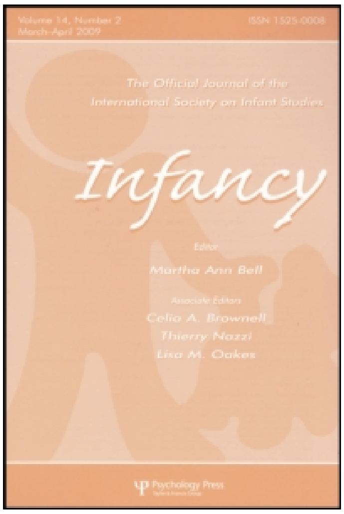

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Faces Attract Infants' Attention in Complex Displays

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Faces Attract Infants' Attention in Complex Displays

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Infant's face preferences have previously been assessed in displays containing 1 or 2 faces. Here we present 6-month-old infants with a complex visual array containing faces among multiple visual objects. Despite the competing objects, infants direct their first saccade toward faces more frequently than expected by chance (Experiment 1). The attention-grabbing effect of faces is not selective to upright faces (Experiment 2) but does require the presence of internal facial elements, as faces whose interior has been phase-scrambled did not attract infants' attention (Experiment 3). On the contrary, when the number of fixations is considered, upright faces are scanned more extensively than both inverted and phase-scrambled faces. The difference in selectivity between the first look measure and the fixation count measure is discussed in light of a distinction between attention-grabbing and attention-holding mechanisms.

Human infants' interest in faces has been widely documented using various experimental methods. For example, a visual tracking procedure revealed that newborns follow face-like patterns further than a variety of other patterns (Johnson, Dziurawiec, Ellis, & Morton, 1991; Turati, Simion, Milani, & Umilta, 2002). From around 1 month after birth, face preference measures have yielded inconsistent results. Turati and her colleagues found that 3-month-olds infants prefer prototypical faces to scrambled ones (Turati, Valenza, Leo, & Simion, 2005), whereas Johnson, Dziurawiec, Bartrip, and Morton (1992) failed to show such a preference in 5-month-olds. A social species like ours depends highly on face-mediated social interactions and individual identification and thus should still benefit

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from mechanisms that allow for orienting and maintaining attention to faces, beyond the first months of life (Gliga & Csibra, 2007; Grossmann & Vaish, 2008; Johnson et al., 2005). A common characteristic of the previously mentioned studies is their use of displays in which faces were presented within the central visual field, for as long as the infant would look at them. It is possible that these are no longer optimal conditions for assessing face preferences in older infants. We know, for example, that more naturalistic faces have to be used to elicit a preference in older infants (e.g., pictures instead of schematic faces or dynamic instead of static faces; Johnson et al., 1992; Mondloch et al., 1999). In this study, we investigate whether we can elicit face preference in 6-month-old infants using a spontaneous measure of attention capture by faces presented in a complex visual array. We expected that these challenging conditions would encourage infants to make a choice in terms of which objects they orient to and scan.

Because different measures may tap into different processing mechanisms and neural substrates (Cohen, 1972; Schiller & Tehovnik, 2001) we were interested in measuring both infants' ability to orient their attention toward faces and their ability to maintain attention on faces. In adults, the power of faces to grab attention has been widely demonstrated, using both direct and indirect measures. In a recent study, adult participants made more frequent first saccades to scenes containing a human figure (Fletcher-Watson, Findlay, Leekam, & Benson, 2008). Also, adults are faster and more accurate at detecting masked faces than they are at detecting masked objects (Purcell & Stewart, 1988) and are better at detecting changes in face identity as compared to other objects (Ro, Russell, & Lavie, 2001). Seeing a face facilitates the processing of stimuli that are spatially associated with it (Bindemann, Burton, Langton, Schweinberger, & Doherty, 2007) and can impair the processing of other nonassociated target stimuli (Mack & Rock, 1998; Ro, Friggel, & Lavie, 2007).

In this study we investigate attention capture by measuring the probability with which 6-month-old infants make a first saccade toward a face, in a display containing a variety of other distracting images (e.g., alarm clocks, mobile phones, birds, cars, and shoes). We also measured the total amount of fixations directed to faces during the fixed presentation period. In the first experiment we aimed to establish whether infants preferentially orient to faces in complex visual arrays. In two follow-up experiments, we manipulate different face properties (both configural and featural) to determine the conditions necessary for attention capture.

EXPERIMENT 1

Methods

Participants. Sixteen 6-month-old infants (M = 174.8 days, SD = 8.7) participated in this study (8 girls, 8 boys). Twelve additional infants were excluded because of experimental error ($n = 6$), fussiness ($n = 4$), for never looking at one of the categories ($n = 1$), or for not fixating the center of the screen before the trial onset in more than 8 trials ($n = 1$).

Apparatus. Corneal reflection data were recorded with the TOBII eye tracker. TOBII has an infrared light source and a camera mounted below a 17-in. flat-screen monitor. It measures the gaze direction of each eye separately and from these measurements evaluates where the individual is looking on the screen. Gaze data were recorded at 50 Hz.

Stimuli. Color images depicting 12 different female faces with direct gaze and the same faces with averted gaze were used. Twelve different exemplars from each of five categories (alarm clocks, mobile phones, birds, cars, and shoes) were also used as distracters. Twelve different slides were created, each containing six images (one face and five distracters, one from each category) placed at an equal distance from the center of the screen (Figure 1). Images were of comparable size. Each slide contained a different set of six images, each image being shown only once in the experiment. To the greatest extent possible, we tried to minimize the differences in color and luminosity among the six images in a slide. Each category was presented in a particular location in 2 of the 12 slides. Two different orders of presentation of the slides were used and counterbalanced between infants.

Procedure. The infant was seated on his or her caregiver's lap, at 50 to 55 cm from the TOBII screen. The height and distance of the screen was slightly adjusted for each baby to obtain good tracking of the eyes. A 5-point calibration sequence was run (for technical details about the apparatus and the calibration procedure, see von Hofsten, Dahlstrom, & Fredricksson, 2005). The recording was started only after at least 4 points were marked as being properly calibrated for each eye. The infant's behavior was monitored by a video camera placed above the TOBII monitor.

FIGURE 1 Sample slides from (a) Experiment 1 and (b) Experiment 3. The areas of interest used in the analysis are delimited around the objects.

Stimuli were presented using Clearview software. When placed at 55 cm from the infant, the six individual images on the slide had an eccentricity of 9.3° and covered an approximate area of 5.2° × 7.3° (Figure 1). Each infant saw 12 slides. Each slide presentation lasted 12 sec. In between the slides a small animation was presented in the center of the screen, ensuring that infant's gaze was directed to the center before the next slide was presented. To maintain infants' attention, the visual presentation was accompanied by unrelated music.

Data analysis. Rectangular areas of interest (AOIs) were defined manually around each object image, using Clearview software (Figure 1). Each side of the rectangle was at a distance subtending approximately 1.1° from the most protruded point of the image. The center of the screen was also delimited within an AOI. For each infant, we calculated the percentage of trials in which the first looks were directed to a certain category AOI (i.e., first looks) and the average number of fixations within an AOI, per slide (i.e., fixation count). Only fixations above 100 msec were included in the analysis. Fixation count was chosen over the classical measure of accumulated looking time because this allowed us to analyze separately the fixations made within the face (i.e., scanning) and those fixations that alternated between the other objects and the face. Only slides where the eye position at the onset was within the central AOI were included in the first look analysis and only infants having at least eight such slides were included in the analysis. Preliminary results showed no difference between faces with direct or averted gaze, for either of the measures; therefore data from these AOI were collapsed. For both measures (first looks and fixation count), faces were compared with an average of all distracter categories (objects), as this was the key hypothesis of this experiment. Using one-sample *t* tests, we also examined whether the percentage of first looks toward faces was different from what would be expected by chance (1 of 6, 16.6%).

Results

After excluding trials in which the center was not fixated at the start of the trial, infants contributed an average 11.1 trials ($SD = .75$) to the first look measure. As presented in Figure 2, a large part of infants' first saccades were directed to the face ($M = 39.8\%$, $SD = 15.3$) and all other categories were close to the chance level of 16.6%. An analysis of variance (ANOVA) with category (objects, faces) and order of presentation yielded a main effect of category, $F(1, 14) = 35.65$, $p < .001$, and no interaction with order of presentation. One-sample *t* tests confirmed that only faces attracted infant's first looks above what was expected by chance, $t(15) = 6.07$, $p < .001$, with 14 out of the 16 infants scoring above the chance level.

To test whether this first look effect was stable along the experiment we averaged separately each three successive trials. An ANOVA with trial number (first 3, second 3, third 3, and last 3) and category (objects, faces) as within-group factors,

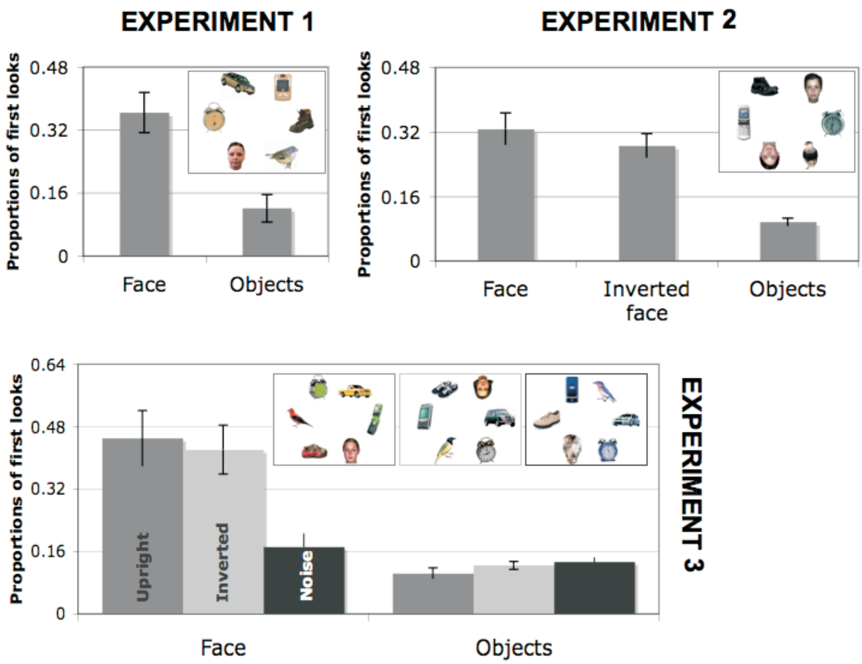

FIGURE 2 Proportion of first looks to each category. 0.16 corresponds to the chance level. The error bars represent standard error.

and order of presentation as between-subject factor revealed a main effect of category, $F(1, 14) = 37.80, p < .001$, but no main effect of trial number, nor an interaction between category and trial number.

Infants also accumulated more fixations within the faces AOI than within any other category AOIs (Figure 3). ANOVA with category (faces, objects) and order of presentation yielded a main effect of category, $F(1, 14) = 31.06, p < .001$, and no interaction with the order of presentation.

To test whether the same pattern of fixation distribution was found throughout the experiment, we averaged separately the fixation counts for each three successive trials for all categories. An ANOVA with trial number (first 3, second 3, third 3, and last 3), category (faces, objects) and order of presentation yielded only a main effect of category, $F(1, 14) = 36.70, p < .001$.

Discussion

We showed here that faces were the target of infants' first looks more frequently than expected by chance, and were also the class of object that attracted the most of

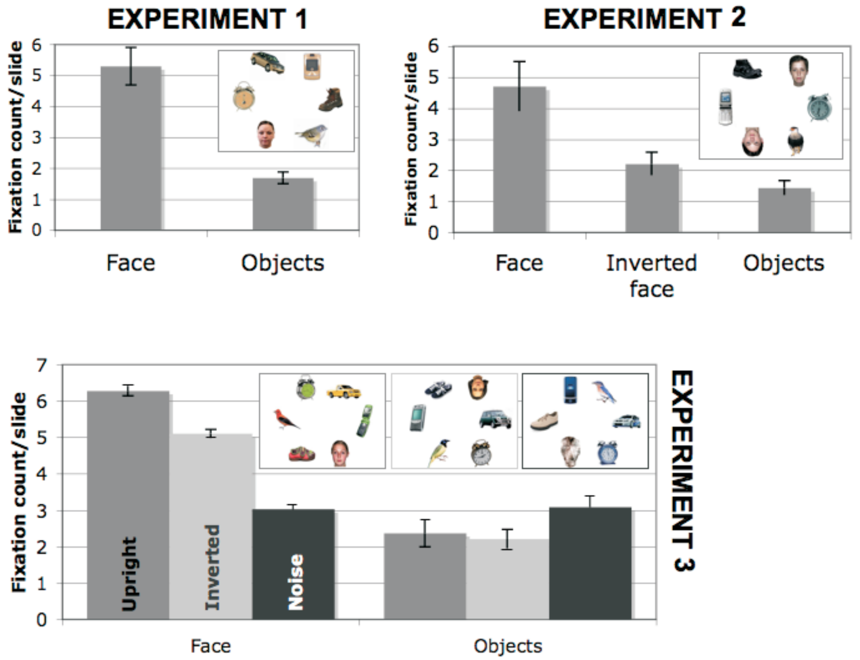

FIGURE 3 Average number of fixations within the different areas on interest. The error bars represent standard error.

subsequent fixations. These effects were observed in the majority of individuals and were stable over the time course of the experiment; that is, no decrement due to habituation, nor increment due to priming of attention by preceding faces, was observed. Thus, with Experiment 1, we established that faces attract 6-month-old infants' attention when presented in a complex array of objects and that both the first looks and the fixation counts effects maintain their strength along the experiment.

In the next experiments we aimed to determine which face properties trigger these effects. We ask specific questions about whether inversion or the absence of internal facial elements interfere with infants' ability to orient attention toward peripherally presented faces.

EXPERIMENT 2

Throughout the first 12 months, face processing mechanisms gradually specialize for processing upright faces (Halit, de Haan, & Johnson, 2003). Already at 6 months of age, electrophysiological measures discriminate between upright and inverted faces, presented centrally (de Haan, Pascalis, & Johnson, 2002). In Experiment 2 we test whether inversion modulates attention capture by peripherally presented faces.

Methods

Participants. Twelve 6-month-old infants (M = 180 days, SD = 10.18) participated in this study (7 girls, 5 boys). Six other infants were not included because of experimental error (n = 1), fussiness (n = 4), or insufficient calibration points (n = 1).

Stimuli. Stimuli were designed similarly to Experiment 1 (Figure 1). The same images as in the previous experiment were used. Twelve slides were created, each containing six images: one upright and one inverted face and four images from the following categories: alarms, mobiles, shoes, and birds. The same 12 different faces were employed in the upright and inverted orientation, in different slides. Because upright and inverted faces were compared within the same slide, only one order of presentation was used in this study.

Procedure and data analysis. These were similar to those used in Experiment 1. Again, distracter categories were collapsed in one variable,objects, which was compared with upright and inverted faces.

Results

In this study infants contributed an average of 10.33 (SD = 1.31) valid trials for the first look measure. Both upright and inverted faces received a higher proportion of first looks than the object categories, as confirmed by a repeated-measures ANOVA, $F(2, 22) = 13.24$, $p = .001$. Paired t tests confirmed that both upright faces and inverted faces attracted significantly more first looks than the objects: upright faces, $t(11) = 5.51$, $p < .001$; inverted faces, $t(11) = 4.90$, $p < .001$. On the contrary, the difference between upright and inverted faces did not reach significance ($p < .1$). For both upright faces and inverted faces, the proportion of first looks toward the faces was significantly above chance level: upright faces, M = 32.6%, $t(11) = 4.06$, $p = .002$; inverted faces: M = 28.6%, $t(11) = 4.02$, $p = .002$.

Upright faces received again more subsequent fixations than the distracter categories, but also more fixations than inverted faces (Figure 3). A repeated-measures ANOVA yielded a main effect of category, $F(2, 22) = 15.81$, $p = .001$. Paired t tests confirmed that upright faces were significantly different than the average values for the object categories, $t(11) = 4.11$, $p = .002$, and also than inverted faces, $t(11) = 4.29$, $p = .001$. No significant difference between inverted faces and the average values for the object categories was found, $t(11) = 2.05$, $p > .05$. A detailed analysis of fixations within the face AOI showed that half of the saccades terminating in these AOIs, for both upright and inverted faces, originated within that AOI (fixations that correspond to the scanning of the face), the other half coming from one of the other five objects. Thus the differences between the upright and inverted faces were due to both longer scanning of the upright face and more "returns" to it (both $p < .01$).

Discussion

As in Experiment 1, we found that faces captured infants' attention above what was expected by chance. The orientation of the face had little effect on the first looks but upright faces received a greater proportion of further fixations than inverted faces. Interestingly, inverted faces were the targets of as few fixations as the other object categories. These looking time differences cannot inform us about the underlying mechanisms. Nonetheless, the equal interest given to inverted faces and objects is in line with the hypothesis that inverted faces are analyzed outside face-selective areas, by general object-processing networks (Aguirre, Singh, & D'Esposito, 1999; Haxby et al., 1999).

The lack of difference in the proportion of first looks toward upright and inverted faces is a surprising result and suggests that configural face properties do not affect the initial orienting mechanism in infants. Inversion has had inconsistent effects on adults' orienting to faces. When asked to detect a change in face identity, adults scored worse when the face was inverted (Ro et al., 2001). Conversely, VanRullen (2006) asked participants to simply detect faces in a complex visual array; in this case no difference was found between upright and inverted faces. Thus, it seems that inversion is detrimental only when additional processing is required (e.g., identification). When having to simply detect a face, low-level properties, like face color spectra or face amplitude spectra, might be enough to trigger attention capture (VanRullen, 2006).

To test whether similar low-level information is used by infants, we asked whether scrambling the phase spectra of faces, while maintaining their amplitude and color spectra, as well as the outer facial contour intact, will leave unaffected an infant's ability to detect faces, as was the case in adults. In this third study infants saw upright, inverted, and phase-scrambled faces, presented together with objects from other five distracter categories.

EXPERIMENT 3

Methods

Participants. Sixteen 6-month-old infants (M = 187 days, SD = 7.42) participated in this study (6 girls, 10 boys). Two other infants were not included because of fussiness (n = 1) or insufficient calibration points (n = 1).

Stimuli. Twelve different color images of upright female faces and their inverted and phase-scrambled versions (noise faces) as well as 18 different exemplars of alarms, mobiles, shoes, birds, and cars were used in this study. Noise stimuli were created from the upright faces by randomizing the phase spectra while keeping the amplitude and color spectra constant, as well as the original outer face contour[1] (Halit, Csibra, Volein, & Johnson, 2004). Eighteen slides were created, each containing one face and five objects, one from each of the previously mentioned distracter categories. Six slides had an upright face, six had an inverted face with a different identity than the upright faces, and six slides had a noise face. Two different orders of presentation of the slides were created by randomization and were counterbalanced between infants. The faces that were employed in the upright orientation in one of these stimulus sets were used in the inverted orientation in the second set, and vice versa.

Procedure and data analysis. These were similar to those used in Experiments 1 and 2. Because the upright, inverted, and noise faces are presented in separate slides, we averaged the first look and fixation count values for the object categories separately for the slides containing upright, inverted, or noise faces.

Results

Infants contributed on average 17 slides (SD = .73) to the first look measure. As in the previous experiments, both faces received a greater proportion of first looks than the object categories. The type of faces did affect this measure, nonetheless, with upright and inverted faces receiving an equally high amount of first looks, whereas noise faces were close to chance level (Figure 2). An ANOVA with category (faces, objects) and type (upright, inverted, noise) as repeated-measures factors and order of presentation as between-subject factor, yielded a main effect of category, $F(1, 14) = 21.53$, $p < .001$, a main effect of type, $F(1, 14) = 21.53$, $p < .001$, and a significant interaction between type and category, $F(2, 28) = 8.20$, $p = .002$. This interaction was due to a significant effect of type for faces, $F(2, 28) = 8.60$, $p = .001$, but not for objects, $F(2, 28) = 2.36$, $p > .1$. Paired t tests confirmed that the difference between the proportion of first looks toward the upright and inverted faces was not significant, $t(15) < 1$, whereas the proportion of first looks received by the noise faces was different from both the upright, $t(15) = –3.76$, $p = .002$, and the inverted faces, $t(15) = –3.76$, $p = .003$. A post-hoc t test revealed that noise faces were not significantly different than the distracter objects, $t(15) = 1.12$,

[1]Specifically, (a) a two-dimensional fast Fourier transformation was applied to all three color components of the images, (b) the phase on each frequency was replaced by a random value between π and $-\pi$ (uniform distribution), (c) an inverse Fourier transformation reconstituted the image, (d) to which the outer contour of the original face was applied as a mask.

$p > .2$. One-sample t tests were run to confirm above chance orienting to upright faces, $M = 45\%$; $t(15) = 3.98$, $p = .001$, and inverted faces, $M = 42.08\%$; $t(15) = 4.05$, $p = .001$, but not to noise face trials, $M = 17.18\%$; $t(15) < 1$.

Infants spent slightly more time looking at the upright than at the inverted faces but directed as few of their fixations to the noise faces as to the other object categories (Figure 3). An ANOVA with category (faces, objects) and type (upright, inverted, noise) as repeated measures and order of presentation as a between-subject factor, yielded a main effect of category, $F(1, 14) = 12.86$, $p = .003$, as well as a significant interaction between type and category, $F(2, 28) = 33.01$, $p < .001$. Type significantly affected the amount of fixations for faces, $F(2, 28) = 22.14$, $p < .001$. Paired t test confirmed that the difference between upright and inverted faces was marginally significant, $t(15) = 2.12$, $p = .05$, and the noise faces were significantly different from both upright faces, $t(15) = -7.25$, $p < .001$, and inverted faces, $t(15) = -4.03$, $p = .001$.

Discussion

In this third study we replicated and extended previous results. We confirmed that the orientation of the face had little impact on the first look measures but affected the amount of time infants spent looking at the face, with upright faces attracting more fixations than inverted faces. In contrast with Experiment 2, in this experiment the difference is only marginally significant. The reason might be the use of two faces per slide in Experiment 2. The simultaneous presentation of an upright and inverted face probably decreased the relative saliency of the inverted faces. Thus, just as newborns, 6-month-olds infants show similar preferences for upright faces (Farroni et al., 2005). The most parsimonious interpretation would invoke similar mechanisms acting at birth and later in the first year of life. Nonetheless, although the existence of an innate bias has to be assumed to explain newborn's preferences, at 6 months of age, infants have probably accumulated more exposure to upright faces, and qualitatively different exposure, in terms of social interactions (Gliga & Csibra, 2007). Experience and not innate biases are probably driving the longer looking toward upright than inverted faces in our study.

Although the inversion of the face did not affect the proportion of first looks, the scrambling of the face phase spectra did lower this measure down to the chance level and also diminished the number of fixations received by the face. This result is different from previous findings in adults. Adults needed amplitude information but not phase information to detect the presence of a face (VanRullen, 2006). The phase spectrum contains information about the internal and external contours. Because the external contour was preserved in our noise stimuli, the lack of internal contours (i.e., the internal facial elements) must have been the crucial factor in decreasing the saliency of the noise faces.

GENERAL DISCUSSION

Beyond the first month of life, studies on face processing in infancy have often, but not always, found a preference for prototypical faces. In this study we confirm that when competing with a variety of other objects, faces are the category that captures infants' attention, as measured by the proportion of first looks faces receive. Moreover, faces maintained infants' attention, receiving more fixations that the other object categories. The success of the design we used in revealing face preferences in 6-month-old infants was probably due to the challenging context of a complex display, with infants having to make a decision regarding which objects to explore.

The measure of spontaneous gaze shifts we used fulfills the definition of stimulus-driven attention capture given by Yantis (1993, p. 677) as being "independent of either the defining or the reported attribute of the target." Infants could not be instructed to attend to the face, nor were they primed to attend to faces by previous exposure. Their orienting toward faces remained strong along the experiment. On the contrary, in a large number of adult studies, participants are asked to actively search for a particular target stimulus (often the face itself). Some of these studies investigated attention capture by showing that the speed and accuracy of face detection is independent of the numbers of distracters, a phenomenon known in visual search studies as "pop-out" (Treisman & Gelade, 1980). Pop-out is thought to be the result of parallel search mechanisms (as opposed to serially scanning the elements of a scene) and is generally found when target and distracters differ in one or more low-level features (e.g., color, orientation). This phenomenon has been measured in infants as well. Adler and Orprecio (2006) showed that the latency of orienting toward arrays containing a + sign among Ls did not increase with the number of distracters in 5-month-old infants. Whether high-level pop-out effects exist, where categories and not visual features grab attention, has highly debated (Hershler & Hochstein, 2005). Because inversion did not prevent face pop-out in his study, VanRullen (2006) concluded that face pop-out effects are also the result of low-level visual properties. In agreement with these findings we also showed that the orienting measures are unaffected by inversion (Experiment 2 and 3). Nonetheless, some face structural information is necessary to grab infants' attention because when we scrambled the phase of the visual frequencies, faces failed to attract infants' first looks (Experiment 3).

The fact that the upright configuration is not more effective in grabbing infants' attention than the inverted faces might seem surprising, in light of previous studies showing early specialization for upright faces (de Haan et al., 2002). Previous studies assessed face processing while faces were already the infant's center of attention. Indeed, when we measured the number of fixations faces received during a trial, we also show a clear preference for upright over inverted faces. Thus, a two-stage process might be driving face processing in infants. A first orienting mechanism increases the chance of detecting people in the periphery and bringing them into the fovea for higher acuity analysis. Some information on the internal structure of faces is required, although not particularly the canonical upright orientation. A moderately selective orienting mechanism is an optimal solution as it allows infants to spot any chance for a social contact and, by orienting their gaze toward people and vocalizing, to actively trigger a closer face-to-face encounter. Once in their central visual field, faces are subject to higher acuity visual processing, which leads to more selective criteria being applied to subsequent fixations. At this point, inverted faces do not succeed in maintaining infants' attention, as shown by the low number of fixations they received in Experiments 2 and 3.

This distinction between attention-getting and attention-holding mechanisms has been previously made in the general context of visual processing in infants (Cohen, 1972) In this study, different visual properties modulate the latency to orient to a checkerboard pattern (e.g., the size of the stimulus) and the time spent scanning the image (e.g., the number of checkers). Whether these differences are only the result of differences in acuity in the peripheral and central retina or of distinct processing mechanisms, further in the visual pathways (or both), is still unknown.

To our knowledge the current study is the first evidence, in infants, of attention capture by faces within complex arrays. Future studies will explore whether the attention-grabbing mechanisms become more selective with age and whether this increased selectivity (e.g., upright faces, faces with direct gaze) is a function of increased peripheral acuity or the result of more specialized orienting mechanisms. Having proved its sensitivity, this paradigm can be used to ask a variety of general questions about the development of visual attention and visual processing, thus bridging the gap between the adult psychophysical literature and classical infant looking time studies.

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