made with a sign test.

Expansion trials

The three groups of subjects did not differ in their frequency of head movements, $F(2,30) = .39$; arm movements, $F(2,30) = 3.14$, $p > .05$; or combined head and arm movements, $F(2,30) = .38$. Thus, the results from the independent groups seem comparable, allowing the data to be pooled across subjects for comparison of the three experimental conditions.

It is clear from Table 1 that there was a significant effect of the number of elements in the display on the frequency of the combined head and arms responses, F(2,60) = 12.58, $p < .01$. A Scheffe analysis showed that the condition 800 Circles resulted in significantly more combined head and arm responses than either the 3 Circles or the 1 Circle conditions ($p < .05$). The latter two did not differ significantly ($p > .05$) although head and arm responses were more frequent in the 3 Circles condition. Two comments are in order. First, the principal hypothesis of this study was confirmed: The 800 Circles condition resulted in more avoidance responses than the condition having only one element. Second, a stimulus composed of only three elements was far from being as effective as the 800-element display in which a large portion of the visual field underwent a transformation. It should also be noted that neither the effect of stimulus order nor the order x stimulus interaction was significant, Fs $(2,60) < 1.0$.

Insert Table 1 about here

Despite the pattern of results confirming the initial hypothesis, the complex response of head and arm movements together is perhaps not the best measure of the differences in effectiveness of the experimental conditions. The frequency of arm movements (Table 2) did not differ significantly in the three conditions, F(2,60) = .99. Head movements (Table 3), however, reproduced exactly the pattern of responding obtained when using the combined head and arms measure. Thus, there was a significant effect of the number of stimulus elements on the frequency of head back responses, F(2,60) = 30.35, $p < .01$. A Scheffe analysis revealed that the 800 Circles condition was more effective in releasing head movements than either of the other two conditions ($p < .05$), which did not differ significantly ($p > .05$). The significant effects of the number of stimulus elements on combined head and arm movements most likely reflected the differential effectiveness of the conditions in releasing head responses. The conditions were most clearly differentiated by head movements directed away from the screen. Finally, it should be noted that neither stimulus order nor the stimulus x order interaction had a significant effect on either head or arm movements, Fs $(2,60) < 1.0$.

Insert Tables 2 and 3 about here

Contraction trials

If only contraction trials are considered, the three groups of subjects did not differ in the frequencies of their combined head and arm movements, $F\ (2,30) = 2.17$, $p > .05$; their head movements alone, $F\ (2,30) = 1.51$, $p > .05$; and their arm movements alone, $F(2,30) = .80$. As in the expansion trials, the independent groups apparently did not differ significantly in their responding to the stimulus displays.

But in contrast to the expansion trials, there were no significant main effects of the number of stimulus elements (cf. Tables 1, 2, and 3). Whatever response measure used (head and arms together, head alone, or arms alone), there were no significant differences among the 800 Circles, 3 Circles, and 1 Circle conditions, Fs $(2,60) < 1.0$. Thus, the differential effects of the three conditions were specific to the expansion trials. More precisely, the relatively greater frequency of head back responses during expansion trials of the 800 Circles display was not reproduced in the contraction trials.

While there were no main effects of stimulus order in expansion trials, order effects are suggested by the results from the contractions: Responding generally became more likely as the session continued (cf. Tables 1, 2, and 3). Thus, arm movements occurred more often in the second and third block of three contraction trials, $F(2,60) = 3.24$, $p < .05$. The same pattern was found for head and arm movements together, $F(2,60) = 2.74$, $p < .10$, as well as head movements alone, $F(2,60) = 2.64$, $p < .10$, although the results achieved only borderline significance.

Generally, the interaction of stimulus order x stimulus condition was not significant for head and arm movements together, head movements alone, $Fs(2,60) < 1.0$, and arm movements, $F(2,60) = 2.44$, $p > .05$.

Comparison of expansion and contraction trials

As in the Ball and Tronick study (1971), head and arm responses occurred more frequently in expansion than in contraction trials (Table 4). Of the 33 subjects, 28 made more combined head and arm responses during expansion trials than during contraction trials. The corresponding figures for head and arm responses considered separately are 31 and 22 respectively. These patterns of results were all significant ($p < .001$, for a two-tailed sign test). The avoidance responses were thus specific to the expansion of elements in the visual field, a finding that confirms the initial hypotheses of the study.

Insert Table 4 about here

Reliability checks

Observations of the principal investigator were verified by another observer on a total of eight subjects representing the three groups. In watching the video tape; the second observer did not know either the experimental condition or its state of expansion or contraction. In general, agreement between the observers was good. Of the 140 expansion and contraction trials examined, there was agreement in 94% of the trials on what constituted a head movement and in 82% of the trials on what was recorded as an arm movement. These results appear to be reliable since a test of correlated proportions (Hays, 1963) revealed only random differences between the observers for both head (χ^2 (1) = 1.13, n.s.) and arm movements (χ^2 (1) = 1.44, n.s.).

Discussion

The principal hypothesis of the study was confirmed: Expansion of small elements scattered over 113° of the visual field released avoidance responses in young infants. The response consisted essentially of movement of the infant's head away from the projection screen, often with agitation of the arms at the same time. In topography the responses were identical to those described by Bower et al. (1970) and Ball and Tronick (1971). It is important to emphasize that the effectiveness of the 800 Circle condition did not simply depend on the expansion of an isolated stimulus element, the 1 Circle condition releasing the avoidance response relatively infrequently. That the 3 Circles condition was no more effective than the expansion of the single element alone suggests that the effectiveness of the 800 Circles condition was not merely due to the greater probability of seeing an element. The 3 Circles stimulus expanded to 41° visual angle, which was well within the infant's effective visual field (cf. Tronick, 1972). It is possible that in order for the head back response to reach its maximum frequency of occurrence the expansion of the stimulus elements must take place over an area covering more than 41° visual angle. The expansion of stimulus elements covering a substantial portion of the visual field is an essential condition for the systematic appearance of head movements--given the relatively small size of the elements used in the present study.

The head and arms avoidance response probably reflects a capacity to see movement in depth, and it is important to emphasize the pattern of responding to justify this hypothesis. First, head movements did not occur at random, the direction of displacement being away from the screen. If subjects had simply been following an element in the condition 800 Circles, for example, they could have followed it toward the left or right periphery of the screen (cf. Ball & Tronick, 1971). This was not the case in the condition with 800 elements since about 70% of the responses (see Table 4) were directed neither to the right nor to the left of but away from the screen. Furthermore, head movements were generally specific to expansion trials, the pulling away from the screen occurring infrequently during contraction of a stimulus. Thus, the subjects responded especially in conditions reproducing the optical transformations corresponding to a progressive reduction of the distance between them and a textured surface. Finally, not only were the head movements generally specific to expansion trials, the elevated frequency of head responses in the condition with 800 elements also occurred only during expansion trials. Apparently, the information processed during the expansion of 800 small elements specified movement in depth for the infants; the infants processed optical information in a manner appropriate to the distal events specified (approach or withdrawal). Reducing the explanation of the responses to some form of <u>general</u> "arousal" would not account for the differential effect of the 800 elements in expansion and contraction trials. In particular, the arousal explanation would not account for the absence of effect of the 800 elements condition during optical transformations corresponding to a progressive increase in the distance between the subject and the texture (i.e., during contraction trials).

Thus, the effects of the 800 Circles condition were not simply due to a general excitation of the subjects. But the increased frequency of head and arm movements in contraction trials toward the middle and end of the experimental session may have in part resulted from some form of general arousal. It is important to emphasize in this regard that no differential effects of the three conditions were found during contraction trials. Hence, the order effects were not specific to a particular condition. A partial explanation for the order effects may lie in the fatigue and uncomfortable posture resulting from a three-week-old baby's holding a seated position for over 3 min. An increased frequency of arm movements was perhaps to be expected as the baby became increasingly agitated. Head movements quite possibly represented the beginnings of avoidance of any optical transformation, that is, a tendency to escape from the experimental setting. It is, of course, entirely possible that one of the factors rendering the situation more and more uncomfortable was simply the expansion trials themselves. The degree of upset reported by Bower et al. (1970) during approach of an object suggests that the latter hypothesis is correct, although confirmation of this view requires further investigation.

Given the age of the subjects, the hypothesis of a tactile-kinesthetic origin (Piaget, 1936, 1937) of the visual depth perception revealed by the head back response seems implausible. Before systematic locomotion or prehension, the young infant uses the visual depth information furnished by an expanding texture. According to Gibson (1969), visual perception of movement in depth involves the processing of invariant information provided by optical transformations specifying a distal event. There is no reason to suppose a priori that the visual abilities required to use the transformations must have tactile origins. Apparently, as suggested by the findings of the present study, the young infant takes into account both the depth information provided by the expansion of a single element in the visual field (Ball & Tronick, 1971) and the supplementary information furnished by a pattern undergoing expansion. It is perhaps the transformation of the inter-element relationships (e.g., the visual angle of the inter-element distances) that underlies the effectiveness of the expanding texture in releasing head responses. A definitive confirmation of this hypothesis requires a refinement of the experimental conditions used in this study.

Thus, the study of optical textures undergoing transformation is crucial for pursuing research on perception of displacement in depth. But at least one question remains: displacement of what? Gibson (1966) argued that movement of an observer toward a surface (e.g., a textured wall), is specified by a stimulus in which all elements of the visual field move toward the periphery and the visual angles of the interelement distances increase. It should be clear that these were exactly the conditions fulfilled by the 800 Circles condition in the present experiment. One might speculate that by the third week of life infants have the visual ability to perceive their own displacement and not merely that of an isolated object. Of course, verification of this view would demand a more detailed account of the properties of the stimulus releasing the head back response. The relative importance of movement of the stimulus elements toward the periphery and an increase in the visual angle of the inter-element distances must be determined. If the avoidance response were influenced most heavily by a combination of these two factors, it could be reasonably concluded that young infants pick up information specific to their own displacement. Animation techniques might allow the experimental separation of the stimulus variables and hence an evaluation of their interaction in the present work. In conclusion, as Vurpillot (1972) has argued, the particular characteristics of the central nervous system of a given species play a crucial role in spatial perception in general and depth perception in particular. It is important to add, however, that information in a stimulus specifying distal variables, such as displacement in depth, is used by a variety of species (Schiff, 1965). Continued research with the looming paradigm--expansion and contraction of elements in the visual field--should reveal more concerning the forms of invariant information used by the young infant.

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Footnote

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Table 1

Number of Combined Head and Arm Movements According to Stimulus Order

	Order					
	Expansion Trials			Contraction Trials		
Stimulus	1	2	3	1	2	3
800 Circles	15	18	18	2	3	7
3 Circles	7	10	11	3	2	3
1 Circle	8	7	6	0	4	5

Note. The figures represent the total number of combined head and arms responses pooled over the three trials of a stimulus and the 11 subjects of a particular group. The maximum number of responses per stimulus-order combination is 33.

Table 2

Number of Arm Movements

According to Stimulus Order

	Order					
	Expansion Trials			Contraction Trials		
Stimulus	1	2	3	1	2	3
800 Circles	15	19	22	10	11	15
3 Circles	20	12	16	9	11	15
1 Circle	16	20	11	7	19	10

Note. The figures represent the total number of arms responses pooled over the three trials of a stimulus and the 11 subjects of a particular group. The maximum number of responses per stimulus-order combination is 33.

Table 3

Number of Head Movements

According to Stimulus Order

	Order					
	Expansion Trials			Contraction Trials		
Stimulus	1	2	3	1	2	3
800 Circles	24	23	23	2	5	7
3 Circles	12	11	16	4	2	4
1 Circle	12	10	9	0	5	6

Note. The figures represent the total number of head responses pooled over the three trials of a stimulus and the 11 subjects of a particular group. The maximum number of responses per stimulus--order combination is 33.

Table 4

Overall Comparison of Avoidance Responses

In Expansion and Contraction Trials

Stimulus	Response	Expansion	Contraction
800 Circles	Head	70	14
	Arms	56	36
	Head and arms	51	12
3 Circles	Head	39	10
	Arms	48	35
	Head and arms	28	8
1 Circle	Head	31	11
	Arms	47	36
	Head and arms	21	9
Totals	Head	140	35
	Arms	151	107
	Head and arms	100	29

Note. The results represent the total number of responses to a given stimulus pooled over all 33 subjects and across stimulus orders. Each figure is based on a maximum of 99 possible responses, resulting in a a global comparison of the 297 expansion and 297 contraction trials.