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Perception of mooney faces by young infants: the role of local feature visibility, contrast polarity and motion

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Abstract

We examined the ability of young infants (3- and 4-month-olds) to detect faces in the two-tone images often referred to as Mooney faces. In Experiment 1, this performance was examined in conditions of high and low visibility of local features and with either the presence or absence of the outer head contour. We found that regardless of the presence of the outer head contour, infants preferred upright over inverted two-tone face images only when local features were highly visible (Experiment 1a). We showed that this upright preference disappeared when the contrast polarity of twotone images was reversed (Experiment 1b), reflecting operation of face-specific mechanisms. In Experiment 2, we investigated whether motion affects infants' perception of faces in Mooney faces. We found that when the faces appeared to be rigidly moving, infants did show an upright preference in conditions of low visibility of local features (Experiment 2a). Again the preference disappeared when the contrast polarity of the image was reversed (Experiment 2b). Together, these results suggest that young infants have the ability to integrate fragmented image features to perceive faces from two-tone face images, especially if they are moving. This suggests that an interaction between motion and form rather than a purely motion-based process (e.g., structure from motion) facilitates infants' perception of faces in ambiguous two-tone images.

Keywords

faces, mooney, infants, role, perception, young, motion, local, polarity, contrast, visibility, feature

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Abstract

We examined the ability of 3- and 4-month-old infants to detect faces in the two-tone images often referred to as Mooney faces (1957). In Experiment 1, this performance was examined in conditions of high and low visibility of local features and with either the presence or absence of the outer head contour. We found that regardless of the presence of the outer head contour, infants preferred upright over inverted two-tone face images only when local features were highly visible (Experiment 1a). We showed that this upright preference disappeared when the contrast polarity of two-tone images was reversed (Experiment 1b), reflecting operation of face-specific mechanisms. In Experiment 2, we investigated whether motion affects infants' perception of faces in Mooney faces. We found that when the faces appeared to be rigidly moving, infants did show an upright preference in conditions of low visibility of local features (Experiment 2a). Again, the preference disappeared when the contrast polarity of the image was reversed (Experiment 2b). Together, these results suggest that young infants have ability to integrate fragmented image features to perceive faces from two-tone face images, especially if they are moving. This suggests that an interaction between motion and from rather than a purely motion-based process (e.g. structure from motion) facilitates infants' perception of faces in ambiguous two-tone images.

Key words: Perception, face recognition, preference, form, motion, infants

Humans have a remarkable ability to detect and perceive faces: for example, adults can detect facial information even from severely impoverished images such as Mooney faces. The Mooney faces are two-tone image of faces derived by thresholding photographs of faces under asymmetrical lighting condition (Mooney, 1957). Unlike most natural images, two-tone images do not contain enough cues to differentiate contours arising from illumination effects (e.g., cast shadows, highlights) from contours arising from object structure (e.g., changes in material, pigmentation or occlusions) without knowing the structure of the object in advance. Although information about local features of faces is severely degraded in Mooney faces, and often too ambiguous for recognition as individual features, adults can relatively easily perceive faces when the Mooney faces are presented in an upright orientation (George et al., 2005). As there are no separable features to be identified, analytical processing is thought to be ineffective with Mooney faces (Latinus and Taylor, 2005) and holistic processing appears essential. Moore and Cavanagh (1998) pointed out that, typically, a 2-tone image does not contain cues to disambiguate between contours arising from illumination effects (e.g., cast shadows, highlights) and those arising from object structure (e.g., occlusions, changes in material). They argued that this ambiguity cannot be solved without the guidance of familiarity cues, and could block the perceptual recovery of depicted object structure. In fact, Moore and Cavanagh reported that two-tone images of novel objects were poorly recognized, suggesting that interpretation of two-tone images in general requires some kind of top-down knowledge about the structure of the object.

Several research groups have therefore used Mooney faces as a tool for investigating the contribution of holistic processing to facial recognition (McKeeff &

Tong, 2007; Latinus and Taylor, 2005; Latinus & Taylor, 2006; Le Grand et al., 2006; Farzin, Rivera, & Whitney, 2009). Given that adults readily detect even unfamiliar faces in two-tone Mooney configurations, it is reasonable to assume that this is guided by some general prototypical representation of facial structure that they have developed. In this paper we use two-tone face images to investigate this ability in infants.

In developmental studies, the ability of infants to detect faces is often assessed by measuring visual preference for upright as compared to inverted faces. For example, studies have shown that even newborn infants preferentially look at an upright face or face like configuration as compared to its inverted counterparts, even though the inverted counterparts are a complete match in terms of complexity, amount of energy or any other low-level image properties (Johnson & Morton, 1991; Mondloch, et al, 1999; Valenza, Simion, Macchi Cassia, & Umilta, 1996; Macchi Cassia. Turati & Simion, 2004). Such findings have been interpreted as showing that even newborns have the ability to detect faces. However there is considerable debate as to whether this preference in newborns reflects face specific or more general processing mechanisms (for a review, see Simion et al., 2007).

For example, Simion et al. (2001; 2002) proposed that the preference for upright faces in the newborns is attributable to a non-face specific, structural property of faces, specifically the "top heavy" property: i.e. more elements are located in the upper part than in the lower part of the stimuli. Even when using geometrical, non face like, stimuli Simion et al. (2002) found that newborns preferred top heavy to inverted versions of the same stimuli. Turati, Simion, Milani, and Umiltà (2002) extended this finding by showing that newborn did not prefer face-like to equally top-heavy non-face like arrangements. Further, newborns preferred the top heavy but non face-like configuration to face like configurations in which the position of the elements was shifted toward bottom half of the stimuli. However, other researchers have shown that newborn's preference for face is not determined by top-heavy arrangement of facial features alone, but also depends on the presence of ecologically valid contrast polarity relations (e.g. Farroni et al. 2005).

There is also evidence that newborns have a more limited representation of facial structure as compared to older infants (Macchi Cassia, Turati, & Simion, 2004; Mucchi Cassia et al., 2006; Turati et al., 2005). Using stimuli based on photograph of faces, Macchi Cassia, et al. (2004) reported that newborns prefer upright over inverted top heavy scrambled faces, just as they prefer upright over inverted normal faces. In contrast, 3-month-olds did not prefer upright over inverted top-heavy scrambled faces even though they do still prefer upright over inverted normal faces. Three month olds also, unlike newborns, preferred upright normal faces over upright top-heavy scrambled faces (Mucchi Cassia et al., 2006; Turati et al., 2005). This pattern of results suggests that the preference for upright face becomes more face specific and representations of facial structure become more sophisticated by 3-months of age.

While most of the previous studies have used facial photograph or schematic face like stimuli that contain well defined features surrounded by a complete contour, some recent studies used images where features and contours are incompletely specified. For example, Gava, Valenza, Turati, and de Schonen (2008) examined the effect of partial occlusion on infants' detection of faces. They examined preference for upright over inverted faces under two occlusion conditions. In one condition, the eyes and part of the external contours were occluded by vertical bars (High Salience Occlusion condition). In the other condition, the position of the face was shifted relative to the occluding bars so that the mouth, the nose and a different part of the external contours was occluded (Low Salience Occlusion condition). Gava, et al. reported that newborn infants preferred the upright faces only in the Low Salience Occlusion condition, where eyes were visible. The results might be interpreted as implying that newborns can detect faces if some low-informative face portions are hidden, even if they cannot when high salience features are hidden. However, the preference for upright faces observed only in Low Salience Occlusion condition is consistent with the top-heavy hypothesis because the up-down asymmetry of faces was affected only in the High Salience Occlusion condition.

Unlike the schematic faces and facial photographs used in almost all previous developmental studies, Mooney face stimuli do not contain individual facial features and the face can be only be perceived when the image fragments are processed as a whole. Therefore, as with adults, Mooney faces provide an additional tool for investigating this aspect of face detection ability in infants. Doi, Koga, and Shinohara (2009) first examined Mooney face perception in 6-, 12-, 18-month old infants. They examined preference for upright over inverted presentations of the same Mooney face images and found that only 18-month-olds showed an upright preference. In contrast, when full gray-scale photographs were used as the test stimuli, younger infants also showed a preference for upright faces. These results suggest that the ability to detect and perceive the face in a Mooney face image does not develop until very late in infancy. However, an even more recent study by Leo and Simion (2009) reported that even newborn infants show a preference for upright over inverted Mooney faces.

One way to reconcile these seemingly discrepant findings is to consider that for newborns, with their predominantly low spatial frequency vision, Mooney face would look more similar to real faces than they would for the older infants with a better ability to differentiate higher spatial frequency detail. Indeed Leo and Simion (2009) argued that, for newborns, Mooney faces would not provide information very different from that provided by photographs of real face. For infants who have better visual acuity, the spurious edge content present in two-tone nature of Mooney faces may have interfered with detection.

Another possibility is that Mooney faces are too impoverished for older infants to show upright face preference because they have developed a more sophisticated representation of faces. Previous studies have suggested that more complex and naturalistic facial stimuli were required to elicit a preference in older infants (e.g., Johnson et al., 1992; Mondloch et al., 1999). This possibility suggests that there should be a condition where infants show the upright preference even in the two-tone image provided that the image is rich enough.

Finally, the differential two-tone facial images used in these studies might explain the differential findings. McKone (2004) noted that the visibility of faces differ substantially even within the original Mooney faces (Mooney, 1957). Neither of previous developmental studies used the original Mooney face images (Mooney, 1957), but used two-tone images produced from a different facial image source. Thus, it could be the case that the Mooney face images used by Leo and Simion (2009) were simply more recognizable than those used by Doi et al. (2009).

In this paper we report experiments intended to establish under what conditions, if any, 3-and 4-month-olds can detect faces in two-tone images. This age group was chosen because previous studies indicate that several abilities relevant to the perception of two-tone Mooney face emerge at around this age. In particular, face detection in two-tone Monney images is dependent on: 1) the ability to integrate image fragments into global structure, 2) sensitivity to shading/shadow cues, and 3) knowledge about facial structure. Findings from several studies provide converging evidence suggesting that these abilities are already present at 3-and 4-months of age. Firstly, studies investigating illusory contour perception show that an ability to perceive coherent global structure from image fragments based on pictorial information alone, emerges at 3-to 4-months of age (Ghim, 1990; Kavsek, 2002; Otsuka et al., 2004; 2008). Secondly, some studies suggested that even 3-to 4-month-olds exhibit sensitivity to shading cues and are able to perceive the 3 dimensional structure conveyed by those cues (Bertin & Bhatt, 2006; Bhatt &Waters, 1998). Finally, face recognition studies suggest that infants become sensitive to the basic structure of faces at around this age. Also, and as already mentioned, three months discriminate and prefer normal face over top-heavy scrambled faces (Mucchi Cassia 2006; Turati et al., 2005). Furthermore, Bhatt et al (2005) found that 3-month olds detected positional change of facial feature when these changes violated the common structure of human faces, so called, first-order relational property (e.g., nose above mouth and two eyes and above nose). In contrast, they did not notice the positional change when first order relational properties were not violated (e.g., a change in the distance between features).

In a pilot study, we used three examples from the original set of Mooney faces (Mooney, 1957) which were judged as easily identifiable by adults. Consistent with recently published data by Doi et al. (2009), we found that infants aged between 3-and 4-months showed no upright preference. However, from this finding alone, it was difficult to determine whether the failure was due to a) the two-tone property of the images, b) the impoverished nature of the image, or c) the infants inability to integrate fragmented image features to form coherent representations of faces. In the present study, we used parametric variations in the spatial properties of two-tone facial images to differentiate between these alternatives, using the upright preference as an index for detection. In experiment 1a, we vary the luminance threshold and background color to determine the role of isolated features as well as the presence or absence of head outline in face detection in two-tone images. In experiment 1b we test for face-specificity of the observed effects by using contrast reversed two-tone facial images. Finally, in experiment 2 we investigated the effect of apparent motion on the detection of two tone face images without isolated facial features.

Experiment 1a (Local facial features and head contour)

For this experiment, we created two-tone facial images by thresholding photographs of three female faces, by setting all grey level values above the threshold to white and those below to black. We chose threshold levels so as to create face configurations that differed with respect to the presence of isolated local facial features (eyes, nose, mouth). We also manipulated background colour so that it either matched hair colour and there was no external head contour, or contrasted with hair colour and there was a clear contour. Both isolated features and external head contour may play important roles in infant face detection as both are normally present in the schematic faces used in previous studies while they are absent in the traditional Mooney faces. Examples of the experimental stimuli can be seen in Figure 1.

Given that Mooney configurations are normally defined as two-tone face images lacking local facial features, our images do not strictly fit this definition as they intentionally contain some isolated facial features. The aim was to create face images that were intermediate between Mooney and schematic faces in terms of feature visibility. This was achieved by varying the threshold used to create the two-tone images from the original grayscale photographs. If the failure to observe the preference for upright configurations with real Mooney faces found in our pilot study was due to the fact that they were too impoverished, the addition of some detailed local facial features may be sufficient to elicit upright face preference even for incomplete two-tone facial images. If, on the other hand, the failure was due to infants' inability to integrate image fragments, the presence of local facial feature will have no effect. Instead, the presence of the head contour could support the integration of fragments within the boundary and elicit an upright preference. As far as we know, there is only one previous study examining the effect of the enclosing contours (Simion et al. 1998). There it was reported that infants' preference for face like stimuli disappeared when enclosing external contours were removed and only internal features were shown. This finding by Simion et al. suggest that enclosing constituent elements helps infants to detect faces. Without head contours, the two-tone face images in the current experiment do not contain continuous contours that define facial area, and this could potentially make integration of information difficult. Therefore, we hypothesized that adding head contours to create a continuous facial outline would facilitate infants' detection of face-like structures in these images.

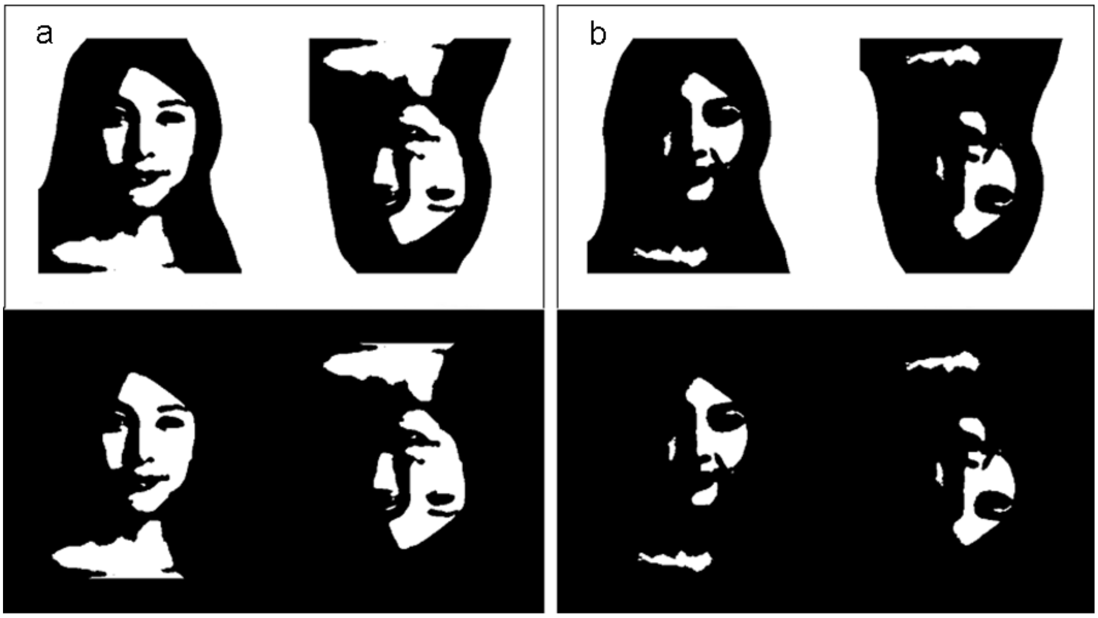

Figure 1. Examples of the upright and inverted Two-tone facial images used in Experiment 1a. Low threshold images (a) and high threshold images (b) in the Head Contours condition (top) and the Non-Head Contours condition (bottom).

Method

Participants.

The final sample consisted of 24 healthy Japanese infants aged 3-4-months (10 male, 14 female, mean age = 118 days, ranging from 94 to 134 days). An additional 12 infants were tested but were excluded from the analysis because, in one or other condition, they showed fussiness (5), they looked only at one side within a trial (4), their side bias was greater than 90 % (2), or their total looking time was less than 20 seconds (1).

Apparatus

All stimuli were displayed on a 21-inch CRT monitor controlled by a computer.

The infant and the CRT monitor were located inside an enclosure, which was made of iron poles and covered with cloth. Each infant sat on his/her parent's lap in front of the CRT monitor. The infant's viewing distance was approximately 40 cm. There were two loudspeakers, one on either side of the CRT monitor. A CCD camera positioned just below the monitor screen was used to videotape the infant's behavior throughout the experiment. The experimenter could also observe the infant behavior live via a TV monitor connected to the camera.

Stimuli.

Stimuli were produced from photographs of 3 Asian female faces pictured in a frontal view. Each facial image subtended about 17 deg × 19 deg of visual angle (VA), and the distance between the images was about 17.5 deg of VA for the infants who viewed stimuli from a distance of approximately 40cm. For low threshold images, the threshold for the two-tone transformation was adjusted so that some of facial features remain recognizable as individual features in the image (Figure 1a). For the high threshold image, the threshold for the transformation from the grayscale to the two-tone image was raised so that facial features (eyes, eyebrow, mouth, and nose) merged and no longer constituted isolated elements in the image (Figure 1b). Threshold values were chosen for each image individually as the value that results in isolated facial features depends on properties of the original photograph (e.g. luminance). For each threshold level, we created images with and without head contours. This was accomplished by using a white (different color from hair – head contours) or black (same color as hair – no head contour) background color.

Procedure.

Each infant participated in two 20-second trials for both the Head Contours condition and the Non-Head Contours conditions with either High or Low threshold images. Half of the infants were randomly assigned to view High threshold images, and half to Low threshold images. Prior to each trial, a cartoon accompanied by a short beeping sound was presented at the center of the monitor. The experimenter initiated each trial as soon as the infant paid attention to the cartoon.

On each trial, an upright and an inverted facial image appeared on either side of the CRT monitor. The two images were identical except for their orientation. Each of infants was assigned randomly to a test with one of the three faces used. The left/right position of the upright face for the first trial was counterbalanced across infants and reversed for the second trial. The order of the two experimental conditions was randomized between infants.

One observer, unaware of the stimulus identity, measured infants' looking time for each stimulus based on the video recordings showing only looking behavior of infants.

Results and Discussion

Table 1. The total looking times (seconds) in the Head Contours condition and the Non Head Contours condition in Experiment1a and 1b.

	Head Contours condition	Non Head Contours condition
Low threshold (Exp.1a)	34.14 (1.45)	34.90 (1.44)
High threshold (Exp.1a)	32.40 (2.15)	35.50 (1.49)
Contrast Negative (Exp.1b)	33.43 (1.10)	33.87 (2.03)

[a] Standard errors for looking times are in parentheses.

Total looking times in each condition are shown in Table 1. A two-way analysis of variance (ANOVA) with threshold level (low: local features present; high: local features absent) as a between-subject factor and head contour condition (present; absent) as a within subject factor revealed no significant differences in total looking times (threshold level: p = .719, condition: p = .258; interaction: p = .491).

A preference score was also calculated individually for each condition. This was done by dividing each infant's looking time at the upright face during two test trials by the total looking time over the two test trials, and then multiplying this ratio by 100. Table 2 shows the mean preference score in each image condition.

Table 2. The percentage of looking times for upright face in the Head Contours condition and the Non Head Contours condition in Experiment1a and 1b.

	Head Contours condition	Non Head Contours condition
Low threshold (Exp.1a)	58.76 (3.16)*	61.05 (3.90)*
High threshold (Exp.1a)	46.50 (4.04)	48.70 (3.10)
Contrast Negative (Exp.1b)	49.61 (3.46)	53.20 (2.98)

[a] Standard errors for looking times are in parentheses.

[b] Asterisks highlight conditions in which the infants viewed upright faces significantly longer than chance (p < .05).

To examine the effect of local features and head contours, we conducted a two-way analysis of variance (ANOVA) with threshold level (low: local features present, high: local features absent) as a between-subject factor and Head contours (present;

absent) as a within subject factor on the individual preference scores. This analysis revealed a significant effect of threshold level, F (1, 22) = 14.33, p = .001, suggesting that the presence of local features played an important role in inducing an upright face preference in 3-and 4-month-old infants. There was no main effect of head contour (p=.569) or any interaction (p=.990).

As our main interest was to see whether infants looked longer at upright or inverted stimuli in each condition, we performed a two-tailed, one-sample t test vs. chance (50% for equal preference) on the mean preference scores. Given that the effect of Head Contour was non significant, data were first collapsed across this factor. There was a significant difference for low threshold images, t (11) = 4.28, p = 0.002 (Bonferroni adjusted), corresponding to a preference for upright over inverted faces (see means in Table 2). There was no significant difference for high threshold test images t (11) = 1.05, p =.632 (Bonferroni adjusted).

The absence of a preference for upright faces in the high threshold image is consistent with our pilot study using original Moony face images, and suggest that 3-and 4-month-olds do not perceive a face in two-tone images with poorly defined local features. In contrast, infants did show an upright preference with the low threshold images. The results from low-threshold condition exclude the possibility that the failure of the infants to perceive Mooney face was simply a result of their being two-tone. In addition, the upright preference in the low-threshold image was observed even in the absence of any head contour defining the facial area. The lack of the effect of Head contours suggests that infants had no difficulty in integrating a fragmented facial image so long as there are some isolated local facial features in the image. That the presence a few identifiable local facial features induces an upright preference even in an incomplete two-tone facial image suggests that this is what the original Mooney face images used in the pilot lacked. One possible explanation of the failure of 3-and 4-month-olds to perceive Mooney face as shown in the high threshold image condition would be that image without isolated feature does not match their internal representation of face. The other possibility would be that the immaturity of configural processing of faces prevented them seeing the face in the Mooney images. As Mooney face image do not contain isolated facial features, perception of the face in such images depends almost entirely on the analysis of configural properties. Previous studies suggested that configural processing of face is functionally immature at around this age and only becomes apparent at around 8-months of age (Bhatt et al. 2005; Schwarzer & Zauner, 2003; Schwarzer et al., 2007, but Quinn & Tanaka, 2009).

While the results of our experiment suggest that local features may be essential for the detection of faces in impoverished two-tone facial configurations, it is still possible that infants' preference for upright faces does not reflect face detection, but is due to some unspecified low-level characteristics of these images. In order to test this, we ran an additional experiment with contrast-revered versions of these images (figure 2). Although contrast polarity reversal preserves many image properties including geometry and edges, this simple manipulation dramatically affects many aspects of face perception (e.g. Anstis, 2005).

Experiment 1b (Reversed contrast polarity)

The aim of Experiment 1b was to establish that the preference for upright two-tone faces shown in Experiment 1a reflects the infants' face detection. For this purpose, we created contrast-reversed version of the low threshold two-tone face images used in Experiment 1a (figure 2).

Previous studies have shown that contrast polarity reversal affects face detection both in adults (Torralba & Sinha, 2001; Tomalski, Csibra & Johnson, 2009) and infants (Dannemiller & Stephen, 1998; Mondloch et al., 1999). Dannemiller and Stephen (1998) and Mondloch et al (1999) reported that 12-week-old infants showed a preference for positive schematic faces over contrast reversed versions of the same stimuli. More recently, Farroni et al. (2005) reported that newborns' preference for upright schematic faces and facial photographs over their inverted counterparts also disappeared when image contrast polarity was reversed. These results suggest that infants detect faces more easily in positive images than in contrast reversed images even though these images share many properties. Adult face detection has also been found to be impaired by contrast reversal (Torralba & Sinha, 2001; Tomalski et al, 2009).

Crucial to the perception of the face images used here, Cavanagh and Leclerc (1989) reported that perception of 3D structure from two-tone image depends critically on the contrast polarity of the image. In particular, shadow regions have to be darker than the nonshadow regions to be perceived as shadow. By disrupting light dark relations between shadow and unshadowed region, contrast reversal makes the perception of two-tone faces considerably more difficult. Therefore, we reasoned that if the observed preference for upright face with natural contrast reflects infants' detection of faces, then the preference would be reduced with contrast reversed version of these images.

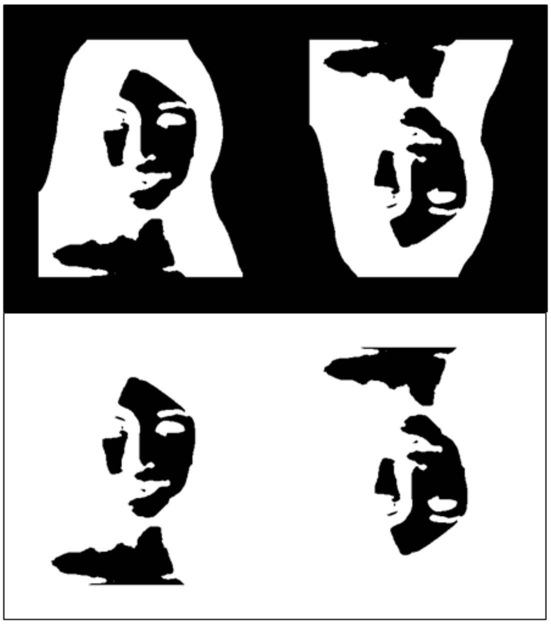

Figure 2. Examples of upright and inverted images used in Experiment 1b. Contrast reversed version of low threshold images in a) the Head Contours condition and in b) the Non-Head Contours condition.

Method

Participants.

The final sample consisted of 12 healthy Japanese infant ages 3-4-months (6 male, 6 female, mean age = 111 days, ranging from 82 to 133 days). An additional 7 infants were tested but were excluded from the analysis because, in one or other condition, they showed fussiness (2), they looked only at one side within a trial (2), their total looking time was less than 20 seconds (1), or their side bias was greater than 90 % (2).

Procedure and Stimuli

Procedure and Stimuli was the same as those in Experiment 1, except that the contrast polarity of the stimulus images was reversed as shown in Figure 2.

Results and Discussion

Total looking time in each condition is shown in Table 1. A paired t-test revealed no significant difference between the total looking times in the Head Contours and in the Non-Head Contours condition, *t* (11) = -0.226, *p* = .826.

The preference score was calculated in the same way as in Experiment 1a. Table 2 shows the mean preference score in each image condition. A two-tailed *t*-test revealed no significant difference between the preference scores in the Head Contours and in the Non-Head Contours condition, *t* (11) = 0.96, *p* = .36, and data was again collapsed across this condition for a one-sample, two-tailed t test (vs. chance, 50%) on preference scores. This showed no significant preference, *t* (11) = 0.53, *p* =.61. A two-way ANOVA with contrast polarity (Experiment 1a (low threshold images): positive, Experiment 1b: negative) as a between subject factor and Condition (Head Contours condition, Non-Head Contours condition) as a within subject factor on the preference score showed a significant main effect of Experiment, F (1, 22)=5.86, *p* = .024, showing that the preference for upright face was significantly lower for the equivalent images in Experiment 1b (negative contrast) than in Experiment 1a (positive contrast). Combined together and in the light of previous work (Cavanagh and Leclerc, 1989; Dannemiller & Stephen, 1998; Farroni et al. 2005; Mondloch et al., 1999; Torralba & Sinha, 2001), the effect of polarity support our assertion that the preference for upright stimuli found in Experiment 1a reflects perception and detection of *faces* in two-tone facial configurations.

It is also possible that providing other information comprised in the infants' daily experience with faces such as motion might help infants to detect faces from two-tone images. In Experiment 2, we test whether adding motion, which is also known to facilitate many aspects of perception in infants, can make even impoverished two-tone faces without local features detectable.

Experiment 2 (Motion vs. static)

The aim of Experiment 2 was to test whether motion affects infants' perception of faces in two-tone Mooney face image that do not contain isolated facial features in the image. Apparent motion displays – displays where two or more static images presented in rapid succession give the impression of movement - have been used in previous newborn and infant studies investigating the contribution of motion processing to the perception of illusory contours (Kavšek & Yonas, 2006; Valenza & Bulf, 2007), perception of partly occluded object (Valenza, et al. 2006), and face recognition (Bulf & Turati, 2010). All of these studies indicate that stimulus motion facilitates infants' perception and recognition of faces and objects (For a review, see Otsuka, Konishi, Kanazawa, Yamaguchi, Abdi, & O'Toole, 2009).

We created apparent motion Mooney face displays that induce the perception of a face undergoing a rigid three dimensional rotation (Ramachandran, Armel, Foster, Stoddard, 1998). In classic demonstrations of apparent motion, two spatially separated objects are presented in rapid sequence. When such images are shown, observers typically report a single object rather than two objects moving smoothly between the two locations. Ramachandran et al. (1998) extended this effect to Mooney face images, and a created an apparent motion display from two face images alternating between two different views.

Based on Ramachandran et al. (1998), we created two-frame apparent motion displays that consist of two Mooney face images of a face seen in slightly different views (Figure 3 top and bottom). The images were presented in two conditions: Moving or Static. In the Moving condition, the two images were shown in alternation within a trial so as to induce the perception of apparent rotation of the face. In the Static condition, the two images were altered between rather than within trials, and thus appeared static. As we found no difference between the head contours condition and Non-head contours condition in Experiment 1, we used only non-head contour condition images in this experiment.

Considering that the two two-tone images depicted the same individual from different views, presenting these two images could potentially support and facilitate the interpretation of 3D facial structure from the image. However, Ramachandran et al. (1998) did not find facilitation of facial interpretation by showing apparent motion display compared to static display. Rather, subjects who did not see face in the static image first perceived only random motion random chaotic motion in the dynamic version of display. Only after the subjects were prompted with a 3D or facial interpretation and the face was perceived, did they consistently report seeing three-dimensional rotation of a face in the display. This suggests that there are strong perceptual interactions occur between motion and form processing. Considering the finding by Ramachandran et al, introducing apparent motion display may not have a facilitative effect if infants have no potential face interpretation. However, we hypothesized that the dynamic property of the stimuli would enrich the impoverished image and might facilitate infants' response.

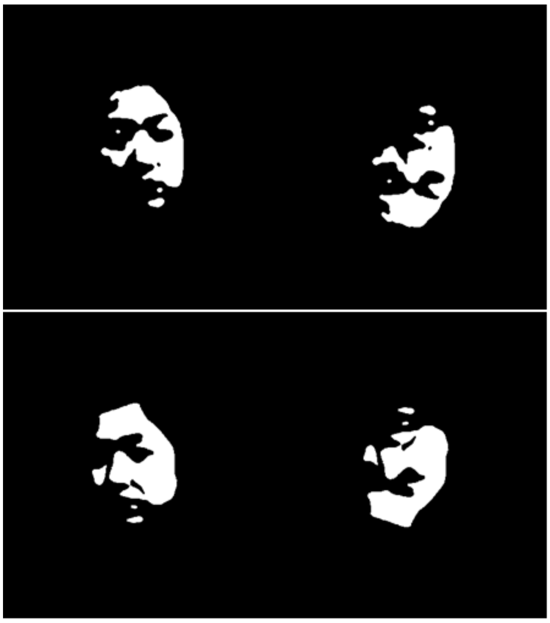

Figure 3. Examples of upright and inverted stimuli used in Experiment 2a. Two-tone Mooney face images depicting identical face from different viewpoint: frontal view (a) and an angled view (b). In the motion condition, these two images alternated repeatedly, which induced perception of rigidly rotating face for adult observer. In the static condition, each image was shown in alternate trials.

Methods

Participants.

The final sample consisted of 12 healthy Japanese infant aged 3-4-months (7 male, 5 female, mean age = 117 days, ranging from 88 to 133 days). An additional 8 infants were tested but were excluded from the analysis because, in one or other condition, they showed fussiness (7), or a side bias was greater than 90% (1).

Procedure and Stimuli.

Procedure and Stimuli was the same as those in Experiment 1, except for the following. Each original face was photographed from two different viewpoints: the frontal view and an angled view (approximately 30 degree of rotation). The images were then transformed into two-tone images (Figure 3 top and bottom). As the high threshold image in Experiment 1, the black/white threshold for the transformation was set so that facial features were not defined by isolated contours. In the moving condition, two two-tone images depicting the same face from different viewpoints were shown alternately within a trial at 1.25 frames per second. For the static condition, one of the two images was shown in the first trial and the other in the second trial. Each infant participated in both the Static condition and the Moving condition. The order of the conditions was randomized across infants.

Results and Discussion

Table 3. The percentage of looking time for upright face in the Moving condition and the Static condition in Experiment 2a and 2b.

	Moving condition	Static condition
Positive (Exp. 2a)	60.99 (3.24)*	45.52 (4.05)
Negative (Exp 2b)	43.99 (4.32)	

[a] Standard errors for looking times are in parentheses.

[b] Asterisks highlight conditions in which the infants viewed upright faces significantly longer than chance ($p < .05$).

A preference score was calculated in the same way as for Experiment 1. Table 3 shows the mean preference score in each condition. A two-tailed, two-sample t-test comparing the Static and Moving condition showed a significant difference between the two conditions, t (11) = 3.39, p = .006. Therefore, a two-tailed one-sample *t*-test (vs. chance) on the preference was performed separately for each condition. The analysis revealed a significant preference only in the Moving condition, t (11) = 3.39, p = .012 (Bonferroni adjusted), but not Static condition, t (11) = 1.10, p = .584 (Bonferroni adjusted).

Total looking times in each condition are shown in Table 4. A paired t-test revealed no significant difference between the total looking times in the Static and Moving conditions, t (11) = 0.417, p = .684, excluding the possibility that infants simply paid more attention to moving stimuli, and hence resulted in a better performance in the moving condition.

Table 4. The total looking time (seconds) in the Moving condition and the Static condition in Experiment 2a and 2b.

	Moving condition	Static condition
Positive (Exp. 2a)	36.28 (1.55)	35.33 (1.46)
Negative (Exp 2b)	36.44 (1.49)	

[a] Standard errors for looking times are in parentheses.

The result from the static condition is consistent with Experiment 1a, and suggests that infants do not detect static faces when isolated facial features are not present in the image. While previous work has shown that infants are able to perform tasks like matching identity between different static views by 3-4 months, at least for grayscale or full colour images (Pascalis, et al., 1998; Turati, et al., 2004), the additional static views in this experiment were not found to improve face detection.

In contrast, results from the moving condition suggest that infants can detect faces even in the absence of easily identifiable local facial features *when the faces* *appear to be rotating*. Interpretation of motion is far from straight forward with these stimuli. For example, the shapes of image features differ between the two frames making correspondences between feature – what goes with what - highly ambiguous. Indeed Ramachandran et al (1998) suggested that, at least in adults, it is not a pure motion process that induces the perception of a three-dimensionally rotating face in the Mooney images, but an interaction between the perception of static form and motion processing. The ambiguity of the image feature correspondences applies equally to our stimuli, making it unclear what source of information is responsible for the upright preference with moving stimuli. In order to test whether pure motion processing can account the preference for alternating upright Mooney faces images, we conducted a control experiment using contrast reversed versions of the moving display.

Experiment 2b (Moving contrast reversed images)

In Experiment 2a, we found that infants prefer upright Mooney faces only in the moving condition. One possible reason for the better performance in the moving condition is that the perception of 3D structure of face is facilitated by motion information (i.e. structure from motion). In fact, previous study has shown that infants as young as 8-weeks-olds could perceive three-dimensional objects shape based solely on motion information (Arterberry & Yonas, 2000). However, in order to test if this was critical here, we conducted a control experiment with contrast reversed versions of the moving display (Figure 4). On the basis that contrast negation disrupts facial form but not motion processing, a pure motion processing based account would predict the upright preference for moving stimuli remain for contrast reversed versions of stimuli.

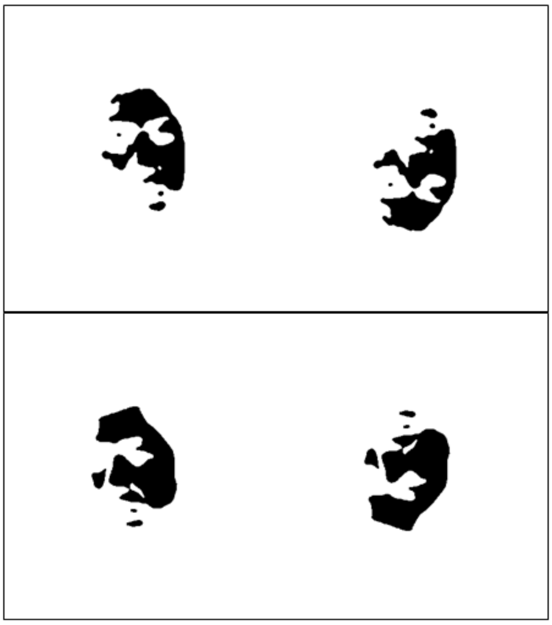

Figure 4. Examples of upright and inverted stimuli used in Experiment 2b. Contrast reversed version of the moving images in Experiment. The top low images and the bottom low images alternated repeatedly during experiment.

Methods

Participants.

The final sample consisted of 12 healthy Japanese infant aged 3-4-months (6 male, 6 female, mean age = 117 days, ranging from 98 to 131 days). An additional 5 infants were tested but were excluded from the analysis because, in one or other condition, they showed fussiness (1), they looked only at one side within a trial (2), or a side bias was greater than 90% (2).

Procedure and Stimuli.

Procedure and Stimuli was the same as those for the moving condition in

Experiment 2a, except for that the contrast polarity of the stimulus images was reversed as shown in Figure 4.

Results and Discussion

Total looking times for each condition are shown in Table 4. Individual preference scores were calculated as for preceding experiments and scores for this experiment shown in Table 3. A two-tailed one-sample *t*-test (vs. chance, 50%) revealed no significant difference, t (11) = 1.39, p = .192. Further, an unpaired two-tailed *t*-test revealed that the preference score for contrast reversed stimuli was significantly lower than for positive stimuli in the moving condition in Experiment 2a, t (22) = 3.15, p = .005. This suggests contrast polarity is critical to infants' preferences, and that a pure motion interpretation cannot explain the upright preference found in the moving condition with positive images.

General Discussion

The present study examined the ability of 3- to 4-month-old infants to perceive faces in two-tone Money facial images. While neither our pilot study using original Mooney faces, or similar face images in Experiment 1a led to an upright face preference, we did find an upright face preference when some isolated features were visible in the image. This indicates somewhat limited face detection from two-tone images in this age group. Any upright preference disappeared when images were contrast reversed, consistent with the involvement of face-specific mechanisms. Experiment 2 showed an upright face preference for two-tone images even without isolated face features when the face appeared to be rigidly rotating. Again this preference disappeared when contrast was reversed, again consistent with the involvement of face detection and ruling out any explanation in terms of motion cues alone. The results, discussed in more detail below, are interpreted as evidence for the importance of isolated facial features in two-tone faces detection and the ability of 3-4 month old infants to integrate form and motion cues for face detection even in impoverished images.

In Experiment 1a, we used two-tone faces differing with respect to whether they portrayed isolated local features and/or an external head contour. When some local features were left visible in the image (Experiment 1 a, low threshold images), infants showed upright face preference irrespective to the presence or absence of head contours. The results of Experiment 1a demonstrate an upright face preference with two-tone facial images which contain some isolated features but which, unlike the schematic or real faces used in other work, are asymmetrical and have incomplete external contours defining the facial area (see Figure 1). When no isolated local facial features were visible in the image (Experiment 1a, high threshold images), infants did not show the upright face preference. The upright face preference for low threshold two tone faces with isolated features disappeared in Experiment 1b when image contrast polarity was reversed, consistent with the original preference indicating face detection.

The results of Experiment 1 suggest that the presence of some isolated high contrast facial features in the image plays an important role in face detection at 3-4months of age. That 3-and 4-month-olds do not show preference for Mooney faces without isolated facial features (Experiment 1 and 2 static condition) is consistent with Doi et al. (2009) who found that 6- and 12-month-olds do not show a preference for upright Mooney. Both sets of results contrast with Leo and Simion's (2009) finding that even newborn infants show a preference for upright Mooney faces.

As outlined in the Introduction, one possible interpretation of these apparently contradictory findings is that initial upright preference for Mooney faces apparent at birth disappears by 3-and 4-months of age because of a combination of improving acuity and a more developed facial representation. For newborns with their poor acuity, the low spatial frequency information in two tone images may indeed be equivalent to that in a full grayscale image and sufficient for face detection. This is no longer true for infants viewing Mooney faces without isolated features at 3-4 months (Experiment 1) or at 6 months (Doi et al, 2009). For 3-4 month olds, our results show that threshold level is critical, and that two tone faces are detectable only if they contain isolated features. The results also show that the failure to detect Mooney faces in older infants is not simply a function of the binary quantization of luminance. Instead it must reflect a more subtle spatial difference between the images that elicit face detection and those that do not. A similar pattern of a face preference in younger but not in older infants has been reported for schematic faces, where more naturalistic or realistic facial stimuli were required to elicit a preference in older infants (e.g., Johnson et al., 1992; Mondloch et al., 1999). In general, as visual acuity develops, infants' representation of local facial features will become more refined. Our results suggest that such refinement occurs by 3-months of age.

In Experiment 2a, 3-and 4-month-old infants showed the upright face preference even in the Mooney face image without isolated facial features when the face appeared to be rigidly rotating but not when it was static. This upright face preference disappeared when images were contrast reversed (Experiment 2b). By introducing dynamic information, we found that even 3-4-months prefer upright over inverted Mooney face even when no isolated facial features are visible. The finding is consistent with previous studies showing that motion information facilitates infants' perception of both objects and faces (Kellman, 1984; Kellman & Spelke, 1983; Otsuka & Yamaguchi, 2003; Otsuka et al., 2009; Owsley, 1983; Valenza & Bulf, 2007). The lack of the upright face preference in the static condition rules out the possibility that the preference was based on structural properties of the image such as top heaviness, or that the Mooney images used in Experiment 2 were simply more recognizable as faces than those used in Experiment 1. Instead, the results suggest that the ability of 3-4month-olds to detect faces in the alternating images reflects an interaction between face related form and motion information.

It is important to note that pure motion processing (i.e. structure from motion) does not account the upright preference for Mooney faces in the moving condition as this was limited to positive contrast polarity (Experiment 2a), and disappeared when contrast polarity was reversed (Experiment 2b). Changing contrast polarity disrupts form but not motion processing. Ramachandran et al (1998), who first developed the apparently moving two frame Mooney face display, argued that it is the recognition of object that induces the perception of 3 dimensional motion in Mooney face displays – motion-from-form rather that the opposite, form-from-motion. Consistent with this, our results suggest an interaction between form and motion processing, where motion supports the processing of form, facilitated infants detection of faces from two-tone Mooney images.

In summary, our results show that the presence of some isolated facial features can result in an upright face preference for 3-4 month olds even in incomplete, static, two-tone images. This extends Doi et al's result by showing detection of face from two-tone image at an earlier age, although here as there, the upright preference was absent for Mooney face images where no isolated features were visible. Both results contrast with Leo and Simion's (2009) finding that newborns do show an upright face preference for Mooney faces without isolated features. We argue this may be due to a combination of improving acuity and the refinement of the face representations involved in detection. Further studies examining infants in a wider age range is required to understand the precise nature of the developmental course of face perception in impoverished two-tone images. The finding that Mooney faces without isolated feature can be detected if they appear to be moving rules out the possibility that our 3-and 4-month-olds were simply unable to process two-tone images in a holistic manner. Instead, the result suggests that at 3-and 4-months of age face detection can benefit from an interaction between form and motion.

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