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Eye contrast polarity is critical for face recognition by infants

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Abstract
Just as faces share the same basic arrangement of features, with two eyes above a nose above a mouth, human eyes all share the same basic contrast polarity relations, with a sclera lighter than an iris and a pupil, and this is unique among primates. The current study examined whether this bright-dark relationship of sclera to iris plays a critical role in face recognition from early in development. Specifically, we tested face discrimination in 7- and 8-month-old infants while independently manipulating the contrast polarity of the eye region and of the rest of the face. This gave four face contrast polarity conditions: fully positive condition, fully negative condition, positive face with negated eyes (" negative eyes") condition, and negated face with positive eyes (" positive eyes") condition. In a familiarization and novelty preference procedure, we found that 7- and 8-month-olds could discriminate between faces only when the contrast polarity of the eyes was preserved (positive) and that this did not depend on the contrast polarity of the rest of the face. This demonstrates the critical role of eye contrast polarity for face recognition in 7- and 8-month-olds and is consistent with previous findings for adults.

Keywords
polarity, critical, eye, face, contrast, recognition, infants

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Abstract

Just as faces share the same basic arrangement of features, eyes above nose above mouth; human eyes all share the same basic contrast polarity relations, with sclera lighter than iris and pupil, and this is unique among primates (Kobayashi & Kohshima, 1997; 2001). The present study examines if this bright-dark relationship of sclera to iris plays a critical role in face recognition from early in development. Specifically, we tested face discrimination in 7- to 8-month old infants while independently manipulating the contrast polarity of the eye region and of the rest of the face. This gave four face contrast polarity conditions: fully positive condition, fully negative condition, positive face with negated eyes ("negative eyes") condition, and negated face with positive eyes ("positive eyes") condition. We found that, within a familiarization and novelty preference procedure, 7- to 8-months-olds could only discriminate between faces when the contrast polarity of the eyes was preserved (positive), and that this did not depend on the contrast polarity of the rest of the face. This demonstrates the critical role of eye contrast polarity for face recognition in 7-to 8-month-old infants, and is consistent with previous findings for adults.

Key words: perception, face recognition, infants, contrast polarity, contrast negative, eyes

Eye Contrast Polarity is Critical for Face Recognition by Infants

Introduction

Humans are the only primates that have a white sclera that contrasts with a darker colored iris and pupil (Kobayashi & Kohshima, 1997; 2001). While color and darkness of skin, hair, and iris vary widely among humans, the color of sclera is near white and universally lighter than the iris and pupil. In this sense contrast polarity relationship between sclera and iris is potentially as fundamental in human faces as the first order spatial relationships between features: two eyes above a nose above a mouth (Diamond & Carey 1986). Here we explicitly test whether the contrast polarity relationship between the sclera and iris is critical for face discrimination by infants.

Previous studies have shown that reversing the contrast polarity of an image severely impairs face perception in adults (e.g. Anstis, 2005; Bruce & Langton, 1994; Johnston, Hill, Carman, 1992; Kemp, McManus, & Pigott, 1990; Lewis & Johnston, 1997). This effect has been attributed to the unusual pigmentation (Bruce & Langton, 1994; Russel, Sinha, Biederman, & Nederhouser, 2006) and/or the unnatural pattern of shading interfering with three-dimensional face perception (Johnston, Hill, Carman 1992; Liu, Collin, Burton, & Chaudhuri, 1999).

Using "contrast chimera" images incorporating both positive and negative contrast within a face, Gilad, Meng, and Sinha (2009) reported that the contrast polarity around eyes is particularly important for face recognition in adults. While familiar faces were poorly recognized in fully negated images (54.35%), performance dramatically improved when the contrast polarity around eyes (eye to eyebrow region inclusive) was made positive (contrast chimeras, 92.32%). In addition, although activation of the right fusiform facial area (FFA) was considerably reduced for fully negative faces, it was as high for the contrast chimeras (negative face with positive eye region) as for fully positive faces. The results of Gilad et al.

demonstrate the critical role of the eye region in the effect of contrast polarity on adult face recognition.

The importance of contrast polarity around the eyes has also been previously reported in a developmental study investigating face preference in infants. Farroni et al. (2005) examined preference for upright over inverted schematic faces (consisting of three dark blobs on a white surface) and for facial photographs in newborn infants. They found that newborns' preference for upright images disappeared when the contrast polarity was reversed. Adding a small dark blob to each of the white blobs, consistent with a dark iris contrasting with a lighter sclera, reinstated the upright face preference for negative schematic faces.

The development of face perception and recognition during infancy has been studied extensively including both the role of experience (Kelly et al., 2007; Kelly et al., 2009; Pascalis, de Haan, & Nelson, 2002) and the aspects of visual information that infants use (Bhatt, Bertin, Hayden, & Reed, 2005; Cohen & Cashone, 2001; Hyden, Bhatt, Reed, Corbly, & Joseph, 2007; Quinn & Tanaka, 2009). However, there are relatively few studies testing the effect of contrast polarity of faces in infants.

Other studies examining preferential looking behavior are consistent in showing that infants perceive positive and negative contrast polarity faces differently, even though this manipulation preserves the geometrical structure and spatial frequency content of the image. Dannemiller and Stephens (1988) and Mondloch et al. (1999) consistently reported that 12 week olds, but not 6 weeks olds or newborns, preferred schematic faces with positive contrast polarity over contrast reversed versions of the same stimuli. In addition, and again consistent with Farroni et al. (2005), Otsuka, Hill, Kanazawa, Yamaguchi, and Spehar (2012) reported that a preference for upright over upside-down two-tone facial images disappeared when the contrast polarity of the stimuli was reversed. The disappearance of an upright face preference for contrast reversed stimuli suggests that the "faceness" of the facial images may be lost when contrast polarity is reversed.

As far as we are aware, there is only one published paper on the effect of the contrast polarity on face discrimination in infants. Using the habituation method, Layton and Rochatt (2007) examined 4- and 8-month-olds's ability to discriminate between unfamiliar faces, and between unfamiliar faces and their mother's face, under positive and negative image conditions with either static or dynamic presentation. In the positive contrast image condition, both age groups discriminated between faces in all of the conditions examined. With negative contrast images however, only the 8-month-olds discriminated between faces, and this was limited to the discrimination of the maternal face from unfamiliar faces under dynamic presentation. This finding of the poorer face recognition performance for negatives is consistent with findings for adult participants (e.g. Bruce & Langton, 1994; Johnston, et al, 1992).

In the present study, we further examined the effect of image contrast polarity on face recognition in infants by testing discrimination with a particular focus on the contrast polarity of the eye regions. While the shadowing of the concavities around the eyes varies considerably between individuals (e.g. some Asian faces have a shallow eye socket and much less prominent orbital rim and so may be hardly shadowed), the contrast polarity within the eyes themselves is universal and not dependent on lighting. Thus we hypothesized that manipulation of the contrast polarity of the eyes alone would be sufficient to adversely impact infant face processing.

We examined infants' face discrimination under four image conditions using a familiarization and novelty preference procedure. The image conditions were created by independently manipulating contrast polarity of the eyes (iris and sclera) and other facial regions. As shown in Figure 1, this gave a total of four conditions: *positive* condition (original grayscale image), *negative* condition (fully negated image), *negative eyes* condition (positive facial image with negated eyes), and *positive eyes* condition (negative facial image with positive eyes). Infants were first familiarized with a face through repeated exposure and then their looking preference between that face and a novel face was tested. After repeated exposure to one face, infants typically prefer to look at a novel face rather than the repeatedly exposed familiar face (novelty preference).

We tested 7- to 8-month old infants as, by this age infants have developed an advantage associated with recognition of human faces (Pascalis et al., 2002), and for own ethnic group faces (Own-race advantage: Kelly et al., 2007; Kelly et al., 2009). At a similar age, sensitivity to the normal range of human facial feature sizes also develops (Lewkowicz & Ghazanfar, 2012). We hypothesized that if common morphological or color properties of own race and species faces are critical for face recognition, then manipulating the contrast polarity of the eyes shared by all human faces would affect face recognition in 7-to 8-month old infants.

Figure 1. Examples of one of the stimulus pairs shown in positive condition (top row), negative condition (second row), negative eyes condition (third row), and positive eyes condition (bottom row).

Method

Participants

The final sample consisted of 48 healthy Japanese 7- to 8-month-old infants (22 male, 26 female, mean age = 227 days, ranging from195 to 253 days). An additional 30 infants were tested but were excluded from the analysis due to fussiness (11), side bias greater than 90 % (6), longer looking times in the last three trials than in the first three trials in the familiarization stage (6), or looking times over the two test trials that were less than the half of total exposure time of test stimuli (Otsuka, Kanazawa, & Yamaguchi, 2006; Otsuka, Konishi, Kanazawa,& Yamaguchi, 2009), or looking times over the two test trials that were less than the half of total exposure time of test stimuli, 10 s (7).

Apparatus

All stimuli were displayed on a 22-inch CRT monitor controlled by a computer (Dospara Prime Galleria). 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. 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 looking 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 grayscale photographs of six Asian female faces pictured in a frontal view and with neutral expression. All faces had dark color iris, eyebrow, and eye lashes, like the two examples shown in Figure 1. In addition, the skin tone of all the faces used was similar, and in all cases lighter than the 50% gray background.

In addition, all facial images shared the same outer elliptical contour which made only the internal features visible. Each facial image subtended about 17 deg × 19 deg of visual angle (VA) when viewed by the infants from a distance of approximately 40cm. The VA between pairs of images was approximately 17.5 deg.

By independently manipulating contrast polarity of the eyes (including sclera, iris and pupil) and other facial regions, we produced the four different contrast polarity variants for each of the six original facial images (see Figure 1). The eye region covered an average of 2.6% of the total area of the face. The six faces used were divided into three pairs, and these pairings were kept constant across all four image conditions.

Procedure

The experiment consisted of two phases, a familiarization phase and a test phase. Infants first participated in six 15-second familiarization trials, followed immediately by two 10-second test trials. 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 this attracted the infant's attention.

The experiment was a between subjects design with twelve infants in each of the four image conditions. Equal numbers of infants (four) were tested with each of the three face parings. Both image condition and face paring were randomly assigned for each infant. Within each face pairing and each image condition, which face was familiarized was fully counter balanced.

During the familiarization trials, identical facial images appeared on both sides of the CRT monitor. In the test trials, the familiar and a novel female face were shown side by side, in the same positions as for the familiarized face. The left/right position of novel and familiar faces were reversed across the two test trials for each infant, with the position of the familiar face in the first trial counterbalanced across infants. Image condition was constant across familiarization and test phases.

Data analysis

One observer, unaware of the stimulus identity, measured infants' looking time for each stimulus based on the video recordings showing only the looking behavior of the infants. To compute the inter-observer agreement, a second observer's measurement of infant's looking time was obtained from 25% of the total data. Inter-observer agreement was high, $r = .98$.

We calculated a novelty preference scores for each condition. This was done by dividing each infant's looking time at the novel face by the total looking time over the two test trials, and then multiplying this ratio by 100.

Results

Table 1.

Mean total looking times in seconds per trial during the familiarization trials and mean total looking time during the two test trials. Standard deviations are given in parentheses.

	Familiarization trials		**Test trials**
	Mean total looking time per trial (s)		Mean total looking time during the two test trials(s)
Condition	Trial 1-3 (max 15s)	Trial 4-6 (max 15s)	(max 20s)
Positive (N =12)	13.09 (1.39)	11.03 (2.40)	15.28 (2.98)
Negative (N =12)	13.64 (1.45)	12.13 (2.45)	15.81 (2.91)
Negative eyes (N =12)	12.76 (1.62)	11.74 (2.74)	15.93 (2.57)
Positive eyes (N =12)	13.35 (1.74)	11.51 (3.28)	14.73 (2.99)

Familiarization trials

Individual looking times per trial were summed over the two identical faces, and then averaged for the first three and last three trials separately (Table 1). A three-way analysis of variance (*ANOVA*) with face contrast polarity (positive, negative) and eye contrast polarity (positive, negative) as between-subject factors and trial (Trial 1-3 or trial 4-6) as a within-subject factor was performed on individual fixation times. This analysis revealed a significant effect of trial F (1, 44) = 33.93, $p < .01$, η^2=.12 (trial 1-3:*M*=13.2, *SD*=1.54; trial 4-5: M=11.60, *SD*=2.68), but no other effects F (1, 44) = 0.75, $p = .39$, η^2=0.012 (face contrast polarity), F (1, 44)= 0.3, $p = .59$, η^2=0.004 (eye contrast polarity), or interactions (all *p*'s >.1). The results suggest that the degree of familiarization and looking time was similar across the four image conditions.

Test trials

A two-way *ANOVA* with face contrast polarity (positive, negative) and eye contrast polarity (positive, negative) as between-subject factors on the total looking time during the two test trials (Table 1) showed no significant main effect for either face contrast polarity, F(1, 44) = 1.07, $p = .31$, η^2=.024, or eye contrast polarity F(1, 44) = 0.16, $p = .69$, η^2=.004 or any interaction between the two, F(1, 44) = 0.06, $p = .80$, η^2=.001. Figure 2 shows average novelty preference scores for each condition (Figure 2).

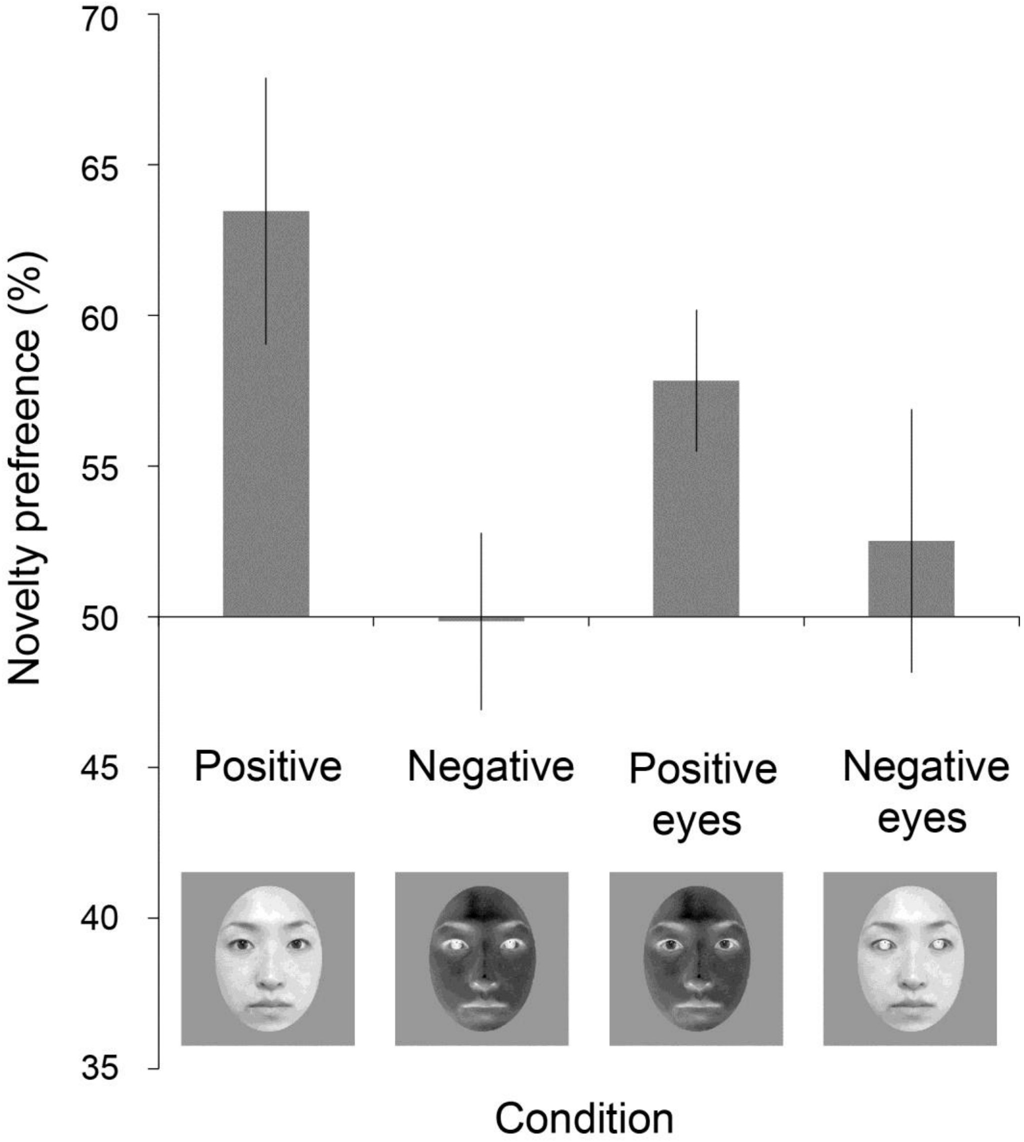

Figure 2. Novelty preference scores obtained from each contrast polarity condition. Error bars represent one *SE*.

We performed a two-way *ANOVA* with face contrast polarity (positive, negative) and eye contrast polarity (positive, negative) as between-subject factors on the individual novelty preference scores. The *ANOVA* revealed a significant main effect of eye contrast $F(1, 44) = 6.88$, $p = 0.012$, $\eta^2=.13$ (positive: M=60.64, SD=2.51; negative: M=51.12, SD=2.59), but neither the main effect of face contrast polarity, $F(1, 44) = 1.26$, $p = 0.27$, $\eta^2=.028$ nor the interaction, $F(1, 44) = 0.18$, $p = 0.67$, $\eta^2=.004$, approached significance. The pattern of results clearly shows that the contrast polarity of the eyes as the major determinant of infant performance.

Two-tailed one-sample t-tests against chance level (50% for equal preference) on the mean novelty preference scores revealed a significant novelty preference in both conditions with positive eyes (positive: $t(11) = 3.04$, $p < 0.01$, d=.88; positive eyes: $t(11) = 3.33$, $p < 0.01$, d=.96), but not in either of the conditions with negative eyes (negative: $t(11) = -.05$, $p = 0.96$, d=.015; negative eyes: $t(11) = .58$, $p = 0.57$, d=.17). These results show that 7-and 8-month-old infants can discriminate faces when the contrast polarity of the eyes is preserved, regardless of the contrast polarity of the rest of the face.

Discussion

The present study examined the role of contrast polarity between the sclera and iris in facial discrimination by 7- to 8-month old infants. Using a familiarization paradigm, the contrast polarity of the eyes and of the rest of the face were independently manipulated. The results suggest that the contrast polarity relationships uniquely characteristic of human eyes, iris and pupil always darker than the white sclera (Kobayashi & Koshima, 1997, 2001), play a critical role in face recognition from early in development. Although the eyes may cover only small portion of the facial image (2.6%), it was only their local contrast polarity that affected face discrimination in these infants.

The contrast polarity of the eyes might not be expected to carry any discriminative power given that it is a relationship shared by all human faces. Nevertheless, we found that reversing this relationship greatly affects infants' ability to discriminate faces, just as it does adults (Gilad et al., 2009). One possible reason for this is that, although the sclera-iris relationship itself is invariant across faces, it may participate in other relationships that do vary between faces. For example, the darkest region of the eye may act as a landmark for establishing the distance between the eyes. Additionally, the presence of positive eyes may be necessary for the processing of individuating information from the rest of the face, including when that information is in negative.

Universally conserved facial features may have a different status to those which vary between faces. The former may serve as 'pre-requisites' for engaging mechanisms specialized for the processing of faces necessary for fine-grained aspects of facial analysis. Faces also share the same basic spatial arrangement of features, sometimes called the first order relations (Diamond & Carey, 1986) and manipulations that disrupt this common spatial relationship, in particular facial inversion, are well known to impair face recognition both in infants (e.g. Bhatt, et al., 2005; Otsuka et al., 2007; Turati, Sangrigoli, Ruely, & de Schonen, 2004) and adults (e.g. Yin, 1969). The present findings together with findings from previous studies suggest that the common contrast polarity relationship of human eyes could play a critical role in face recognition similar to that played by first order spatial relationships. For example Farroni et al.'s (2005) report that the upright face preference in newborns disappeared when the contrast polarity of the face was reversed. As outlined in the introduction, in an fMRI study with adults Gilad et al. (2009) reported that the BOLD response in right FFA was reduced when the contrast polarity of the whole face was reversed, but preserved when contrast polarity of the eye-region was made positive. Similarly, in a follow up study using near-infrared spectroscopy, we found that the right lateral area of infants' brain showed an higher hemodynamic response to the presentation of normal faces than to objects, but this was not the case for faces with contrast reversed eyes (Ichikawa et al., 2012). These studies are consistent with the mechanisms that are normally responsive to faces failing to work when the contrast polarity of the eyes is reversed.

In contrast to the current study, Gava, Valenza, Turati, and de Schonen (2008) recently reported that newborns could successfully recognize faces even when the eyes and eyebrows were occluded. Apart from the age of the infants tested, one noticeable difference between the Gava et al.'s study and the current study is the presence of external facial features in their images. Infants might successfully discriminate between faces even with contrast reversed eyes only when external facial features are included. Alternatively, our results could be interpreted as showing that the saliency of the eyes overshadows other available information. That is, the presence of unusual, contrast reversed eyes may have had a greater negative impact on an infants' ability to use information from the rest of face than do occluders.

Considering that the consistency of contrast polarity of the eyes is unique to humans among primates (Kobayashi & Kohshima, 1997; 2001), there is possibility that infants perceive faces with negative eyes as non-human, and that this lead to poorer recognition as would be expected (Pascalis et al., 2002). Alternatively, it is also possible that infants' perceived faces with negative eyes as human, but are unable to recognize such faces in the absence of positive eye contrast. It is not clear how to separate these possibilities in principle and doing so is beyond the scope of the current study and its results. The current study's main contribution is in clearly demonstrating the critical importance of contrast polarity of the eyes for face recognition in 7-to 8-month old infants and in suggesting possible explanatory frameworks.

References

Anstis, S. (2005). Homage to Peter Thompson: the Tony Blair illusion. *Perception, 34*(11), 1417-1420.

Bhatt, R. S., Bertin, E., Hayden, A., & Reed, A. (2005). Face processing in infancy: Developmental changes in the use of different kinds of relational information. *Child Development, 76*, 169-181.

Bruce, V., & Langton, S. (1994). The use of pigmentation and shading information in recognising the sex and identities of faces. *Perception, 23*(7), 803-822.

Cohen, L. B., & Cashon, C. H. (2001). Do 7-month-old infants process independent features or facial configurations? *Infant and Child Development, 10*(1-2), 83-92.

Dannemiller, J. L., & Stephens, B. R. (1988). A critical test of infant pattern preference models. *Child Development, 59*(1), 210-216.

Diamond, R., & Carey, S. (1986). Why faces are and are not special: an effect of expertise. *Journal of Experimental Psychology General*, 115(2), 107-117.

Farroni, T., Johnson, M. H., Menon, E., Zulian, L., Faraguna, D., & Csibra, G. (2005). Newborns' preference for face-relevant stimuli: effects of contrast polarity. *Proceeding National Academy of Sciences of the United States of America, 102*(47), 17245-17250. doi: 0502205102

Gava, L., Valenza, E., Turati, C. & de Schonen, S. (2008). Effect of partial occlusion on newborns' face preference and recognition. *Developmental Science, 11*(4), 563-574. DOI: 10.1111/j.1467-7687.2008.00702.x

Gilad, S., Meng, M., & Sinha, P. (2009). Role of ordinal contrast relationships in face encoding. *Proceeding National Academy of Sciences of the United States of America, 106*(13), 5353-5358. doi: 0812396106

Hayden, A., Bhatt, R. S., Reed, A., Corbly, C. R., & Joseph, J. E. (2007). The development of expert face processing: are infants sensitive to normal differences in second-order relational information? *Journal of Experimental Child Psychology, 97*(2), 85-98. doi: S0022-0965(07)00014-8

Ichikawa, H., Otsuka, Y., Kanazawa, S., Yamaguchi, M.K., & Kakigi, R. (2012,). Contrast reversal of the eyes diminishes infants' face processing. *Perception Supplement*, *41*, 111.

Johnston, A., Hill, H., & Carman, N. (1992). Recognising faces: effects of lighting direction, inversion, and brightness reversal. *Perception*, *21*, 365-375.

Kelly, D. J., Liu, S. Y., Lee, K., Quinn, P. C., Pascalis, O., Slater, A. M., & Ge, L. Z. (2009). Development of the other-race effect during infancy: Evidence toward universality? *Journal of Experimental Child Psychology, 104*(1), 105-114. doi: 10.1016/j.jecp.2009.01.006

Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Ge, L. Z., & Pascalis, O. (2007). The other-race effect develops during infancy - Evidence of perceptual narrowing. *Psychological Science, 18*(12), 1084-1089.

Kemp, R., McManus, C., & Pigott, T. (1990). Sensitivity to the displacement of facial features in negative and inverted images. *Perception, 19*(4), 531-543.

Kobayashi, H., & Kohshima, S. (1997). Unique morphology of the human eye. *Nature, 387*(6635), 767-768. doi: 10.1038/42842

Kobayashi, H., & Kohshima, S. (2001). Unique morphology of the human eye and its adaptive meaning: comparative studies on external morphology of the primate eye. *Journal of Human Evolution, 40*(5), 419-435. doi: 10.1006/jhev.2001.0468

Layton, D., & Rochat, P. (2007). Contribution of motion information to maternal face discrimination in infancy. *Infancy*, *12*(3), 257-271.

Lewis, M. B., & Johnston, R. A. (1997). The Thatcher illusion as a test of configural disruption. *Perception, 26*(2), 225-227.

Lewkowicz, D. J., & Ghazanfar, A. A. (2012). The development of the uncanny valley in infants. *Developmental Psychobiology, 54*(2), 124-132. doi: 10.1002/dev.20583

Liu, C. H., Collin, C. A., Burton, A. M., & Chaudhuri, A. (1999). Lighting direction affects recognition of untextured faces in photographic positive and negative. *Vision Research, 39*(24), 4003-4009. doi: S0042698999001091

Mondloch, C. J., Lewis, T. L., Budreau, D. R., Maurer, D., Dannemiller, J. L., Stephens, B. R., & Kleiner-Gathercoal, K. A. (1999). Face perception during early infancy. *Psychological Science, 10*(5), 419-422.

Otsuka, Y., Hill, H., Kanazawa, S., Yamaguchi M.K., & Spehar, B. (2012). Perception of Mooney faces by young infants: The role of local feature visibility, contrast polarity and motion. *Journal of Experimental Child Psychology*, 111, 164-179. doi:10.1016/j.infbeh.2009.09.001

Otsuka, Y., Kanazawa, S., & Yamaguchi, M.K. (2006). Development of modal and amodal completion in infants. *Perception*, 35(9), 1251-1264. doi:10.1068/p5258

Otsuka, Y., Konishi, Y., Kanazawa, S., & Yamaguchi, M.K. (2009). The effect of occlusion on motion integration in infants. *Journal of Experimental Psychology: Human perception & Performance*, 35(1), 72-82. doi: 10.1037/0096-1523.35.1.72

Otsuka, Y., Nakato, E., Kanazawa, S., Yamaguchi, M. K., Watanabe, S., & Kakigi, R. (2007). Neural activation to upright and inverted faces in infants measured by near infrared spectroscopy. *Neuroimage, 34*(1), 399-406. doi: S1053-8119(06)00879-2

Pascalis, O., de Haan, M., & Nelson, C. A. (2002). Is face processing species-specific during the first year of life? *Science, 296*(5571), 1321-1323. doi: 10.1126/science.1070223

Quinn, P. C., & Tanaka, J. W. (2009). Infants' Processing of Featural and Configural Information in the Upper and Lower Halves of the Face. *Infancy, 14*(4), 474-487. doi:

Pii 913379726

Russell, R., Sinha, P., Biederman, I., & Nederhouser, M. (2006). Is pigmentation important for face recognition? Evidence from contrast negation. *Perception, 35*(6), 749-759.

Turati, C., Sangrigoli, S., Ruely, J., & de Schonen, S. (2004). Evidence of the Face Inversion Effect in 4-Month-Old Infants. *Infancy, 6*, 275–297.

Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology*, *81*(1), 141-145.