FIGURE-GROUND SEGREGATION IN 4- AND 9-MONTH-OLD INFANTS

By

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Approved by:

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STATEMENT BY AUTHOR

SIGNED: ____________________

This thesis is dedicated to my mother for having loved and raised me on her own since I was seven, and to my father for having given me so much good, level-headed advice. You have done so much for me, and I will love you both forever.

I would also like to thank my best friends, Angela, Chris, Emily, Anthony, and everyone else for having given me so much love and support over the years. You have been my family all through college (a couple of you for much longer than that), and I could not imagine having had this experience without you.

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Abstract

When two regions share an edge, one region is typically perceived to have a definite shape (figure) while the second (ground) is shapeless and appears to continue behind the figure. In adults, when convex and concave regions are adjacent, convex regions are generally seen as figure. While previous studies indicate that infants as young as 3 to 4 months of age use visual cues to organize their visual field, the development of figure-ground segregation and the use of figure cues within the first year of life has not yet been studied. Here, we investigate 4- and 9-month-old infants' use of convexity as a figural cue. Using a habituation paradigm, we found that 9-month-old infants exhibit a familiarity preference for convex shapes prior to habitation, and a novelty preference for concave shapes following habituation; 4-month-old infants do not exhibit either of these preferences. This indicates that 9-month-old infants used convexity as a figural cue, whereas 4-month-old infants do not. Our data suggest that substantial world experience is required before convexity operates as a figural cue.

Figure-Ground Segregation in Four- and Nine-Month-Old Infants

In a visual scene, when two regions in the visual field share an edge, we typically perceive one as having a shape (called the "figure") and the other one as a background that appears to continue behind the figure (called the "ground"). The ground is shapeless near the edge that it shares with the figure. This is the phenomenon of *figure-ground segregation*. According to Kellman and Arterberry (1998), the first step in this perception of figure versus ground is the location and definition of the object's boundaries, otherwise known as edge detection. Important in this process, especially as it affects perception of depth, is the accretion and deletion of texture. First, depth perception refers to our ability to visually perceive our surroundings in three dimensions. Accretion and deletion are depth cues that refer to a farther surface becoming progressively visible or hidden at an occluding edge, respectively, during relative motion. For example, as an opaque sphere gradually moves across a textured background, the texture of the background becomes hidden at the object's leading edge (deletion) and is revealed at the object's trailing edge (accretion). With no other cues present, accretion/deletion is known to supply adult humans with enough information to define an object. Using the habituation paradigm (to be discussed later in further detail), infants as young as three months old have been shown to recognize edges based on accretion/deletion, but no inferences could be made about whether they saw one surface in front of the other (Kaufmann-Hayoz, Kaufman, & Stucki, 1986). However, in another study, Granrud et al. (1984) showed that by the age of 5 to 7 months old, infants are able to perceive both object shape and depth based on accretion/deletion of texture.

Following edge detection, Kellman and Arterberry (1998) state that edge classification and boundary assignment, which culminate into unit classification, are also major factors in the process of object perception. This is of particular interest in understanding visual perception when objects are partly occluded. In such instances, Mareschal and Johnson (2002) found that T-junctions serve as a rather important visual cue. T-junctions occur at the intersection of an occluded object with its occluder, where the projected edge of the farther object visually stops at the undisrupted edge of the nearer object (the occluder), forming what resembles the stem and bar, respectively, of the letter T. In processing where the T-junctions occur, the visual system is able to identify the presence of an occluded object and complete it behind the occluder. This ability to perceptually complete objects that have been partially occluded is known as amodal completion. To be more specific, amodal completion is a phenomenon that occurs when people are able to view objects as a whole unit despite the fact that not all the visual information is present. Instead of viewing the partially occluded object as several fragments, people view it as one whole continuing behind the occluder, forming a complete object in their minds.

In a study on four-month-old infants' ability to perceive unity when occlusion of an object is present, Kellman and Spelke (1983) habituated infants to an occluded object. They presented the infants with a display of a rod behind a rectangular block, where one segment of the rod protruded out of the top of the block and the second segment protruded out of the bottom of the block, aligned with the top segment. At each intersection of a rod segment with the rectangular block, a T-junction occurs, providing a visual cue that there is an occluded object. Here, the rod is the farther edge that stops at the block, forming the stem of the T, while the block's edge remains undisrupted, forming the bar of the T. However, Kellman and Spelke's display also included the visual cue of common motion, where the two aligned segments of the rod moved in synchronized lateral translation behind the block. They predicted that, if the infants were able to classify the rod as a single unit, mentally completing it behind the block, then they should generalize more toward a display of a complete rod as opposed to a display of two rods, separated where the block had originally been. The results of their study showed that infants as young as four months old were, indeed, able to form whole units from partly occluded objects in their visual perception. While common motion may have played a significant role in unit formation (the second part of their study shows that it is rather effective), the experimenters also presented a suggestion that T-junctions, inherent to the nature of an occluded display, are of particular importance to the infants' perception of depth, contributing to their recognition of a whole unit that has been partially occluded behind some other object.

In the discernment of figure and ground, a more basic element than perceiving depth is the perceptual organization/grouping of elements in our visual field. Because our environment presents us with so many visual stimuli, our brain must organize—or "group"—all these components into something that makes sense to us. Research in the past decade on visual development reveals that infants are able to use various cues to organize their visual world. Past studies have indicated that infants are able to use good continuation, uniform connectedness, lightness similarity, common region, proximity, and even illusory regions—those that are not defined by explicit enclosing contours—in their perceptual organization of the world around them (Quinn & Bhatt, 2005; Hayden, Bhatt, & Quinn, 2006; Quinn & Bhatt, 2006; Bhatt, Hayden, & Quinn, 2007; Quinn, Bhatt, & Hayden, 2008; Hayden, Bhatt, & Quinn, 2008). Good continuation refers to perceiving points that create the smoothest or straightest path as belonging together, and uniform connectedness refers to the perception of connected regions as being part of the same unit. Lightness similarity is where elements that are similar in luminance tend to be grouped together. Common region and proximity are grouping cues that utilize space, where the former refers to perceiving objects within the same region as a unit (eg., dots within a circle as opposed to those outside of it), and the latter refers to perceiving objects that are simply close together as a unit. These visual cues are part of a set of fundamental perceptual principles first identified by the Gestalt psychologists that determine how the perceptual input is organized. These principles also include figural cues, cues that determine which of two contiguous regions is the shaped entity—the figure—and which is the ground. Among those cues is the one we are studying here: convexity.

In adults, when convex and concave regions are adjacent to each other, regions that have convex edges are generally the ones that are considered figure. The concave regions are not perceived to have shape; they are perceived as portions of a surface that complete amodally behind the convex figures. The Gestalt scientists proposed an explanation for this phenomenon in the 1920s, where they determined that use of convexity as a figural cue was innate because people everywhere have this bias toward convexity in their genetic make-up (Peterson, 1999). Their evidence, however, stems from studies that only used displays with eight alternating convex-concave regions. A study done by Peterson and Salvagio (2008) investigated how context affects the strength of the figural cue of convexity by varying the number of regions in their displays. The results of their research shows that the strength of convex cues, while pretty weak at a single edge, increases with the number of alternating convex-concave regions; thus, the strength of convexity is not completely innate but can be, in fact, determined by context.

These results raise the question of whether the use of convexity as a figural cue must be developed through experience. More specifically, is convexity a strong visual cue during our first year of life? The present experiments will examine if and how infants use convexity as a figural cue. As with all of the previously discussed research, aside from that of Peterson and Salvagio (2008), this study will be conducted on infants who cannot simply verbally communicate as to which region they perceive as figure and which region they perceive as ground. Thus, a habituation paradigm will be used. Fagan (1976) was able to successfully use this habituation paradigm in his study on infants' recognition of faces. In his experiment, he had what he called the "familiarization period," where the infant was exposed to pairs of identical faces. Following this was the "recognition test," where he paired a previously exposed face to a novel one and observed the infant's response. The results were rather interesting as they indicated that infants' preference at test depended on the length of the familiarization period. A shorter familiarization period elicited a *familiarity preference*, where the infant would prefer to look at the face he had seen during habituation at test. However, a longer familiarization period elicited a *novelty preference*, where the infant looked at the novel face for a greater amount of time. This occurs because the novel face is more interesting than the face to which infants had previously been exposed to, so they will spend more time observing it.

In addition, Slater, Morison, & Rose (1984) conducted a study on infants' ability to habituate to simple geometric shapes and complex colored patterns, and subsequently, on their ability to display novelty preferences. Their results support the use of the habituation paradigm, where one stimulus is repeatedly presented to the infant in the first phase. The infant's looking time is measured at each exposure. Infants will look at the stimulus less and less as they become more familiar with it (habituate to it). Once habituation is complete, the infant's ability to distinguish between the original stimulus and a new stimulus is tested in the second phase. If infants can distinguish between the original and the novel stimulus, then they will exhibit dishabituation, where looking time will increase with the presentation of the novel stimulus versus the habituation stimulus (Goldstein, 2007).

Recently, Raz (2008) studied whether or not infants as young as four and nine months can use convexity to distinguish between figure and ground. Much of our perceptual development occurs within the first year of life. Thus, two age groups were used in order to address the issue of learning in development with respect to the ability to use convexity as a figural cue: 4-month-old and 9-month-old infants in both groups habituated to a display with alternating convex and concave regions, and then they viewed single convex or concave shapes while their looking times were recorded. If convexity is, as the Gestalt psychologists proposed, purely innate, then both 4-month-old and 9-month-old infants will perceive convex regions as figures in the habituation display and will show a novelty preference for concave shapes at test. However, if convexity is a learned cue, then the 9-month-olds should exhibit a stronger novelty preference for concavity at test while the 4-month-olds should exhibit a weaker (if not lack of a) novelty preference for concavity at test. This prediction follows if the 9-month olds' greater experience with the world, which is largely composed of objects with convex parts, can be applied to the habituation display.

In Raz's (2008) study, infants were shown an 8-region stimulus in which 4 black regions with convex parts alternated with 4 white regions with concave parts (Figure 1) until they became habituated to it. (Henceforth, these regions will be called "convex" and "concave" regions, respectively.) In 8-region displays, adults perceive the convex regions as figures on approximately 90% of the trials.

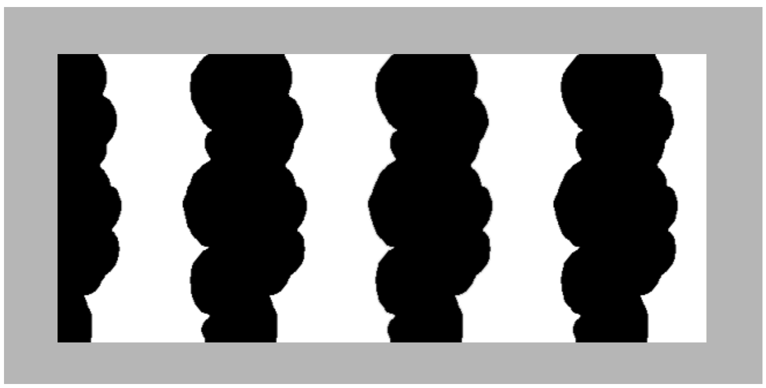

Figure 1. 8-region alternating black convex and white concave habituation display.

In the testing phase, infants were shown stimuli of the individual concave and convex regions (Figure 2). These regions were shown in either high luminance cyan or low luminance cyan on a medium luminance grey background to balance for any effects of brightness. If the cue of convexity is a figural cue for infants as it is for adults, Raz expected that the infants would exhibit a greater looking time (i.e., novelty preference), for the individual concave region at test.

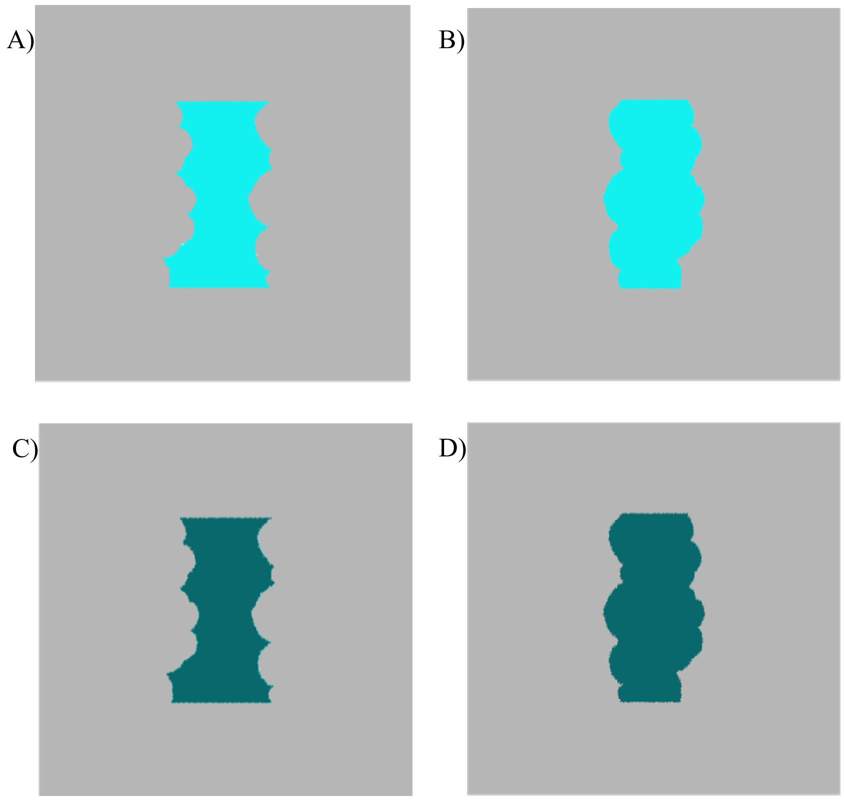

Figure 2. Individual test displays: A) high luminance concave shape, B) high luminance convex shape, C) low luminance concave shape, and D) low luminance convex shape.

Raz found that both 4-month-olds and 9-month-olds exhibited a novelty preference for concave displays, as expected if they perceived the convex regions of the habituation display as the figure. However, whereas the 9-month-olds' novelty preference was significantly correlated with the number of habituation trials ($r = 0.688$, $p < .05$), as expected if magnitude of novelty preference increased with habituation time, the 4-month-olds' was not ($r = -0.16$, n.s.). Thus, it is not clear whether the 4-month-olds' looking times at test were a consequence of their experience with seeing the convex regions as figures in the habituation display. An alternative possibility is that the 4-month-olds looked longer at the concave shapes at test because of an a priori novelty preference for concave shapes. That is, they may show a preference for concave shapes at test because they have learned that objects in their world tend to be convex; this novelty preference might be evident in their responses even if convexity does not affect the perceived organization of the habituation display. Another possibility is that infants in Raz's study preferred attending to the black shape during habituation, and results reflect habituation to the black shape. While informative, Raz's study did not use a fully balanced design as only habituation displays with black convex regions were used. For a fully balanced design, half of the infants should have been habituated to a display where the convex regions were white and the concave regions were black. This is an issue that we address in our current study.

With Raz (2008) (which we will refer to here as Experiment 1) as the precursor, the purpose of this study is to determine the reason for the infants' novelty preferences for concavity. The procedures of this study closely follow that of Raz (2008); however, crucial changes to the habituation stimulus will be applied to test for the cause of novelty preference in infants. The study will consist of three experiments. In Experiment 1A, the habituation stimulus will consist of an 8-region alternating *white convex*/black concave stimulus. We plan to run the same number of subjects tested by Raz so that, when combined, the two experiments constitute a balanced design. The combined data set will then allow us to test whether convexity is a figural cue when it is not confounded with color. We predict that, if Raz's (2008) infants were using convexity as a figural cue, then the switch in color of the regions of the habituation stimulus should not alter the results. Specifically, this fully balanced study should continue to show that both 4- and 9-month-olds show a novelty preference for concave shapes at test. On the other hand, if the unbalanced nature of Raz's test affected her results, then the combined results of the two experiments will show a different pattern. Furthermore, we were interested in testing if infants come into the lab with a preference for concavity, or whether their preference is a result of the habituation period. Thus, we conducted Experiments 2 and 3. In Experiment 2, we tested for a priori preferences in the 4-month-olds by displaying a habituation stimulus that contains an 8-region display of alternating black and white stripes, devoid of any convexity cues. We predicted that, if the 4-month-olds are bringing in an a priori preference for convex regions as figure, then they should exhibit a novelty preference for concave shapes after being habituated to the stripes display. In Experiment 3, we examined a priori preferences for convex versus concave shapes in infants before they participated in the habituation procedure. We then measured whether habituation changed these a priori preferences. This within-subjects procedure will give us a better understanding of what a priori preferences the infants have and whether and how they are changed through learning during the habituation period.

Experiment 1A

Method

Participants

The participants were 71 infants in the Tucson, Arizona area. The recruitment process began with the previous study by Raz (2008), and it included 37 infants at the ages of 4 months (after exclusions, N=20; age range = 3.50 – 4.47 months) and 34 infants at the age of 9 months (after exclusions, N=23; age range = 8.83 – 9.70 months). Twelve 4-month-olds and twelve 9-month-olds were given the white convex/black concave habituation display. Infants were excluded if they did not meet the average habituation looking time criterion of three seconds (4-month: N=5, 9-month: N=2), if they became fussy and could not complete the study (4-month: N=7, 9-month: N=6), if they were of low birth term or low birth weight (4-month: N=2, 9-month: N=1), and if experimenter error occurred (4-month: N=3, 9-month: N=2). These infants were identified in a database maintained by the Gerken infant development laboratory, and their parents were contacted and asked if they would like to participate in the study.

Stimuli and apparatus

A script was used to contact potential participants which provided an overview of the study being conducted, the location and length-of-visit of the study, and contact information. A consent form allowing for the conduction of the study on the infant was prepared for the parent to sign. For the actual conduction of the study, there was a testing room in which a chair facing the testing screen was present. The various visual displays that the participants were exposed to consisted of convex and/or concave shapes (the IV). A camera was placed in the testing room for visual observation of the infant by the experimenter, who was in a different room (the "control center"). A program designed for a habituation-paradigm experiment was run on a computer with a keyboard; it calculated the infant's looking time to determine if novel preference was present (the DV). This was present in the control center, where two monitors were also present: one showed the stimuli that was presented to the infant, and the other was connected to the camera and thus showed live feed from the testing room for observation of the infant.

Procedures

The parent of the identified infant was contacted using the script, and the consent form was signed prior to conduction of the study. The parent and child were escorted into the testing room, where the parent sat in the chair with the child on his or her lap, facing the testing screen. The study was comprised of a habituation paradigm and was, thus, divided into “Part I (Habituation)” and “Part II (Test).” The habituation paradigm follows the concept described previously, in the Introduction. Specifically, in this study, the following mathematical equation defines when the infant is fully habituated: Habituation occurs when $L_n+L_{n-1}+L_{n-2} \leq ½(L_1+L_2)$, where L=looking time and n=total number of exposures, and $n < 30$.

The first image that the infant saw on the screen was a crawling baby (Figure 3), which was accompanied by a beeping noise; this acted as the attention getter. Once the infant looked at the screen, the next image appeared. Part I (Habituation) consisted of presenting the infant with the 8-region alternating white convex and black concave figure (Figure 4) on the testing screen. The procedures for this condition were consistent with that of Raz’s (2008) when she ran the participants with the 8-region alternating black convex and white concave display.

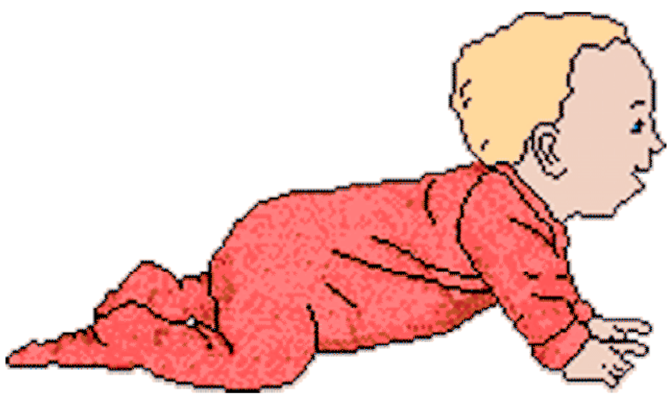

Figure 3. Attention getter: crawling baby display.

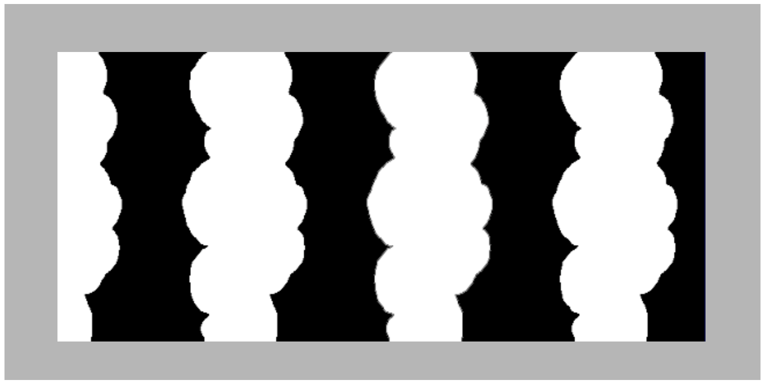

Figure 4. 8-region alternating white convex and black concave habituation display.

Once habituation was complete, Part II (Test) began. The test displays loomed toward the infants once and then receded toward the projection screen. After this initial looming motion, the test displays remained stationary on the projection screen until the infants looked away. To accustom infants to looming, the first test display was a vertically-elongated cyan rectangle; the rectangle was the same luminance (either high or low) as the concave and convex test displays (Figure 2A & B or 2C & D, respectively). Infants in the high luminance condition then received the test displays in *either* ABBA *or* BAAB order, and infants in the low luminance condition received these test displays in *either* CDDC *or* DCCD order (labeled according to Figure 2). One quarter of the participants received ABBA, the second quarter received BAAB, the third quarter received CDDC, and the last quarter received DCCD. Each test display was preceded by the attention getter stimulus (Figure 3). Infants' looking time at each test display was recorded to determine whether or not a novelty preference existed based on the habituation paradigm.

Results and Discussion

Data from Experiments 1 and 1A were combined so that the results represent that of a fully balanced experiment. An ANOVA with two factors [age: 4 versus 9 months;

test shape: convex versus concave] was run. The ANOVA showed a main effect of test shape, $F(1, 41) = 3.39$, $p < .10$. Infants looked longer at concave than convex test shapes. The main effect of age was not significant, $F(1,41) < 1$, nor was the interaction between age and test shape, $F(1,41) < 1$. Thus, the ANOVA did not reveal any effects involving age. The data from the 4-month-old infants were highly variable, however. Accordingly, we computed a "novelty preference" scores for each age group, as follows.

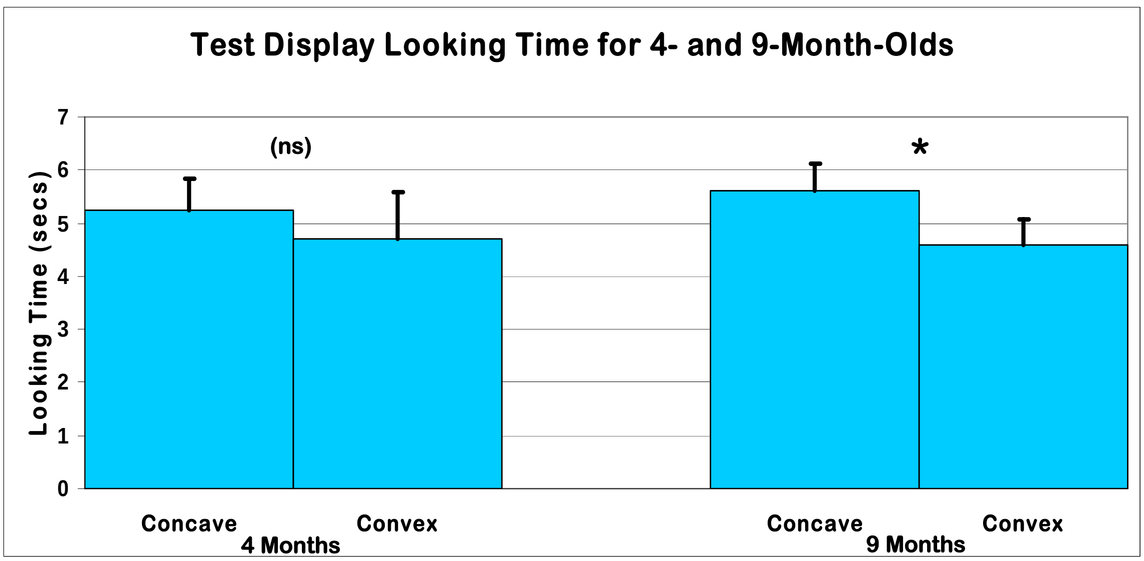

Figure 5: 4- and 9-month-olds' results from Experiment 1, showing looking times for both concave [5.24, 4.70, respectively] and convex [5.62, 4.58, respectively] displays at test. Error bars are standard errors of the means.

The "novelty preference" score was computed by subtracting each infant's mean looking time at the two convex test figures from his or her mean looking time at the two concave test figures. A positive novelty preference score indicates that infants looked longer at concave test shapes, whereas a negative novelty preference score indicates that infants looked longer at convex test shapes. Novelty preference scores were averaged across subjects in each age group to find mean novelty preference scores for 4-month-olds and 9-month-olds.

In 9-month-old infants, the mean novelty preference score [*M* =1.03 s] was significantly different from zero, $t(22) = 2.53$, $p < .05$. Thus, 9-month-old infants exhibited a novelty preference for the concave figure at test, suggesting that they saw the convex regions as the figure in the habituation stimulus. Thus, it would seem that 9-month-old infants are, indeed, able to use convexity as a figure cue. In 4-month-olds, the novelty preference score [0.54 s] was not significantly different from zero, $t(19) < 1$. Furthermore, the 4-month-old data were highly variable (*SE*=0.65 > *M*=0.54). This indicates that the 4-month-old infants were not exhibiting a significant novelty preference for the concave test figures; thus, there is no support for 4-month-olds' ability to use convexity as a figure cue.

We attribute the absence of a difference between the 4- and 9-month-old infants to the high variability in the 4-month group. We wondered whether the 4-month-old infants came into the lab with an a priori preference for concave shapes. If so, their behavior at test might be highly variable. We tested infants' a priori preferences in Experiments 2 and 3.

Experiment 2

In Experiment 2, we examined whether 4-mo old infants came into the lab with a priori preferences for concave shapes by replacing the black and white convex/concave habituation display with a display in which equal-area black and white regions with straight edges alternated with each other (see Figure 6). This "striped" habituation display appears flat. Habituation to this display should not lead to a novelty preference for concave shapes. Thus, if such a novelty preference is obtained in Experiment 2, we will conclude that it reflects an a priori preference rather than a habituation-induced novelty preference.

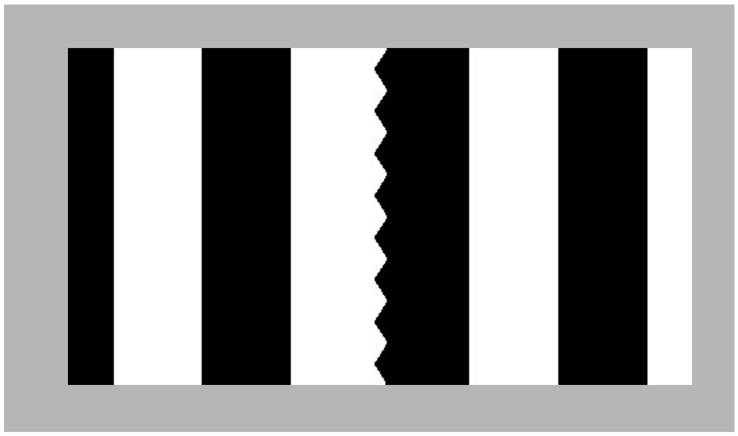
Figure 6. 8-region alternating black and white stripes habituation display.

Method

Participants

The participants were 18 infants in the Tucson, AZ area who were at the age of 4 months (after exclusions, N=9; age range = 3.57 – 4.47 months). Infants were excluded if they were of low birth term or birth weight (N=1), if a program or experimenter error occurred (N=2), if the data showed readings of zero seconds (N=1), and if they were uninterested in the screen or became fussy, resulting in their inability to complete the study (N=5).

Stimuli, apparatus, and procedure

The stimuli, apparatus, and procedure used in Experiment 2 were the same as those used in Experiment 1 except that an 8-region display of alternating black and white stripes was used instead of an 8-region display of alternating convex and concave shapes.

Results and Discussion

4-month-old infants' mean looking times at the concave and convex test figures are shown in Figure 7. A *t*-test (paired, 2-tailed) showed their novelty preference score [*M* = 0.21 s] was not statistically different from zero, t(9) <1. This suggests that, at 4 months of age, infants have not yet developed an a priori preference for either concave or convex figures.

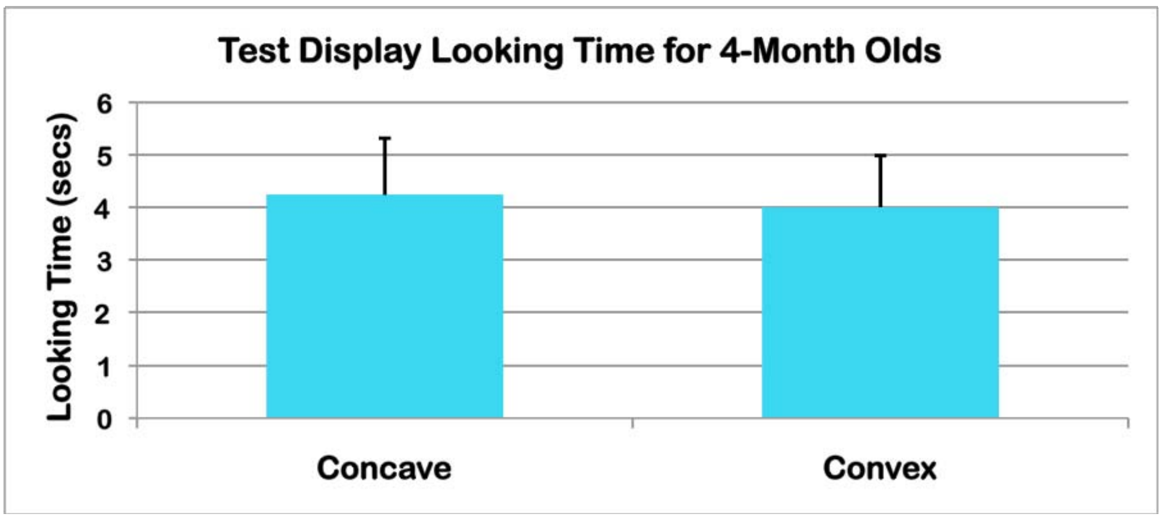

Figure 7. 4-month-olds' results from Experiment 2, showing looking times for concave [4.24] and convex [4.01] displays at test. Errors bars are standard errors of the mean.

Experiment 3

The variability of the 4-month old data in Experiment 1 does not appear to be due to a priori preferences for either concave or convex shapes, at least not as measured after habituation to a striped display. In Experiment 3, we assessed baseline preferences of both 4- and 9-month-old infants when they entered the laboratory, and then habituated them to alternating convex and concave displays. The method allows us to assess how each infant's a priori preferences are changed by habituation. It also allows us to assess a priori preferences in both 4- and 9-month-old infants before they are subjected to the habituation procedure.

Method

Participants

The participants were 39 infants in the Tucson, AZ area, including 32 infants at the age of 4 months (after exclusions, N=15; age range = 3.63 – 4.50 months) and 7 infants at the age of 9 months (after exclusions, N=5; age range = 8.90 – 9.40 months). Infants were excluded if they were of low birth term or low birth weight (4-month: N=2), if they did not meet the average habituation looking time criterion of three seconds (4-month: N=11, 9-month: N=2), if there was experimenter error (4-month: N=1), and if they were not interested in the screen or became fussy, resulting in their inability to complete the study (4-month: N=3).

Stimuli and apparatus

The stimuli and apparatus were the same as those used in Experiment 1.

Procedure

The design of Experiment 3 was the same as that of Experiment 1 except that a pre-test was inserted prior to habituation. Thus, Experiment 3 had three parts. In Part I (Pre-Test), infants were shown a single concave shape and a single convex shape of either high or low luminance (see Figure 2). These displays loomed once on the testing screen in order to capture the infant's attention. Infants in the high luminance condition received these test displays in *either* AB *or* BA order, and infants in the low luminance condition received these test displays in *either* CD *or* DC order. The vertically-elongated cyan looming rectangle display of the corresponding luminance was shown once prior to these convex/concave pre-test displays to prevent surprise effects on the looking times for the concave and convex pre-test shapes. One quarter of the participants received AB, the second quarter received BC, the third quarter received CD, and the last quarter received DC. Their looking time at each display was recorded to determine whether or not the infants came into the lab with an a priori preference for convex or concave figures. Part II (Habituation) and Part III (Post-Test) were the equivalent of Experiment 1's Part I (Habituation) and Part II (Test), respectively.

Results and Discussion

An ANOVA with three factors [age: 4 versus 9 months; test shape: convex versus concave; test phase: pre-test versus post-test] was run. The ANOVA showed a trend toward an interaction between test phase and age, $F(1,17) = 3.65$, $p < .08$. 9-month-olds showed a decrease in looking time from pre-test to post-test for both convex and concave shapes, with a greater decrease for convex than for concave. On the other hand, 4-month-olds showed small increases in looking time from pre-test to post-test for both convex and concave shapes. No other main effects or interactions were significant, $ps > .12$.

To assess these effects more closely, we subtracted the mean duration of looking at the convex shapes from the mean duration of looking at the concave shapes in both Part I (Pre-Test) and Part II (Post-Test). In 9-month-old infants, the difference score at Pre-Test [-1.35 s] differed significantly from zero, $t(4) = -7.64$, $p < .005$: 9-month-old infants looked at the convex pre-test displays for significantly longer than they looked at the concave pre-test displays, indicating that they had a baseline preference for convex shapes. (See Figure 8.) We take this as a *familiarity preference* based on experience outside of the lab (familiarity preferences are expected if infants are not habituated).

Objects in the world are likely to have convex parts. The a priori preference for convex pre-test shapes shows that 9-month old infants have learned this regularity.

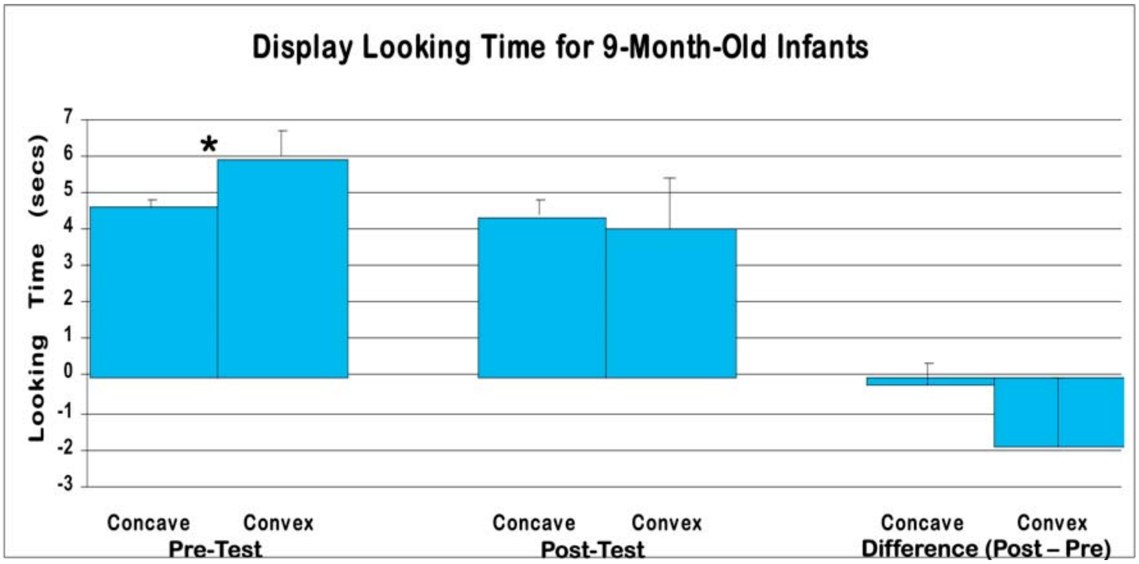

Figure 9: 9-month-olds' results from Experiment 3, showing looking times for both concave and convex displays at Pre-Test [4.60, 5.95, respectively] and Post-Test [4.38, 4.04, respectively], and the Post-Test minus Pre-Test differences [-0.23, -1.91, respectively]. Error bars are standard errors of the means.

At Post-Test, the five 9-month olds tested in Experiment 3 did not show a novelty preference for concave shapes. However, their preference for convex shapes was eliminated following habituation. With a larger number of 9-month-old infants, we expect to observe a novelty preference following habituation, replicating Experiment 1. (4 of the 5 9-month-olds exhibited a novelty preference; they showed a large negative difference score, indicating a preference for the convex test figure post habituation.)

As can be seen in Figure 10, in 4-month-old infants, the difference score at Pre-Test [0.53 s] was not significantly different from zero, $t(14) < 1$, nor was the difference score at Post-Test [-0.08 a], $t(14) < 1$. The 4-month-old Post-Pre difference [-0.60] was also not significantly different from zero, $t(14) < 1$. This indicates that the 4-month-old infants are not exhibiting a significant preference for the concave figure before or after habituation; therefore, there is no support for 4-month-olds' ability to use convexity as a figure cue.

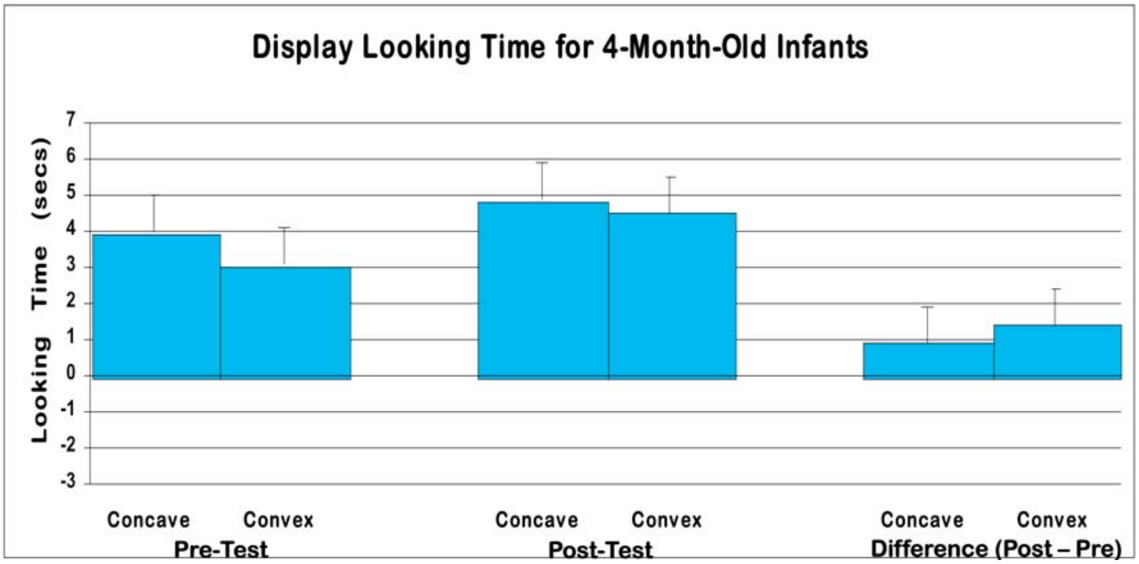

Figure 10: 4-month-olds' results from Experiment 3, showing looking times for both concave and convex displays at Pre-Test [4.22, 3.28, respectively] and Post-Test [5.30, 4.87, respectively], and the Post-Test minus Pre-Test differences [1.08, 1.59, respectively]. Error bars are standard errors of the means.

General Discussion

Overall, we found that infants at the age of 9 months are able to use convexity as a figure cue. In Experiment 3, we found that 9-month-olds showed a familiarity preference for convex displays during Pre-Test, indicating that they have learned that objects in their world are likely to be convex. Furthermore, in Experiment 1A, 9-month-olds exhibited a significant novelty preference for concave displays at test, indicating that they used convexity as a figural cue to organize the habituation display. Although this novelty preference [0.34 s] was not significant at Post-Test in Experiment 3, it does seem to be emerging out of the significant familiarity preference [-1.35 s] at Pre-Test. This follows the idea that infants must first overcome their familiarity preference before they can show a novelty preference; a significant novelty preference at Post-Test may be found with a larger number of subjects. In summary, it would seem that 9-month-old infants have had enough experience with the real world to learn that objects tend to be convex; thus, they are able to use convexity as a figural cue.

On the other hand, 4-month-old infants have not yet had enough experience with objects in their world to use convexity as a figural cue. In neither Experiment 1A nor Experiment 3 did infants at the age of 4 months show a novelty preference for concavity at test, indicating that they are not using convexity as a figural cue to organize the habituation display. Furthermore, the results of Experiment 2 and 3 show that 4-month-olds do not come into the lab with an a priori preference for either convex or concave figures. Unlike 9-month-old infants, 4-month-old infants do not show a preference for convex shapes when they enter the laboratory. Combined with the pattern of findings obtained with 9-month-olds, these findings suggest that experience and/or development is necessary before convexity can serve as a figural cue.

Further research on infants' ability to perform figure-ground segregation using convexity as a figure cue might include a longitudinal study, where 4-month-olds are retested again at the age of 9 months. This may provide insight into the visual development of infants. In addition, research in this area may extend to address the issue of whether or not it is possible to give an infant at a certain age who cannot perform figure-ground segregation sufficient experience with convex cues in the laboratory so that they will be able to do so based on the cue of convexity. If results show support for the idea that "flooding" the infants with a sufficient amount of convex cues will allow them to perform figure-ground segregation based on those cues, then this would strengthen the theory that experience is a major factor in the use of convex cues in figure-ground segregation. Thus, while infants are born into the world equipped/prepared for everything that they must perceive, after a certain amount of exposure, the human brain becomes less malleable, less plastic. However, before that threshold is reached, modifications and adjustments can still occur based on the environment and exposure. Thus, figure-ground segregation can be affected by experience. Future research can then be done on whether or not infants can be “flooded” with enough concave shapes to bias them to use concavity as the main figural cue in figure-ground segregation; essentially, can a concave world be created where the concave regions are perceived as the figure instead of the ground.

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