VISUAL PERCEPTION AND INFANT DEVELOPMENT:

CAN INFANTS USE CONVEXITY AS A CUE FOR FIGURE/GROUND SEGREGATION

By

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STATEMENT BY AUTHOR

SIGNED: ______________________________

I would like to dedicate my honors thesis to my grandparents and my parents. I could not push myself as hard as I do without your support and love. Thank you for all you do for me, I love you forever.

I would also like to thank my advisor Dr. Mary Peterson. Thank you, Mary, for your help and guidance through my undergraduate years at the University of Arizona. I have really valued your wisdom and advice throughout the years and I will miss working in the Visual Perception Lab.

Visual Perception and Infant Development:

Can Infants use Convexity as a cue for Figure/Ground Segregation?

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There has been much research performed regarding an adult's ability to distinguish figure regions from their background. Convex regions are more likely to be seen as figure than concave regions. No research investigates the development of this ability. The current work will identify between what age infants learn to distinguish figure from ground using convexity as a cue. Nine month old and 4 month old infants were tested. We found that 9 month and 4 month old infants use convexity to distinguish figure from ground by showing novelty preference for concave test displays. It appears as though the ability to use convexity as a cue for figure is a developed skill. Future research will allow us to see if the infants are using the habituation display to perform figure/ground segregation or if they are using knowledge from the outside world to tell them that convex regions are figure.

Adjacent regions that share a border in the visual field are either designated as "figures" or as "grounds." Regions seen as "figures" have a definite shape and appear to rest on top of a background: they are the objects in the visual field. The regions seen as "grounds" are shapeless near the border they share with figures and are seen as continuing behind the figure regions. The border between the two regions is assigned to the figure (Rubin 1915, 1958). This is the phenomenon of *figure-ground segregation*. Figure-ground segregation allows humans to recognize objects in their visual field.

Many different cues can lead to figure ground segregation. Objects are defined as solid shapes that are continuous, move within a specific boundary and when in contact with another object (Peterson, 2001; Spelke, 1990; Spelke, Guthiel & Van de Walle, 1995). Spelke's definition of an object primarily focuses on object movement. This means that things that move together go together and can therefore be classified as an object.

Objects are also determined by grouping, heuristics. For instance, the cue of "common region" specifies that shapes within the same boundary are likely to be grouped together (Palmer, 1992). Therefore, based on common region, humans are able to identify what an object is regardless of patterns within the boundary.

In the research presented here we focus on one specific figural cue: convexity. Global convexity, in which boundaries of an object appear to be cloud-like or to bulge outward, is a strong cue to distinguish a region as figure (Peterson, 2001; Kanizsa and Gerbino, 1976). The Gestalt scientists proposed that convexity was an innate cue because people everywhere have this bias for convexity (for summary see Peterson, 1999). But the innateness hypothesis has not been tested directly. It is important to do so because, widespread use of a visual cue such as convexity might arise from learning that objects in our world tend to be convex.

Most of the research that has been conducted on figure/ground segregation has tested human adults. There has not yet been any work examining the development of figure-ground segregation in infants in general or their use of convexity as a figural cue in particular. Visual perception is one of the most important skills developed during the first year after birth. In fact, many other skills, such as language development and learning about the surrounding world, are dependent on the development of visual perception. Infants' ability to perceive begins very early in life; however it does not appear to be an innate skill.. The ability of humans to, detect edges, assign boundaries, and use common motion as a grouping cue, develops early in life so that infants can begin to perceptually organize their visual world (Kellman and Arterberry, 1998). Kellman and Arterberry showed that 3-month old infants were able to discriminate between two shapes specified by accretion and deletion (the process of revealing and concealing a farther surface; Johnson & Mason, 2002; Kaplan, 1969). Thus, 3-month old infants can use cues provided by the edges of a shape to detect the differences between two shapes. Additionally, Kellman and Arterberry (1998) found that infants between the ages of 5 and 7 months of age began to reach for objects with edges marked by accretion and deletion. Based on those studies, Kellman and Arterberry hypothesize that infants' sensitivity to edges improves between birth and 6 months of age.

Other, related, developmental research suggests when figure/ground segregation might occur. For instance, Yonas and colleagues (1979,1981) found that infants at age 5 months reacted to looming objects that appeared to be coming too close to them, indicating that they were able to assign a boundary to an object using looming motion as a cue.

Additionally, Bhatt et al. (2007) found that infants between 3 to 4 months of age were able to use common region as a cue to organize information in their visual fields. Thus, by 3 to 7 months of age, infants can use some cues to organize the visual field into objects. But there is no reason to assume that all figural cues are available at the same age. Some may need more development or more experience than others. In the present research, we examined when infants begin to use convexity as a cue to which of two adjacent regions is the figure.

Since infants are unable to communicate what they are seeing we will use a habituation paradigm while monitoring their eye movements. Fagen (1976) used a habituation paradigm to study face recognition in infants. His experiment started with a *familiarization period* in which the infants were exposed to a face multiple times. The infant's looking time was measured on each familiarization trial; it gradually decreased over repeated exposures of the same face. When the infant’s looking time leveled off at a relatively short time, Fagen considered the infant “habituated” to the display. After habituation, Fagen paired the already exposed face with a new one and measured which picture the infants preferred to look at (i.e., spent more time looking at). He found that infants revealed their memory for the face they saw during the familiarization by looking at one of the paired faces longer than the other. When infants look longer at a display that was seen on the familiarization task, they are said to show a "familiarization preference." When infants look longer at a display that was not seen on the familiarization trials, they are said to show a "novelty preference" (Goldstein, 2007). Infants can show both types of preference depending on the conditions present during familiarization trials.

Slater, Morison, & Rose (1984) exposed infants to stimuli made up of different geometric shapes, and found that infants tend to show a novelty preference at test. . We used familiarization displays containing alternating equal-area convex and concave shapes to test whether or not infants use convexity as a cue to figure assignment. At test we showed infants single shapes from the larger familiarization display – either convex shape or the concave shape. We hypothesize that if infants saw the convex regions as figures in the familiarization display, they will have habituated to the convex shapes. The concave shapes will then appear to be novel and we expect that infants will show a novelty preference at test by looking longer at the concave shapes than the convex shapes.

The goal of this study is to determine when the convexity cues for figure-ground segregation become effective in development. Specifically, the current research will examine the ability of 4 month and 9 month old infants to use convexity as a figural cue. In this study, the infant is shown an 8-region alternating black convex and white concave display until they have habituated to it. We use eight region displays because it is known that convexity is a very strong cue in eight region displays of the type we used (Kanisza & Gerbino, 1976; Peterson & Salvagio, under review). In the testing phase, the infant is shown looming images of individual convex and concave shapes extracted from the familiarization display. We hypothesized that if they saw the convex regions as figures during habituation, then they should show a novelty preference for concave shapes. Of course, it is possible that infants will look longer at the concave test shapes because of their experience with convex objects and shapes outside the laboratory, and not because they habituated to the familiarization display. We return to this issue later in the paper.

Method

Participants

In this experiment, 10 9-month-old infants (mean age = 9.19 months SD=, 6 boys and 4 girls) and 12 4-month-old infants (mean age =4.14 months, SD=6 boys and 5 girls). Four 9 month olds were omitted for fussing, 2 were omitted for experimental error (pressing the look key at the wrong time) and 1 was omitted because we feel she did not habituate to the display. Three 4 month olds were omitted due to fussiness and 3 were omitted due to experimental error.

Stimuli

Examples of the stimuli used in this experiment are depicted in Figure (1). Every trial began with an attention getter which was an image of a cartoon crawling baby. This image was displayed as a beeping sound was played continuously in the room. Once the infant looked at the screen, the beeping sound and crawling baby were terminated and the trial began.

During each familiarization trial, all infants were shown an eight-region display composed of eight alternating black convex and white concave regions; this display was presented on a perceptually medium grey background (determined by pilot testing with adults. On each familiarization trial the eight region display appeared on the large screen in front of the infant and remained static until the infant looked away. Cohen et al (2000) created a computer habituation program that determines when infants have habituated to the familiarization image. In the current study we will be habituating the infants to an eight-region display composed of alternating black convex and white concave regions. (See Figure 1) Infants will first be habituated to the black and white familiarization display.

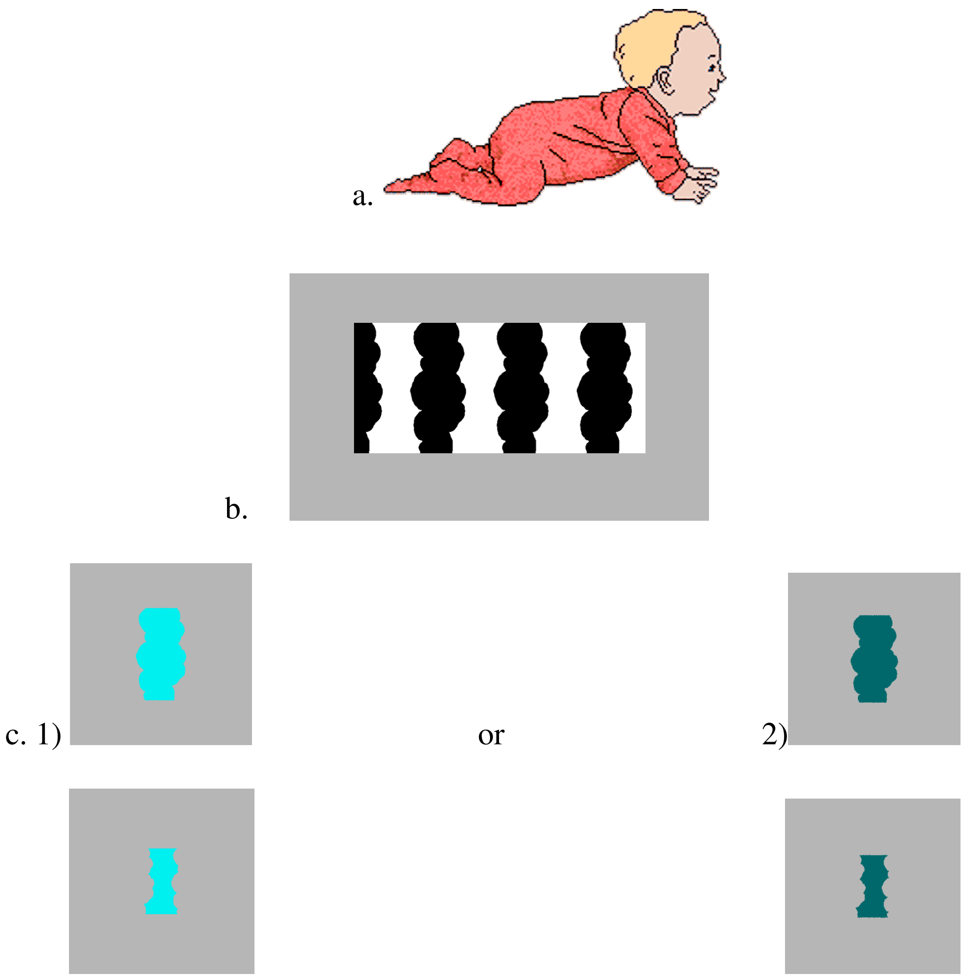


Figure 1. The above displays were used during the experiment for both 9 and 4 month olds. A) is the attention getter that was accompanied by a beeping noise. B) is the habituation 8- region display with black convex and white concave regions. C) Two types of test displays infants saw either high luminance cyan (1) test displays or low luminance cyan test displays (2).

Then they will be exposed to 4 individual cyan-colored looming shapes that are either convex or concave (ABBA pattern). Each infant will see the looming regions in one luminance only (either high luminance —similar to the white regions -- or low luminance – similar to the black region) to negate any luminance preference they might have. Using the novelty preference, it can be said that if infants use convexity as a figural cue, then they should show a novelty preference and look at the concave shape longer during test than the convex shape because on the familiarization trials, they had repeatedly seen the convex shape because they saw the convex region as figure with the have reached the habituation criterion (when either 30 familiarization trials have occurred or the summed looking times on three consecutive trials are less than one-half the sum of the first three trials)

Three types of shapes were shown on test trials. The infants saw these test shapes in either high luminance cyan or low luminance cyan on a medium luminance grey background. The first shape shown to each infant was a rectangle. The rectangle loomed towards the infant and then away from the infant once only. The rectangle was used prior to the convex and concave shapes to get the infant comfortable with the looming shapes. The looming was created by enlarging the rectangle and then shrinking it back to its original size. Nest, either the convex or the concave shape loomed toward and away from the infant. For half the infants, the looming started with a convex shape and concave for the other half. A total of four convex and concave shapes loomed towards the infants in an ABBA or BAAB sequence.

Apparatus and Procedure

Apparatus

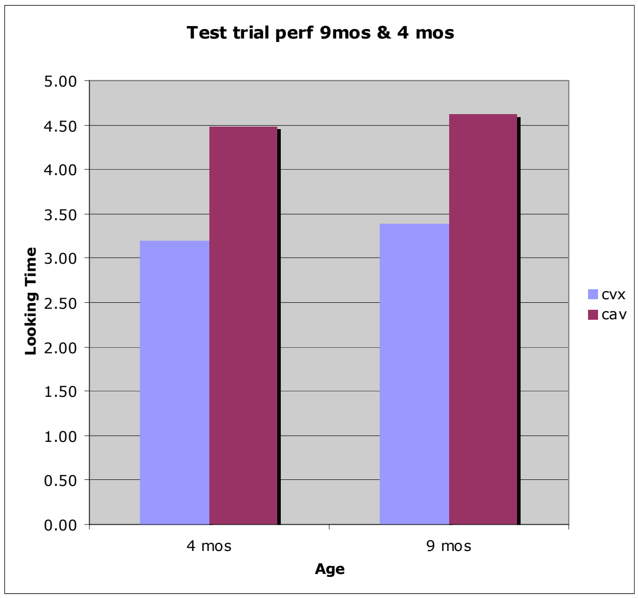
All the displays were shown on a flat screen 76 inches high by 51 inches wide. The actual screen that the displays appear on measures 36 inches high and 47 inches wide. The infants sat on their mother's lap approximately 36 inches from the screen. The images were projected onto the screen by a monitor attached to the ceiling. The visual angle projected onto the screen for the attention getter is 35.3 degree. The visual angle for the 8-region habituation display is 15.4 degrees and 14.7 degrees for the test stimuli. A video camera, located above the screen, was used to allow the experimenter sitting in the control room to monitor the infant's eye movements.

Procedure

Before the start of the study, guardians of the infants were informed of what would occur during the experiment. They were told that the infant would sit on their lap facing the screen and that they were not allowed to communicate with the infant or direct the infant's attention to any of the images. They were also informed of the beeping noise that would play during the attention getter. Then the experimenter briefly explained the procedure of the experiment. The study started when the guardian and the infant entered the room and were comfortably sitting in the chair. A video camcorder was in the room facing the infant so that the experimenter could monitor the eye movements of the infant. The experimenter was unaware of which test displays were being displayed on the screen. First, the crawling baby attention getter came on the screen along with the beeping noise to get the infant to look at the screen. Once the infant's eyes were directed towards the screen the attention-getter was removed and the eight-region familiarization display was shown. The experimenter held down a key on the keyboard as long as the infant was looking at the screen. Once the infant looked away, she released the key. If the infant happened to look back at the screen the key would be pressed again and the display would not disappear. However, if the infant looked away for longer than 2 seconds the attention getter would come back on the screen until the infant redirected his or her attention to the screen. This continued until the infant habituated to the eight-region familiarization display. The test portion of the experiment began immediately after habituation. First, the rectangle loomed towards the infant and remained on the screen until the infant looked away for. Then, one at a time in an ABBA order the test regions (convex or concave) loomed and then stayed on the screen until the infant looked away. Looking times for each test region were recorded.

Results

The infants' looking times were averaged for each type of test trial (convex or concave shape). Then the mean time looking at the convex shape was subtracted from the mean time looking at the concave shape. Hence, a positive difference indicates a novelty preference. As can be seen in Figure 2, 9-month old infants looked significantly at concave than convex shapes at test (mean difference = 1.1 s; $T(9) = 2.26$, $p< = .033$). This is the predicted novelty preference if the infants saw the convex regions as figure in the familiarization displays. Consistent with this view, 9-month old infants showed a significant positive correlation ($r = .688$, $p < .05$) between the number of habituation trials and the magnitude of their novelty preference: the larger the number of habituation trials, the greater their novelty preference. This correlation relates the performance of the 9-month old infants at test to their perception of the familiarization display. Thus, we take the 9-months old infants' novelty preference as evidence that they saw the convex regions of the eight-region displays as figures.



Age	4 months	9 months
T-test	2.12, p=.05	2.26, p< .04
Correlations (N habit, pref for cav)	-.16	0.688
Correlation (Mean habit duration, pref for cav)	-.36	.06

Figure 2. The graph depicts a novelty preference for the concave test displays for both the 9 and 4 month old infants. However, correlations given in the table allow us to see that 9 month olds have significant positive correlation with N habit and preference for the concave, while 4 month olds have a strong negative correlation for Mean Habit and preference for concave at test.

Four-month old infants also looked longer at the concave test shapes than the convex test shapes (mean difference = 1.3 s; $T(11) = 2.196$, $p = .05$). Is there any evidence that the novelty preference exhibited by the 4-month old infants was due to their experience looking at the familiarization display in the laboratory? Unlike what was observed for the 9-month old infants, the 4-month old infants' novelty preference did not correlate with the number of habituation trials ($r = -0.16$, n.s., or with the mean duration of habituation trials ($r = -0.36$, n.s.).Without corroborating evidence, it is possible that the 4-month old infants' preference for concave test shapes is a sign of experience outside the laboratory, where objects are more likely to be convex than concave. Perhaps 4-month old infants show a novelty preference for the concave test shapes because of experience outside the laboratory.

Discussion

In the present study both 4-month old and 9-month old infants looked longer at the concave than the convex test shapes, thus exhibiting a novelty preference for the concave regions at test. We are interested to see if both ages are using the same information to show a novelty preference for the concave shapes

Figure-ground organization allows humans to use different cues to extract a region to be seen as figure. The ground region then appears shapeless as it continues behind the figure region. Peterson and Salvagio (2007) show that convex regions are a strong cue for figure in adults, especially with the number of regions present in a display. A display with eight regions shows that adults have an 89% preference for convexity. Based on the evidence found we know that by 9 months of age infants have developed the ability to use convexity as a cue for figure, however we are not sure if 4 month old infants are able to use convexity as a cue for figure/ground segregation or just have experience in the outside world to tell them that convex shapes are figures.

From the evidence found in this experiment, 4 month olds are showing some ability to distinguish between convex and concave shapes that loom toward and away from them. These results are consistent with other data found that infants, early in life, are receptive to organizational cues such as lightness similarity, connectedness and common movement (Needham et al., 1997, Spelke 1990; Spelke, Gutheil, G., & Van de Walle, G., 1995). On the other hand, cues such as form similarity do not generally appear to be developed until later in development. (Quinn & Bhatt, 2006). It can be concluded from these results, that many Gestalt principles are developed early in life, but development occurs during different stages.

Furthermore, we investigated the correlation between the habituation displays and the novelty preference for convexity. What we found was that 9 month olds appeared to use the eight regions in the habituation display to extract the convex region as figure. As a result, they showed the novelty preference for the concave region. The results with the 4 month old are not clear if they are in fact using the habituation display to perform figure ground segregation or if they are just using their knowledge of convex regions in the outside world to show a novelty preference for the concave test displays. If 4 month old infants are in fact only using experience from the outside world to distinguish convex regions as figure, then it is possible this skill is not developed enough for 4 month olds to apply to a new alternating convex/concave display. They do not have enough experience with this distinction to apply to objects not common in their world.

A follow up experiment will be implemented to test where the novelty preference for concavity for each age group comes from. This experiment will expose the infants, once again, to an alternating black and white eight region convex/concave display. On test trials following habituation, the infants will view one of two convex shapes (rather than one convex and one concave shape): one from the habituation display and one from a new eight-region display. We expect that if our predictions are correct that nine month olds concave preference arises from the habituation display, but the same is not true for four month old infants, then the nine-month old infants will show a novelty preference for the new convex region whereas the 4 month old infants will not show a novelty preference because both test shapes are convex so nothing distinguishes them from the shapes the infants are exposed to daily. A finding such as this will corroborate our hypothesis that different experiences underlie the novelty preferences shown by 9- and 4-month old infants in Experiment 1. Furthermore, it will show that infants to begin to use convexity as a cue for figure after 4 months of age but before 9 months of age.

Another possibility is that infants saw the convex regions as figures during the familiarization trials because they were black, not because they were convex. For adults, the contrast of the black and white regions was equal against the medium grey background eliminating a preference for either black or white regions because one contrasted more with the background. However, for infants, the contrast may not have been equal.. To provide a solution to this dilemma, in future experiments, infants will be habituated to an eight-region contrast reversed display with white convex and black concave alternating regions. If there is no preference to see black regions as figures, the results obtained with the contrast reversed display should be the same as those obtained in the present experiment. On the other hand, if infants preferentially perceive black regions as figures, then they should perceive the concave regions as figures in the new contrast-reversed displays and the convex shape, rather than the concave shape, will appear novel at test. Perhaps different results will be obtained for the 9-month old and 4-month old infants.

Regardless of why 4-month old infants showed a preference for concave test shapes in the experiment presented here (experience in the outside world, etc.), our results suggest that convexity may not be a very strong figural cue in the 4-month old infants. If convexity is a weak cue, then any tendency to see convex regions as figure for might be easily altered. To test this, we will inundate infants with pictures of concave shapes. These displays will move around, which is known to be a strong cue for figure (Peterson, 2001; Spelke, 1990; Spelke, Guthiel & Van de Walle, 1995). After this learning session, the infants will view the eight region display containing alternating black and white convex and concave regions, followed by the convex or concave test shapes used here. If the infants show a novelty preference for convex shapes after being trained with concave shapes it can be concluded that at 4 months of age, the cue for convexity as figure is not strong enough to sustain change. Therefore, if, after flooding 4 month olds vision with images of concave shapes, they learn to see concave regions as figure, then it can be said that through experience in the world infants learn that convex shapes are figures. This makes sense since most toys that infants are exposed to like bouncy balls, rattles and pacifiers have convex edges to avoid harming the infant. If, however, the infants do not see concave shapes as figure after being flooded with concave regions as figures, then the ability to see convex shapes as figure regions might be an innate skill.

Until then, based on the results from the present experiment, it can be concluded that development of the ability to see convex shapes as figure might be completed by 4 months of age. Future experiments will indicate the salience of this skill between 4 and 9month olds.

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