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Vertical Symmetry Is Special to Infants; Vertical Symmetry in Upright Human Faces More So

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Abstract: Symmetry has long been viewed as a feature of objects that facilitates ease of perception. Three experiments investigated 4- to 5-month-old infants' detection and processing of vertical symmetry, oblique symmetry, and asymmetry in novel patterns and faces. In Experiment 1, infants showed the fewest shifts in visual fixations to vertical symmetry in patterns and faces, supporting the view that vertical symmetry is processed more efficiently than oblique symmetry or asymmetry. In Experiment 2, stimulus presentation disallowed more than a single visual fixation, and infants looked longer at a face that is vertically symmetrical compared to obliquely symmetrical or asymmetrical, and they looked equally to patterns regardless of symmetry. In Experiment 3, where pattern exposures were prolonged and inverted faces viewed, infants discriminated vertical symmetry in patterns but lost the advantage with vertical symmetry in faces. Thus, symmetry in patterns requires more processing time from infants, and inverting the face costs infants the normal perceptual advantage of symmetry, even though components of the face remain symmetrical. These findings suggest that infants are prepared to exploit symmetry in their everyday perceptual worlds.

Keywords: infants; symmetry; eye tracking; perception

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1. Introduction

Symmetry is defined as the point-for-point correspondence of pattern elements (enantiomorphs) about an axis. Aristotle [1] and Darwin [2] both noted that people prefer symmetrical forms. Moreover, a venerable history of psychological research has repeatedly demonstrated that symmetrical forms are not only preferred but are consistently processed more efficiently, detected more rapidly, identified more quickly, discriminated more accurately, remembered more veridically, and reproduced more faithfully than asymmetrical forms. Scholars have offered numerous reasons for the advantages of symmetry: redundancy of information, global encoding strategy, stimulus structure or organization, minimal required neural circuitry, etc. [3]. Consider several examples. Symmetry in the structure of forms has long been considered to be a component in pattern "goodness" [4–6], and pattern "goodness" is thought to ease stimulus encoding. Or, the facility of adults' processing of visual symmetry may be attributable to global scans in analyzing visual information [7–9]; Locher and Nodine [10] showed that adult perceivers tended to scan only one-half of symmetrical shapes but the entirety of asymmetrical ones. Or, symmetry detection in a shape is effortless, perhaps because the two enantiomorphs have matching parts ([11], "minima rule"). Not all orientations of symmetry provoke equivalent advantages, however; vertical symmetry is special. Vertically symmetrical forms are preferred and processed more efficiently than horizontally or obliquely symmetrical forms even when the amount of information is identical across forms. When compared to matched oblique symmetries, to horizontal symmetries, and to asymmetries, adults prefer vertical symmetries and detect them more easily, identify them more accurately, and sort them more quickly [12–19]. Moreover, adults better remember vertical symmetry than other types of symmetry in tasks that rely on recognition [15] or on reproduction [20]. In contrast, the so-called "oblique effect" documents diminished detection, discrimination, and identification of visual (as well as other sensory, e.g., haptic) stimuli that deviate from the vertical [21–23]. Thus, vertical symmetry is perceptually special, and the privileged status of vertical symmetry may be due to the fact that visual stimuli which are significant in the perceptual life course are vertically symmetrical—notably, parents, progeny, predators, and prey.

1.1. Infant Perception of Symmetry

How early in life does the advantage with vertical symmetry manifest? Here, we compared infants' perceptions of vertical with oblique symmetries (see Figure 1) to address the question of whether the advantage with symmetry, and particularly vertical symmetry, arises early in life. There is a growing literature about the early ontogeny of a perceptual advantage with symmetry, and especially vertical symmetry, but a complete understanding of infants' perception of symmetry still eludes us. The three experiments we report aimed to identify, assess, and compare young infants' detection and processing of vertical symmetry, oblique symmetry, and asymmetry in novel patterns and faces. The earliest developmental salience of symmetry over asymmetry, and of vertical symmetry especially, was established in studies conducted by Bornstein and colleagues. In the first study [24], 4-month-olds showed no preference for symmetry, but they habituated faster to vertically symmetrical patterns than to otherwise equivalent horizontally symmetrical or asymmetrical patterns; 12-month-olds also preferred vertically symmetrical patterns to both horizontal symmetrical and asymmetrical patterns. In the second study [25], 4-month-olds were tested in a habituation–dishabituation paradigm, and they discriminated vertically symmetrical patterns from horizontal symmetrical and from asymmetrical patterns but failed to distinguish between horizontal symmetrical and asymmetrical or between asymmetrical patterns. In the third study [26], 4-month-olds' more sophisticated perceptions of symmetry in visual patterns were assessed in four experiments. Experiments 1 and 2 evaluated infants' perception of the specialty of vertical symmetry by manipulating the structure and orientation of comparable patterns. Confirming previous research, infants displayed no preferences among vertical or obliquely symmetrical patterns or patterns that repeated about the vertical axis. However, infants reached a habituation criterion (i.e., a criterion 50% reduction in looking relative to their baseline level of looking) in fewer trials for vertically symmetrical patterns than for obliquely symmetrical patterns or patterns that repeated across the vertical axis. Experiment 3 was designed to determine infants' capacity to integrate information in visual patterns distributed in space. The spatial separation of pattern components from contiguous to discontiguous was manipulated. Infants processed vertically symmetrical patterns whose components were contiguous or nearly contiguous about the vertical axis more efficiently than patterns whose components were discontiguous. Infants lost the advantage with vertical symmetry and, by inference, their holistic perception of the visual pattern with the spatial separation of components from the vertical meridian. Experiment 4 examined infants' sensitivity to perceptual organization and synthesis of pattern form by manipulating the organization of individual components of a vertical pattern. Infants perceived the symmetrical organization of the pattern above their individual components in the pattern by discriminating vertically symmetrical patterns from asymmetrical patterns with a vertical organization. Together, these experiments demonstrated that the detection and recognition of vertical symmetry precedes more general preferences for symmetry early in life.

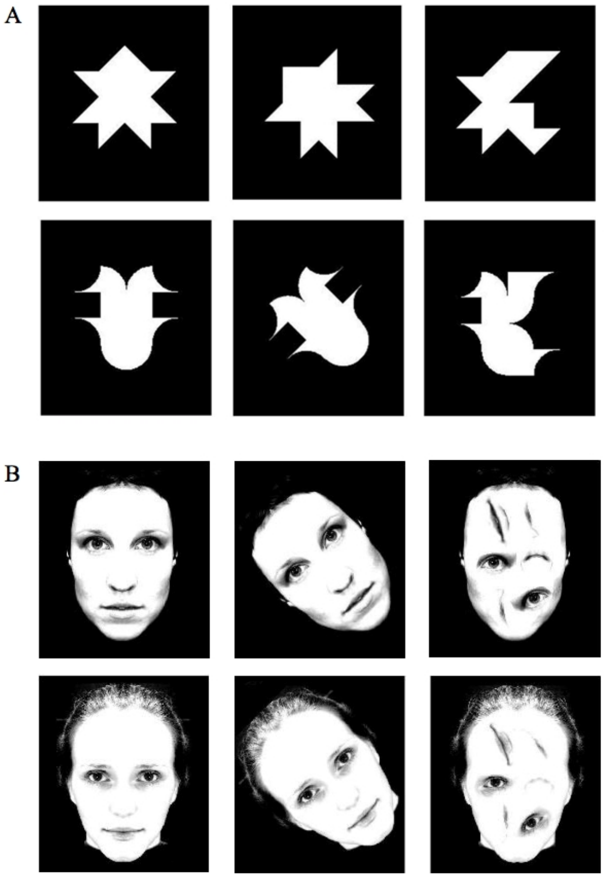

Figure 1. Stimulus images used in Experiments 1 and 2. (**A**) Panel A displays the pattern images, and (**B**) panel B displays the face images. The left panels show vertically symmetrical stimuli, the middle panels show obliquely symmetrical stimuli, and the right panels show asymmetrical stimuli. Note that all stimuli in each row were constructed of the same components.

1.2. Symmetry in Faces

Faces are perhaps the most commonly and earliest experienced vertically symmetrical objects in the infants' visual world [27]. A prominent basis for human interaction is reflected in the recognition and identification of faces, and vital socially significant information is conveyed in facial features [28]. Much is now known about many general aspects of infant face processing. For example, neonates look preferably at face-like stimuli over other patterned stimuli [29–31], and infants look more at upright than at inverted or scrambled faces [32,33]. Studying 4- to 15-month-old infants, Samuels and colleagues [34] paired normal faces varying in adult-rated attractiveness with the same faces digitally altered to appear perfectly symmetric; symmetry did not interact with infants' preference for attractive faces. Rhodes and colleagues [35] presented 5- to 8-month-old infants with face images varying in vertical symmetry and learned that infants look (marginally) longer at symmetric faces. Neither of the preceding two studies compared infants' attention between differing axes of symmetry. Less is known, too, about how infants scan individual components of a face. Infants tend to look at eye regions of faces more than at mouth regions [36,37]; however, they scan about equally at eye and mouth regions in dynamic faces when the speaker attempts to engage the infant's attention by smiling and uttering simple vocalizations [27]. Eyes and mouths convey many relevant cues about a social partner, such as where to look (eyes) and how to decode the speech stream (mouth). Whether innate, early maturing, or based on extensive experience, the special quality of vertical symmetry to infants may derive from the importance of the vertically symmetrical face; as Pascal observed, "our notion of symmetry is derived from the human face" (cited on p. 12 [38]).

1.3. The Current Study

Symmetry is a pattern characteristic that facilitates perception and cognition. For all the consensus about the advantages of symmetry, and vertical symmetry, in mature perception, the extant literature has left unaddressed some significant questions about the infant origins and early perception of symmetry. Three experiments were designed to address some of those residual questions: (a) whether and how variation in symmetry affects infants' visual scanning of patterns or faces, (b) whether and how the detection of pattern or facial symmetry depends on infants' visual scanning, and (c) whether and how any advantage of vertical symmetry in infancy depends on the stimulus orientation or processing time. To address those questions, we compared the distribution of visual scans of vertically symmetrical patterns and faces to scans of obliquely symmetrical and asymmetrical ones, and we examined continuity of scans in the detection of vertical symmetry and the effect of inversion on the detection of facial symmetry to oblique symmetry and asymmetry. Based on the extant adult and infant literature, we expected that infants would more efficiently shift their visual fixations to vertical symmetry in patterns and faces, thereby giving evidence that they process vertical symmetry more efficiently than oblique symmetry or asymmetry; that when stimulus presentation disallows more than a single visual fixation, infants would look longer at a face that is vertically symmetrical compared to one that is obliquely symmetrical or asymmetrical; that the contiguity of enantiomorphs around the vertical axis would promote the advantage with vertical symmetry; that when patterns are exposed for longer durations, infants would discriminate vertical symmetry more easily; and that when faces are inverted, infants would lose the advantage with the vertical.

2. Materials and Methods

2.1. General Method for the Three Experiments

2.1.1. Infants

Infants between 4 and 5 months of age were recruited through the use of purchased mailing lists of newborns in a suburban metropolitan area and came from middle- to high-socioeconomic status families primarily of non-Hispanic European–American descent. All parents of qualifying infants who expressed interest within recruitment windows for the experiments were invited to participate. All infants were of term and healthy at birth and at the time of testing. Attrition rates (4–8 infants per experiment) and reasons (fussiness or equipment failure) were comparable to other infant eye-tracking and looking-time studies [39]. All parents signed informed consents before the start of the experiments. In all three experiments, infants were tested in accordance with the ethical principles of the Declaration of Helsinki, and the research was approved by the Institutional Review Board of the NICHD. Power analysis using an estimated effect size of 0.25 revealed that samples sizes of 28 infants and above were adequate for each of the three experiments [40]. The sample sizes across the three experiments are ns = 30 (13 females), 45 (24 females), and 32 (14 females), respectively.

2.1.2. Stimuli

Stimuli comprised two different classes: patterns and female faces that were all novel to the infants (i.e., never seen before). The novel patterns were white on a black background, and each rendered in three conditions of symmetry: (a) symmetric about the vertical axis, (b) symmetric about an oblique axis rotated 45° counterclockwise from vertical, and (c) asymmetric, cut vertically and horizontally then rearranged into different configurations (see Figure 1). Female faces were also white photographic images on a black background and rendered in the same three conditions of symmetry (see Figure 1). The method for constructing these stimuli produced variation in symmetry but constancy on all other visual properties, for example, luminance, contour, and components [18]. Patterns subtended $6.7^{\circ} \times 7.0^{\circ}$ of the visual angle within the background. Faces subtended $7.5^{\circ} \times 10.5^{\circ}$ of the visual angle.

2.1.3. Procedures

Infants were seated in a dimly lit room 60 cm in front of a monitor in an infant chair, which was situated between the transmission component of the head movement-tracking system (to the rear) and a monitor on which the stimuli were displayed (in front). The eye camera was located beneath the stimulus monitor. Stimuli were presented on a 48.26 cm Planar color monitor positioned at the infants' eye level using specific software which differed by experiment (described below). Preliminary analyses revealed no effects of infant gender or of stimulus presentation order, so analyses in all three experiments collapsed across these variables.

3. Experiment 1

The extant infancy literature indicates that infants process vertical symmetry most efficiently. This finding led us to hypothesize that infants would (need to) scan vertically symmetrical patterns and faces less than obliquely symmetrical and asymmetrical patterns and faces. In Experiment 1, therefore, we asked whether infants process vertical symmetry in patterns and in faces more efficiently than oblique symmetry or asymmetry based on shifts in their visual fixations. To this end, infants viewed 12 trials, 6 with novel patterns that were vertically symmetrical, obliquely symmetrical, and asymmetrical, and 6 faces that were also vertically symmetrical, obliquely symmetrical, and asymmetrical (see Figure 1). During each 10 s presentation, we recorded the infants' eye scans, and later coded the location (on or off the target) and the number of shifts on the target region. We predicted that infants would make fewer fixation shifts with vertically symmetrical stimuli (patterns or faces) compared to asymmetrical stimuli because they would not need to fully explore both sides of the vertical stimulus. We also predicted that obliquely symmetrical stimuli would not share the processing advantage of vertically symmetrical stimuli given previous research using habituation [24,25], resulting in more shifts in fixation to obliquely, compared to vertically, symmetrical stimuli.

3.1. Experiment 1 Method: Materials and Apparatus

An Applied Science Laboratories (ASL; Bedford, MA, USA) Model 504 infant eye-tracking system captured infants' fixations for each stimulus image. The system used infrared corneal reflection to record fixation coordinates on the stimulus plane continuously at 60 Hz. An Ascension Technologies (Burlington, VT, USA) electromagnetic motion tracker corrected camera angles for spontaneous head movements that exceeded the frame limits of the optical tracking. Infants wore a motion-tracking sensor attached to a headband throughout the session. Signals from the motion tracker were integrated with the eye camera control unit and used to guide the camera's pan/tilt motors when corneal reflections were lost. GazeTracker (EyeResponse Technologies, Charlottesville, VA, USA) software, running on a second microprocessor, controlled the stimulus presentation on the stimulus monitor and synchronized eye movement recordings with stimulus presentations.

3.2. Experiment 1 Method: Procedure

Following Bornstein and colleagues [41,42], the eye-tracking system was calibrated for each infant individually by presenting a rotating red plus sign (1.27°) in the upper left and lower right corners of an otherwise uniform white field. Across two trials, the plus sign appeared. When infants were judged to be fixating the targets, the known locations of those targets were mapped onto the corneal reflections for each infant using standard ASL calibration procedures [43]. Infants viewed all 12 stimuli in one of four randomized orders with the restriction that variants of the same pattern or face did not appear consecutively. Infants viewed each stimulus once, preventing bias by previous exposures to the same stimulus. Between trials, a uniform field of 16 black + elements (each 2.54°) on a white background appeared. This image maintained infant attention toward the stimulus screen without systematically biasing fixation toward any particular region of the display. Each trial began with a key press when the infant was looking toward the display. The duration of each stimulus presentation was 10 s.

3.3. Experiment 1 Method: Data Analysis

To analyze data from the eye-tracking system, we plotted fixations of 200 ms or more directly on each stimulus image for each participant using the GazeTracker software package [41,42]. The analysis options in GazeTracker were set to include gaze point changes of less than 1° of visual angle as part of the same fixation, and any changes greater than 1° constituted different fixations. Coders blind to the conditions, parameters, and hypotheses of the experiment analyzed the scan plots to determine two dependent variables. The first was the location of fixations. Coders classified fixations as "on target" if their corresponding markers overlapped the pattern or face, including any part of its outer boundary. The second variable was the shift in fixations. Coders tallied the number of fixation shifts on the target region of each stimulus for each trial and averaged them over trials. A second coder similarly evaluated 15% of the sessions; ratings coincided on 100% of the individual trials.

3.4. Experiment 1 Results

Figure 2 shows mean fixation shifts by stimulus class and symmetry condition. Planned comparisons for a 3 (symmetry condition) by 2 (stimulus class) ANOVA examined differences in shift totals between the vertically symmetric and obliquely symmetric conditions and between the vertically symmetric and asymmetric conditions for each stimulus class. The analyses for pattern stimuli revealed significantly fewer fixation shifts with vertically symmetric patterns than with obliquely symmetric ones, $F\ (1,29) = 4.22$, $p = 0.049$, $\eta p2 = 0.13$, and with asymmetric ones, $F\ (1,29) = 8.19$, $p = 0.008$, $\eta p2 = 0.22$ (see means and standard errors in Figure 2). Analyses for faces also revealed significantly fewer fixation shifts with vertically symmetric than with obliquely symmetric ones, $F\ (1,29) = 6.89$, $p = 0.014$, $\eta p2 = 0.19$, and with asymmetric ones, $F\ (1,29) = 4.79$, $p = 0.037$, $\eta p2 = 0.14$ (see Figure 2). Vertical symmetry reduced the frequency of fixation shifts in infants' visual exploration of otherwise equivalent patterns and faces, suggesting that vertical symmetry engenders reduced processing requirements relative to oblique symmetry and asymmetry. This finding is consistent with earlier conclusions from other tasks that vertical symmetry occupies a privileged status in infants' visual processing [26]. The design of Experiment 1 also constitutes a replication of infant perceptual advantage with vertical symmetry found in previous studies using overall looking time measures, but here, we used eye scanning [41,42].

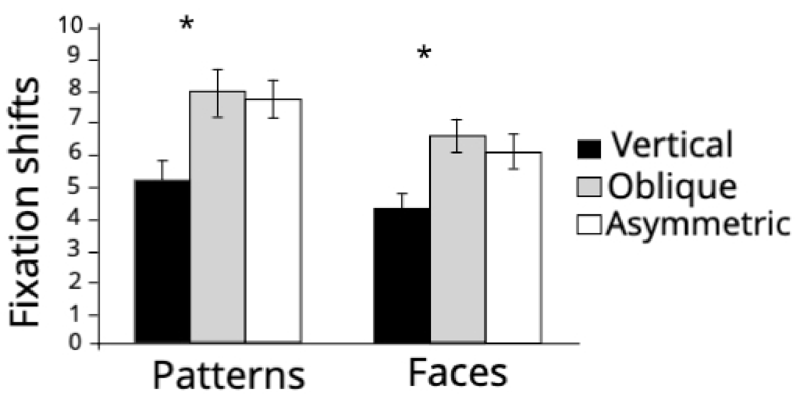

Figure 2. Mean fixation shifts in Experiment 1 by symmetry condition and stimulus class. Error bars indicate standard error of the mean. * = $p < 0.01$.

That fixation shifts were significantly fewer for vertical symmetric images raises the question of whether symmetry detection depends on eye movements and whether form detection varies with symmetry. Does infants' detection of vertical symmetry depend on visual scanning, or can infants detect vertical symmetry within individual fixations? If vertical symmetry fosters global (contra local) processing, then we would expect reduced scanning to vertical vis à vis other symmetrical arrangements. Experiment 2 addressed this question.

4. Experiment 2

Infants in Experiment 1 processed vertical symmetry with fewer scan shifts than oblique symmetry and asymmetry. One implication of this finding is that infants might perceive vertical symmetry holistically. This deduction led us to hypothesize that, were visual stimuli to be presented in shorter durations than a saccade, infants would retain the advantage with vertical symmetry. Adult observers rate the degree of symmetry and make comparative judgments of symmetry in pairs of stimuli in brief (200 ms) presentations [44], characterize shape symmetry on the basis of information available within a single (25 ms) fixation [8], and perceive the holistic gist of complex symmetrical stimuli in single (100 ms) fixations [9]. Another deduction is that the recognition of degraded targets should be impaired if infants engage in a local, rather than global, visual analysis. In Experiment 2, therefore, we asked whether infants would show an advantage with vertical symmetry in novel patterns and faces, where the presentation of the visual stimuli occurred in durations that disallowed visual scanning. Adults can form robust very short-term memory representations in 50 ms but require 500 to 1500 ms to form robust visual long-term memory representations [45,46]. To unambiguously isolate very short-term memory in infants, we used a single brief exposure to a given stimulus (500 ms) followed by a brief retention interval (1000 ms). These temporal parameters reflect the time course of fixating an object in a natural scene and then shifting fixation to another object [47]. This procedure allowed us to test whether infants' detection of vertical symmetry depends on coordinated, continuous scans of visual stimuli, or whether infants could detect vertical symmetry without connected shifts of fixation. Thus, infants viewed 12 trials of patterns and faces, as in Experiment 1, except that the stimulus duration was abbreviated to 500 msec, and we measured infants' attention to each stimulus type across 10 cycles. We predicted that infants would look longer at the stimuli that do not need continuous fixation or unbroken scanning, and we further predicted that vertically symmetrical faces, and possibly patterns, would fit this criterion.

4.1. Experiment 2 Method: Materials and Apparatus

The task was administered with a computer running e-Prime software v1.2 (Psychology Software tools, Pittsburgh, PA, USA) which controlled the stimulus presentation on the stimulus monitor and timing. The inter-trial attention-getting stimulus was a colorful geometric form. A Sony CCD TRV67 video camera was positioned above the center of the stimulus monitor screen with its viewfinder trained on the infant's face. The camera was connected to a viewing monitor near the experimenter. An additional computer (Apple Power Mac) running Habit 2000 software [48] was used to code and record infants looking from the experimenter's view of the infant's face on the viewing monitor.

4.2. Experiment 2 Method: Procedure

On each trial, the attention-getting image appeared first, and the experimenter observed the infant's fixation in a video monitor. The experimenter initiated the presentation of the first trial after infants were judged to be fixating in the direction of the stimulus. On each trial, a single stimulus was presented 10 times briefly and in rapid equal-interval succession. Through each trial, the stimulus alternated with a patterned noise mask at 500 ms intervals for 10 cycles. Following the 10th presentation cycle, the attention-getting image reappeared until the initiation of the subsequent trial. The 500 ms interval was chosen following Hood and Atkinson [49]. That work examined infants' latencies to shift fixations from a central target appearing first to a peripheral stimulus presented subsequently. At 6 months, latencies averaged over 1500 ms. The temporal conditions of the present study thus precluded connected saccades while still enabling selective attention to the stimulus as a whole. Fixation time differences between stimuli constitute evidence for stimulus discrimination. We used a fixed-trial procedure. Every infant viewed twelve 10 s trials, each involving a different stimulus image. As in Experiment 1, we created four stimulus orders, randomly assigned across infants. In each 10 s trial, the experimenter coded the infants' continuous fixation by depressing a key on the coding computer when the infant was fixated on the stimulus and releasing the key when the infant looked away. Inter-trial intervals varied somewhat according to the time required for the infant to re-establish fixation but generally did not exceed 3 s. A second coder coded the infants' looking times in 20% of the sessions. Agreement was high, $r = 0.94$.

4.3. Experiment 2 Results

Infants' looking time was analyzed with the same statistical design used in Experiment 1. Planned comparisons examined differences in fixation times between the vertical and oblique symmetry conditions and between the vertical symmetric and asymmetric conditions for each stimulus class. Analyses for patterns revealed no difference in fixation times between the vertically symmetric patterns and obliquely symmetric ones, $F(1, 44) = 2.45$, $p = 0.124$, or asymmetric ones, $F(1, 44) = 1.26$, $p = 0.270$. Analyses for faces, however, revealed significantly longer fixation times on vertically symmetric than obliquely symmetric ones, $F(1, 44) = 7.97$, $p = 0.007$, $\eta p2 = 0.15$, and asymmetric ones, $F(1, 44) = 5.71$, $p = 0.021$, $\eta p2 = 0.12$ (see means and standard errors in Figure 3). Under experimental conditions that prevented fixation shifts during image viewing, infants did not fixate on patterns differently across symmetry conditions, suggesting that the infant detection of vertical symmetry in patterns may depend on connected eye movements. In contrast, infants discriminated faces by the symmetry condition: infants looked significantly longer at vertically symmetric faces than obliquely symmetric or asymmetric faces. Thus, infants detected vertical symmetry in the face within brief individual fixations. Stimulus structures that do not require unbroken scanning for detection by observers likely have some information processing advantage relative to those that do. Given earlier demonstrations that young infants' attention to pattern structure reflects more efficient processing of vertical symmetry [24], attention differences in Experiment 2 appear to reflect differences in processing efficiency.

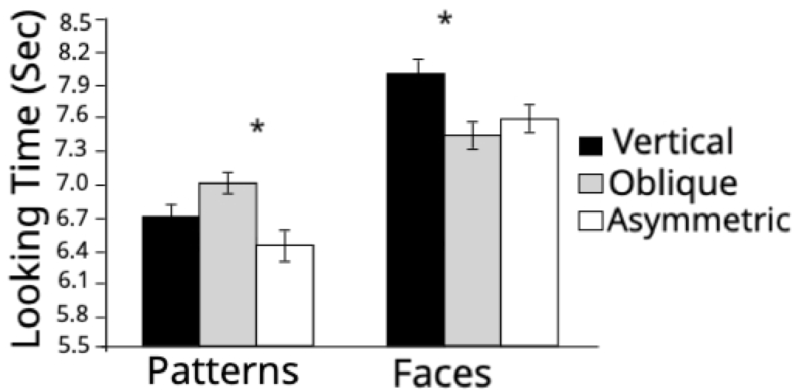

Figure 3. Mean fixation times in Experiment 2 by symmetry condition and stimulus class. Error bars indicate standard error of the mean. * = $p < 0.05$.

In Experiment 2, infants' perception of symmetrical patterns was disrupted by temporal degradations. In order to perceive the symmetry, infants needed to integrate enantiomorphs across time. Similar disruptions occur under various spatial degradations. For example, the separation of components of a visual pattern interferes with holistic perception of the pattern. Adults normally process vertically symmetrical patterns efficiently only when enantiomorphs (the elements of a symmetrical pattern which correspond about the axis) are separated across the vertical meridian by less than 4° of the visual angle [7,50,51]. The perceptual advantage of symmetry appears to degrade when enantiomorphs are separated by 5° or more because symmetry depends on either (a) constraining spatial parameters to facilitate point-for-point mirror matching of left–right halves of the pattern across its vertical meridian, or (b) limiting the visual span of the pattern to foster perception of the pattern as a whole [7,16,52]. The advantage of symmetry is retained only when enantiomorphs are narrowly aligned about the vertical meridian. Adults perceive symmetrical patterns with discontiguous enantiomorphs as they do for otherwise equivalent but unstructured asymmetrical patterns; infants do so as well. Thus, the contiguity of enantiomorphs of a symmetrical pattern about the vertical midline promotes the perception of a holistic pattern [7,16,50,51]. Experiment 3 in Bornstein and Krinsky [26] assessed infants' ability to integrate information in visual patterns that are separated in space by manipulating the spatial separation of pattern components. Infants processed vertically symmetrical patterns with enantiomorphs that were contiguous or nearly contiguous about the vertical axis (0° to 2.5° separations) more efficiently than vertically symmetrical patterns with discontiguous enantiomorphs (5° and 10° separations). Experiment 4 in Bornstein and Krinsky [26] assessed infants' sensitivity to the perceptual organization and synthesis of the pattern form by manipulating the organization of individual components of a vertical pattern. Infants demonstrated sensitivity to the symmetrical organization of the pattern above their perception of components in the pattern when they discriminated between vertical symmetrical patterns and asymmetrical patterns with a vertical organization. The results of the present Experiment 2 showed that human infants also lose the advantage with vertical symmetry when symmetrical patterns are degraded in time as they do when symmetrical patterns are degraded in space. However, the same was not true for faces. In Experiment 3, we advanced our investigation into parameters that support or disrupt the advantage with vertical symmetry in patterns and faces.

5. Experiment 3

Experiment 3 had two purposes. First, infants in Experiment 2 did not discriminate patterns between symmetry conditions in the absence of connected, continuous scanning, but it remains possible that they might discriminate patterns with additional time to construct a representation [46]. We hypothesized that allowing infants longer exposures to such patterns would restore the relative advantage with vertical symmetry. Second, from infants' discrimination of faces by symmetry conditions in Experiment 2, it is not clear whether their discrimination was based on symmetry alone or if the canonical configuration of facial features played a determining role in their perception. In adults, early face-sensitive event-related potential (ERP) components are disrupted by the manipulation of two structural properties embedded in faces, namely, the canonical up–down featural arrangement and vertical symmetry [53]. We hypothesized that vertical symmetry in faces in their canonical configuration lends advantage to symmetry, and so inverting faces would disrupt that advantage. To address these two issues, in Experiment 3, infants viewed six vertically symmetrical, obliquely symmetrical, and asymmetrical patterns as shown in Figure 1, each presented 20 times for 500 ms. Infants also saw six vertically symmetrical, obliquely symmetrical, and asymmetrical faces, presented 10 times for 500 ms each but shown inverted. We predicted that increasing the number of opportunities to view each pattern would allow infants to perceive the symmetry in the symmetrical patterns, thus inducing a preference for vertical symmetry (shown by longer looking times to these stimuli than to the other two symmetry types). We also predicted that inverting the faces would disrupt the advantage with vertical symmetry in faces, even where the components of the face retain vertical symmetry.

5.1. Experiment 3 Method: Materials, Apparatus, and Procedure

The task was also administered with a computer running e-Prime software, which controlled the stimulus presentation on the stimulus monitor as well as timing. For patterns, we extended the trial length used in Experiment 2 from 10 to 20 s; thus, infants saw twenty 500 msec alternations of the stimuli and mask. For faces, we inverted the images and presented them over ten 500 msec alternations of the stimuli and mask. As in Experiment 1, infants viewed 12 trials, 6 of alternating patterns and masks and 6 of alternating inverted faces and masks.

5.2. Experiment 3 Results and Discussion

The looking time was analyzed using the same statistical design as the previous experiments. Planned comparisons examined differences in fixation times between the vertical and oblique symmetry conditions and between the vertical symmetry and asymmetry conditions for each stimulus class. Infants looked less at vertically symmetric patterns compared to obliquely symmetric ones, F (1, 31) = 4.41, p = 0.044, $\eta p2$ = 0.13, and at vertical ones compared to asymmetric ones, F (1, 31) = 6.04, p = 0.020, $\eta p2$ = 0.16 (see means and standard errors in Figure 4). Analyses for faces revealed no differences in fixation times between vertical symmetric and oblique symmetric faces, F (1, 31) = 1.72, p = 0.200, or asymmetric faces, F (1, 31) = 2.55, p = 0.120.

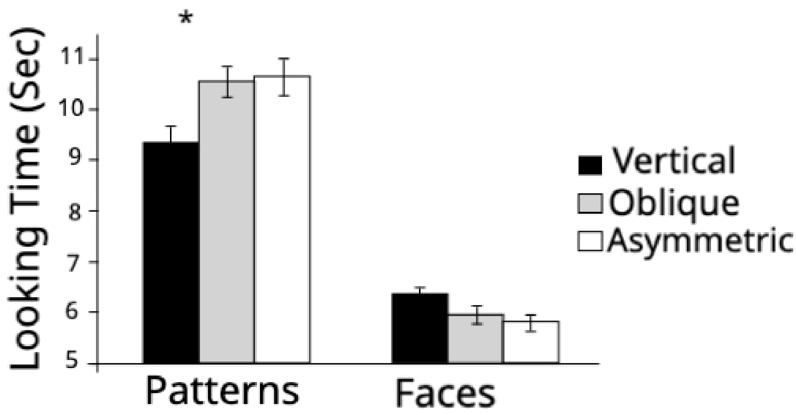

Figure 4. Mean fixation times in Experiment 3 by symmetry condition and stimulus class. Error bars indicate standard error of the mean. * = $p < 0.05$.

Infants in Experiment 3, having additional exposure time to view the novel patterns, responded differently between symmetry conditions. Relative to Experiment 2, extending the durations of rapid exposures restored infants' advantage with patterns with vertical symmetry. Despite still relatively brief intervals of visual access, infants differentiated novel patterns on the basis of symmetry, preferring verticality. When presented with inverted faces, infants provided no evidence of differentiating the faces by symmetry condition. Because infants differentiated vertical symmetry from other conditions in both Experiments 1 and 2, these results collectively suggest that the canonical arrangement of facial features supersedes elements in the processing of vertical symmetry in faces. When attention to vertical symmetric faces is compared directly between Experiments 2 and 3, infants looked significantly longer at upright canonical than inverted faces, $F(1,75)$ = 23.72, $p < 0.0001$, $\eta p2$ = 0.24.

6. General Discussion

Philosophers, estheticians, and scientists have long regarded symmetry as special. People prefer symmetry, process symmetry more efficiently, and remember symmetry better than other comparable visual patterns. However, not all symmetries are the same or provoke equivalent advantages; ample evidence indicates that vertical symmetry is special in form perception. In three experiments, we studied several aspects of the perceptual advantage with vertical symmetry in novel patterns and faces. Specifically, we asked (a) whether variation in symmetry conditions affect infants' visual scanning of patterns or faces, (b) whether the detection of pattern or facial symmetry depends on visual scanning, and (c) whether the advantage of vertical symmetry depends on orientation or processing time. In Experiment 1, we measured infants' scanning of visual stimuli, and exposure to vertical symmetry resulted in a reduction in the distribution and frequency of fixation shifts in infants' visual exploration of novel patterns and human faces. The simplest explanation for this reduction is that vertical symmetry demands fewer processing resources. This finding comports with the consensus that symmetric patterns are more readily processed and with the conclusions from other contexts that vertical symmetry enjoys a privileged status in infants' visual form processing [24]. The observation that infants' visual discrimination by symmetry is related to their visual scanning raises an additional question of whether infants' detection of symmetry in visual stimuli depends on connected scan paths during viewing (Experiments 2 and 3). When each stimulus was presented over a series of very brief exposures that disallowed scans, infants discriminated between symmetry conditions with faces but not patterns. Patterns required more exposure time for discrimination than did faces. Finally, faces were discriminated by symmetry, but only when presented in their canonical upright orientation (Experiment 1 versus 3). This finding is consistent with the large body of literature demonstrating the deleterious consequences of inversion in face processing [54]. In relation to the finding that vertical symmetry may reduce the perceptual demands of stimuli, the advantage with faces may be specific to the canonical configuration of their features and not just the features themselves or verticality. This finding is consistent with the widely reported sensitivity of the human visual system to the facial structure from very early in life [28]. Infants are known to discriminate between forms on the basis of a variety of low-level stimulus variables. The present experiments demonstrated that particular stimulus organizations, specifically vertical symmetry, also facilitated form discrimination holistically in infants as young as 4 months. Babies discriminated vertically symmetrical forms from obliquely symmetrical and asymmetrical ones that were equated on all low-level stimulus dimensions. In the present experiments, infants' perceptual advantage with symmetry appears specific to vertical symmetry, and infants in earlier studies did not discriminate horizontal symmetrical forms from asymmetrical ones [25]. Thus, the structural organization in horizontal or oblique symmetries appears not to facilitate form discrimination early in infancy; indeed, for infants, these non-vertically symmetrical orientations might just as well be asymmetrical. The early perceptual advantage with vertical over horizontal symmetry suggests that infants respond to symmetrical organizations in a hierarchical manner as do adults [14,19,55,56].

Why does the orientation of the axis of symmetry affect the infant's response to stimulus organization? The infants' advantage with vertical over oblique symmetry is not simply a preference [24,57]. Rather, the special status of vertical symmetry may result from an interaction between the orientation and the unique qualities of symmetry. Three levels of explanation for this effect suggest themselves. One is anatomical: the perceptual bias for vertical symmetry may be rooted in the bilateral symmetry of the perceiving visual system [13,16,58,59] and associated orientational anisotropy [60]. A second level of explanation is motor: symmetry is recognized by matching enantiomorphs across the meridian of a form [7]. A greater density of infant scanning occurs along the horizontal [61] and would therefore facilitate an advantage with symmetry along the vertical. But, contra this motor explanation, we found the detection of vertical symmetry in the absence of visual scans. A third level of explanation is experiential: the special status of vertical symmetry could result from infants' experiences in a visual world dominated by vertically symmetrical forms. An especially significant symmetrical form for the infant is the human face. It could be, therefore, that the vertically symmetrical property of the face plays a singularly important role in the infant's processing bias for vertical symmetry, or it is equally plausible that the emergence of sensitivity to the global characteristics of the face is tied to the infant's ability to use symmetry as an important organizing stimulus dimension. The findings of these experiments together suggest that vertical symmetric patterns are possibly perceived as holistic. Some authorities have contended that infants are more sensitive to parts of configurations than to the whole [48,61]. That infants scan vertically symmetrical patterns less indicates that infants do not need to perceive isolated elements that construct a stimulus, however. Infants appear to be sensitive to the higher-order characteristic of vertical symmetry, and not just to verticality or to symmetry, a conclusion that accords with the extant literature [62–64] that very young infants perceive holistic qualities in some two-dimensional forms. For somewhat older infants, the global or configural properties of visual stimuli appear to take precedence in processing as they do in adults [65–67].

7. Limitations and Future Directions

These experiments have some limitations that prompt future directions of study. First, we used novel never-before-seen patterns and faces in these experiments, which is an experimental advantage, but we were limited to a discrete set of patterns and faces. Future studies need to examine the generalizability of these findings with additional stimuli. Second, we tested only one age group of infants, those at 4 months. To answer the question of whether infants are born with an advantage with vertical symmetry (as might be the case) calls for a re-assessment of these findings with newborns. Last, we brought several different behavioral methods and tasks to bear on uncovering infant visual biases, but additional work, for example, using functional near infrared spectrometry, could be designed to determine the neurological bases and locations of these visual information-processing effects.

8. Conclusions

Symmetry is a feature of objects that facilitates perception. We reported three experiments of 4- to 5-month-old infants' detection and processing of vertical symmetry, oblique symmetry, and asymmetry in novel patterns and faces. In Experiment 1, infants showed the fewest shifts in visual fixations to vertical symmetry in patterns and faces. These results support the view that vertical symmetry is processed more efficiently than oblique symmetry or asymmetry. In Experiment 2, the stimulus presentation disallowed more than a single visual fixation, and infants looked longer at a face that is vertically symmetrical compared to obliquely symmetrical or asymmetrical ones, and they looked equally to patterns regardless of symmetry. In Experiment 3, where pattern exposures were prolonged and inverted faces viewed, infants discriminated vertically symmetry in patterns but lost the advantage with vertical symmetry in faces. Thus, symmetry in patterns requires more processing time from infants, and inverting the face costs infants the normal perceptual advantage of symmetry, even if components of the face remain symmetrical. Together, our findings suggest that infants are prepared to exploit symmetry in their everyday perceptions.

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