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Development of upper visual field bias for faces in infants

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Data availability

The data that support the findings of this study are available from the corresponding author, S. T., upon request.

Ethical approval

This study was approved by the ethical committee of Chuo University.

Competing interests

The authors declare no competing interests.

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Research Highlights

Face is processed efficiently when presented in the upper relative to the lower visual field, called upper visual field bias for faces.

The present study found the upper visual field bias for faces in infants aged over 7 months, but not in under 6 months.

Infants over 7 months preferentially memorized face in upper visual field even though they equally observe two faces each in upper and lower visual field.

The results suggest that the face-body representation maintaining spatial relationship acquired during development might contribute to this visual field asymmetry.

Abstract

The spatial location of the face and body seen in daily life influences human perception and recognition. This contextual effect of spatial locations suggests that daily experience affects how humans visually process the face and body. However, it remains unclear whether this effect is caused by experience, or innate neural pathways. To address this issue, we examined the development of visual field asymmetry for face processing, in which faces in the upper visual field were processed preferentially compared to the lower visual field. We found that a developmental change occurred between six and seven months. Older infants aged 7–8 months showed bias toward faces in the upper visual field, similar to adults, but younger infants of 5–6 months showed no such visual field bias. Furthermore, older infants preferentially memorized faces in the upper visual field, rather than in the lower visual field. These results suggest that visual field asymmetry is acquired through development, and might be caused by the learning of spatial location in daily experience.

Keywords:
Upper visual field bias, Infant, Development, Face, Memory

Introduction

The visual processing of objects varies depending on where the objects occur in the visual field. For example, facial detection and identification occurs more readily when a face is presented in the left visual field, rather than when presented in the right (Carlei et al., 2017; Rizzolatti, et al., 1971). This hemifield superiority of face processing is based on the fact that the face in the left visual field is quickly projected to the right hemisphere, such as the fusiform face area (FFA), which is devoted to face processing (Kanwisher, McDermott, & Chun, 1997). This left hemifield superiority of face processing is observed in infants around six months of age both in behavior and physiology, indicating the emergence of a functional bias in the visual field (Adibpour et al., 2018; Deruelle & de Schonen, 1998; de Schonen & Mathivet, 1990).

The bias of visual field in the face processing is observed not only along the horizontal meridian (right vs. left), but also along the vertical meridian (upper vs. lower). Specifically, faces presented in the upper visual field in adults receive advantages in detection and memory consolidation akin to left hemifield superiority (Carlei et al., 2017; Fecteau et al., 2000; Felisberti & Currie, 2019; Felisberti & McDermott, 2013; Liu & Ioannides, 2010; Quek & Finkbeiner, 2014; Quek & Finkbeiner, 2016). Also, a visual illusion called “fat face illusion,” in which a face in lower visual field is perceived bigger than that in upper visual field, has been reported (Sun et al., 2012; Sun et al., 2013; Rawal & Tseng, 2020). This visual illusion occurs in humans but not in chimpanzees (Tomonaga, 2015). It occurs only for faces and not for objects (Sun et al., 2012), implying a face-specific visual field phenomenon in the vertical meridian. Although the underlying mechanisms of this visual field advantage in vertical meridian are controversial, visual experience in daily life should contribute to forming this upper visual field bias. Humans learn the spatial relationship of a face that is mounted on a body, and this learned spatial relationship should affect perception and recognition in adults. For example, exposure to spatial relationships causes the contextual effect on face and body perception (de Haas et al., 2016). Accordingly, recognition is impaired when the parts of the face and body are presented in a position different than where daily experience predicts (Chan et al., 2010). While this experience might be related to the upper visual field bias for faces, there is no evidence regarding the influence of experience on the emergence of this bias. To address this issue, our study examined the upper visual field bias for faces during infancy.

The current study hypothesized that accumulating experience with the face and body spatial relationship produces an upper visual field bias for faces. This hypothesis was derived from an existing set of developmental studies. These studies used a head-mounted camera on infants, revealing that the proportion of viewing faces was very high at the early age of about one month, while the proportion of viewing other body areas such as hands increased as the infants developed (Fausey et al., 2016; Jayaraman et al., 2015). This finding suggests that there is a difference in the proportion of viewing the face and body throughout development. Accordingly, this study aims to argue that, if the upper visual field bias for faces is caused by experience, bias should be detected in older infants but not in younger infants.

The present study investigated whether infants aged 5–8 months demonstrated an upper visual field bias for faces, and explored the bias's developmental trajectory. We focused on the 5- to 8-month-olds for two reasons. First, infants of these ages are capable of detecting a face in peripheral visual field (Di Giorgio et al., 2012; Gliga et al., 2009; Kelly et al., 2019; Simpson et al., 2019). Additionally, the left visual field bias for faces has already been observed in this age range (Adibpour et al., 2018; de Schonen & Mathivet, 1990; Deruelle & de Schonen, 1998). Based on these findings, it is plausible that infants aged 5–8 months have developed abilities in the face processing involving the upper visual field bias for faces. We hypothesized that older infants aged 7–8 months would show a stronger upper visual field bias for faces than younger infants aged 5–6 months, provided that the emergence of upper visual field bias for faces is influenced by visually experiencing the face and body spatial relationship in daily life.

We conducted three behavioral experiments. In Experiments 1 and 2, we investigated whether infants showed visual bias to a face in the upper visual field, and whether this visual bias was specific to the face, not to the object. In Experiment 3, we further examined whether this upper visual field bias influenced the memory processing of faces in the upper visual field in 7- to 8-month-old infants. Experiment 3 was designed to evaluate the effect of the upper visual field bias on learning and memory.

Experiment 1 (face)

This experiment examined whether infants showed an upper visual field bias for faces. We presented two faces, vertically or horizontally, and measured infants' visual bias for faces in each face pair condition using the forced-choice, preferential-looking method (Teller, 1979; Teller, 1997). If the upper visual field bias for faces had been acquired during infancy, infants would look at the top face more often than the bottom face in the vertical arrangements. We predicted no specific bias for horizontal pairs.

Methods

Participants

We tested twenty-five 5- to 6-month-old infants (12 boys and 13 girls, mean age = 165.24 days, *SD* = 16.25 days) and twenty 7- to 8-month-old infants (10 boys and 10 girls, mean age = 228.20 days, *SD* = 18.23 days). Five of the 5- to 6-month-old infants we tested were excluded due to crying interruptions in the middle of the experiment; consequently, twenty 5- to 6-month-old infants (9 boys and 11 girls, mean age = 167.55 days, *SD* = 14.55 days) were included in the final analysis. All infants were full-term at birth without any history of a neurodevelopmental disorder, and were healthy at the time of the experiment.

The infants were recruited through local newspaper flyers in Tokyo, Japan and all were Japanese. Written informed consent was obtained from all parents prior to the experiment.

Materials

All stimuli were presented on an LCD monitor (EIZO FlexScan EV2451) with a refresh rate of 60 Hz and a resolution of 1920 (horizontal) × 1080 (vertical) pixels using PsychoPy v1.90.1. Two loudspeakers were placed on each side of the monitor. Infants sat on their parents' laps in front of the monitor at a distance of 60 cm. A camera (Logicool C920R) was placed below the monitor to record the infants' behavior digitally throughout the experiment. This allowed the experimenter to observe the infants' behavior without interfering with the measurements. Infants and parents were tested inside an enclosure made of plastic poles and black cloth. Infants' eye movements were recorded using a Tobii eye-tracking device (Tobii pro spectrum; Tobii Technology, Inc., Danderyd, Sweden) attached below the screen. The eye tracker with a freedom of head movement within an area of 34 × 26 × 65 cm binocularly recorded the x-y coordinates of current fixation at a sampling rate of 150 Hz via the PsychoPy program. We analyzed the recorded x-y coordinates obtained from both eyes. Parents were asked to keep their eyes closed during the experiment.

Stimuli and procedure

The stimuli were four colored Japanese female faces taken as frontal views showing a neutral expression (Fig.1a). These four female faces were identical to those used in our previous study (Tsurumi et al., 2021). All stimuli were cropped into an oval shape (5.1° in width and 7.4° in height) to remove the outer features, such as the neck, shoulders, and hair. Two different faces (i.e., different persons) were presented on the top/bottom pair or right/left pair side by side in each trial. The distance between the center of a face and the center of the monitor was 7.16°.

We adopted a preferential looking procedure to investigate the upper visual field bias for faces. A trial sequence is shown in Figure 1b. A cartoon image was presented at the center of the monitor at 2 Hz, with a brief sound as a fixation point to obtain the infants' fixation in the center of the monitor. After infants fixated on the cartoon, the cartoon disappeared and a pair of two female faces were presented either vertically or horizontally for one second. The faces were directly followed by the presentation of a random dot pattern as a masking stimulus for one second. There were 12 pairs of two faces, in which six unique face identity pairs (e.g., A-B, A-C, A-D, and so on) were presented in both orders (e.g., A-B and B-A). Thus, we conducted 24 trials (2 meridians × 12 pairs of faces) for each infant. The order of the trials was randomized.

Infants' eye movements were recorded throughout the experiment. Before the test, a subject-controlled 5-point calibration using the Tobii built-in calibration function was conducted for each infant to ensure eye-tracking precision and accuracy. During the calibration, the fixation marker (cartoon image) moved around the screen between five points (top left, top right, bottom left, bottom right, and center) in a random order. The calibration was completed when infants successfully fixated on all five points. The calibration was suspended when infants became fussy or cried because of the repetition of the calibration exercise. After calibration, test trials were administered.

Results and discussion

We examined infants' visual bias for faces using the forced-choice, preferential-looking method combined with eye-tracking. Based on this method, we focused on which face infants first looked at after the disappearance of cartoon fixation. Infants' initial fixation at a face was defined by the first gaze sample that landed on one of the two faces, and the individual proportion of initial face fixation was calculated at each location.

Figure 2a shows the proportion of initial fixations at the top/right face in both age groups. To investigate whether the upper visual field bias for faces occurred, we first conducted a three-way analysis of variance (ANOVA) on the proportion of the initial face fixation, with age (5-6 months and 7-8 months) as the between-participant factor and meridian (vertical and horizontal) and location of face (top/right, location 1 and bottom/left, location 2) as the within-participant factor[1]. This analysis revealed a significant three-way interaction, $F(1,38) = 5.16$, $p = .029$, $\eta_p^2 = .12$. Thus, to further examine whether there was a

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[1] The authors thank Genevieve L. Quek for suggesting this analysis.

developmental difference between ages in the proportion of initial face fixation at each meridian, we conducted a two-way ANOVA with age as the between-participant variable and location in each meridian as the within-participant variable. In the vertical meridian, we found a significant interaction, $F(1,38) = 8.04, p = .007, \eta_p^2 = .17$. To characterize the upper visual field bias for faces, we performed a two-tailed paired *t*-test in each age group with Bonferroni's correction. For 7–8 months, we found a higher proportion of initial fixation toward the top faces over the bottom faces, $t(19) = 5.38, p < .001, d = 1.67$, indicating an upper visual field bias for faces. For 5-6 months, there were no significant differences, $t(19) = .52, p = .608, d = .23$. We also found that the proportion of initial fixation at the top face in 7- to 8-month-olds was significantly higher than that of in 5- to 6-month-olds, $t(38) = 2.84, p = .007, d = .88$. In contrast, there was no significant interaction, $F(1,38) = .21, p = .652, \eta_p^2 = .01$, and the main effect of age, $F(1,38) = .00, p = 1.00, \eta_p^2 = .00$, and location, $F(1,38) = .56, p = .459, \eta_p^2 = .01$ in horizontal meridian, suggesting no bias between right and left. Additionally, we found a positive correlation between age (days) and the proportion of initial face fixation at the top face in vertical pairs ($r = .46, p = .003$), but not in horizontal pairs ($r = .04, p = .814$) (Fig. 3).

Interim summary

We found that the proportion of initial fixation at the face in the upper visual field was higher in 7- to 8- month-olds but not in 5- to 6- month-olds, and there was a developmental difference in upper visual field bias for faces between these age groups. These results suggest that 7- to 8-month-olds show an upper visual field bias for faces, and this bias has been established by 7 months developmentally. In Experiment 2, we examined whether the bias observed in 7- to 8- month-olds was specific to faces by presenting house images.

Experiment 2 (house)

We used images of houses in Experiment 2 to investigate whether the upper visual field bias seen in 7–8 months was specific to faces, or general for any visual objects. If the upper visual field bias observed in Experiment 1 was specific to faces, we would not find such biases in the paired house images. The experimental method was identical to that used in Experiment 1, except that the images of faces were replaced with houses.

Methods

Participants

We tested twenty-six 7- to 8-month-old infants (12 boys and 14 girls, mean age = 228.50 days, *SD* = 17.63 days). Six infants were excluded due to the crying interruptions in the middle of the experiment, so that twenty 7- to 8-month-old infants (9 boys and 11 girls, mean age = 228.50 days, *SD* = 17.63 days) were included in the final analysis. All infants were full-term at birth without a history of neurodevelopmental disorders, and were healthy at the time of the experiment. The infants, who were all Japanese, were recruited using the same procedure as in Experiment 1. Written informed consent was obtained from all parents.

Stimuli and procedure

The stimuli consisted of four colored house images collected from the public domain using a Google image search engine (Fig.1a). We chose these houses because their shapes are symmetrical, and they have inner features, such as doors and windows. The size of these stimuli was adjusted to equalize with face stimuli in Experiment 1 and subtended 7.4° in width and 5.1° in height. The distance between the house image and the center of the monitor was the same as that used in Experiment 1 (7.16°). The experimental procedure was identical to that used in Experiment 1, except for replacing the face with house stimuli.

Results and discussion

We calculated the proportion of initial fixation toward a house likewise Experiment 1. Figure 2b shows the proportion of initial fixations landing on the top house (vertical meridian) and right house (horizontal meridian). To examine whether the upper visual field bias observed in Experiment 1 was specific to faces, we conducted a three-way ANOVA on the proportion of the initial fixation, with stimulus type (face in Experiment 1 and house in Experiment 2) as the between-participant factor and meridian (vertical and horizontal) and location of stimulus (top/right, location 1 and bottom/left, location 2) as the within-participant factor. We found a significant three-way interaction, $F(1,38) = 8.85$, $p = .005$, $\eta_p^2 = .19$. Thus, we conducted a two-way ANOVA with stimulus type and location in each meridian. We found a significant interaction in the vertical meridian, $F(1,38) = 10.22$, $p = .003$, $\eta_p^2 = .21$.

The proportion of initial fixation toward the top face was significantly higher than that toward the top house, $t(19) = 3.02$, $p = .007$, $d = .99$, indicating that the upper visual field bias was stronger in faces than in houses. Finally, there was a significant difference in the proportion between the top and bottom faces, $t(19) = 5.38$, $p < .001$, $d = 1.67$, but not in houses, $t(19) = 1.41$, $p = .173$, $d = .44$. This suggests that there was no upper visual field bias for the houses. In the horizontal meridian, we found no significant interaction, $F(1,38) = 2.11$, $p = .155$, $\eta_p^2 = .06$, and main effects of stimulus type, $F(1,38) = .00$, $p = 1.00$, $\eta_p^2 = .00$, and location, $F(1,38) = .01$, $p = .925$, $\eta_p^2 = .00$. These results showed no visual bias to house images, implying that the upper visual field bias observed in 7- to 8-months in Experiment 1 was specific to faces.

We examined the development of upper visual field bias for faces in infants by using face and house images. When presented with face (Experiment 1), older infants aged 7-8 months but not younger infants aged 5-6 months showed visual bias for faces in the upper visual field. However, older infants showed no visual bias for the houses (Experiment 2). These results suggest that the upper visual field bias for faces emerges over 7 months, and experience with faces through development is related to the emergence of upper visual field bias for faces. Although we found an upper visual field bias for faces in older infants, whether this bias also influences further infants' cognitive processes, such as memory, remains unknown. Therefore, we investigated the effect of upper visual field bias for faces on infants' memory processing in Experiment 3.

Experiment 3

In Experiment 3, we further examined whether the upper visual field bias for faces influenced infants' memory processing by using the familiarization/novelty preference method. First, we concurrently presented the two female faces vertically and familiarized infants with these faces for 15 seconds. After this familiarization, we tested whether infants showed a novelty preference between these two faces. The aim of this study was to investigate whether infants habituated only to the faces in the upper side during the familiarization phase. Therefore, we predicted that infants would show a novelty preference for the faces that had been presented at the bottom, although these faces were presented for equal exposure duration during the familiarization phase. If the face at the top modulated the encoding of the face, infants would be habituated only to the faces presented at the top.

Methods

The apparatus was same with that used in Experiments 1 and 2.

Participants

We tested thirty 7- to 8-month-old infants (19 boys and 11 girls, mean age = 228.70 days, *SD* = 16.35 days). Ten infants we tested were excluded due to crying interruptions in the middle of the experiment (*n* = 7) or a side bias during the test phase (*n* = 3) in which infants looked at only one side of the monitor for more than 90% of the looking time during the test phase. As a result, 20 7- to 8-month-old infants (13 boys and 7 girls, mean age = 226.75 days, *SD* = 14.65 days) were included in the final analysis. All infants were full-term at birth without a history of neurodevelopmental disorders and were healthy at the time of the experiment. The recruitment procedure of participants was identical to that of Experiments 1 and 2; thus, all infants were Japanese. Written informed consent was obtained from all parents.

Stimuli and procedure

The stimuli were two Japanese female faces used in Experiment 1 (Fig.1a; two faces from the left). The size and position of the faces were identical to those used in Experiment 1.

We adopted a familiarization/novelty preference procedure to investigate whether faces were differently learned depending on where they were presented in the upper or lower visual field. This procedure consisted of a familiarization phase followed by a test phase. During the familiarization phase, a pair of faces was presented vertically (one in the top and the other in the bottom) for 15 s in each trial. The location of each face was consistent throughout the familiarization phase. The positions of the two faces were counterbalanced across the infants; thus, half of the infants received the pair of Face 1 in the upper visual field and Face 2 in the lower visual field, while the rest observed the pair in the other way around. After the familiarization phase consisted of six trials, the test phase followed. We presented these two faces simultaneously side by side, one on the right and the other on the left of the center of the screen, for 10 s in each trial. We conducted two trials in the test phase in which the positions of the two faces swapped across the first and second trials (e.g., Face 1 that appeared in the right in the first trial appeared in the left in the second trial).

Before initiating the familiarization phase, a subject-controlled 5-point calibration was conducted for each infant. The calibration procedure was identical to that used in Experiments 1 and 2. After a successful calibration, we conducted the familiarization phase, immediately followed by the test phase.

Results and discussion

Familiarization phase

We found that the proportion of initial fixation at the top face during the familiarization phase was significantly higher than chance level, as in Experiment 1, $t(19) = 2.00$, $p = .049$, $d = .62$.

The time spent on each face during the familiarization phase was averaged across the first three and last three trials for each infant. The mean looking times of the first three trials (6.48 secs, *SD* = 2.47) and the last three trials (4.85 secs, *SD* = 2.32) were compared using a *t-test* to confirm whether infants were familiarized with the two faces through the familiarization phase. The looking time across the first three trials was longer than that across the last three trials, $t(19) = 4.13$, $p < .001$, $d = .67$, suggesting that the infants were familiarized with the two faces.

Furthermore, we conducted a two-way ANOVA on the looking time with trial and location of faces (top and bottom) acting as the within-participant factor, to examine whether there was a difference in looking time for each face (Fig.4a). The analysis revealed a significant main effect of the trial, $F(5,95) = 7.52$, $p < .001$, $\eta_p^2 = .28$, indicating that the looking time in the fifth and sixth trials was significantly shorter than that in the first trial (all $ps < .001$). There was no significant effect of face location, $F(1,19) = .89$, $p = .355$, $\eta_p^2 = .05$, and interaction, $F(5,95) = .59$, $p = .704$, $\eta_p^2 = .03$. This suggests that infants looked at the two faces equally.

Test phase

We calculated the preference scores for the faces presented at the bottom during the familiarization phase in the test phase by dividing the infants' looking time on the face presented at the bottom during the familiarization phase across the two trials, by the total looking time across the two test trials. The mean preference score for faces presented at the bottom is shown in Figure 4b. A *t-test* against chance level (0.5) revealed that infants looked at the face on the bottom for a longer period of time than that on top, $t(19) = 3.93$, $p < .001$, $d = 1.22$.

In the current experiment, we examined whether the upper visual field bias for faces influenced infants' memory processing by testing the recognition of two faces after familiarization. We found that 7- to 8- month-olds showed a significant preference for the face presented at the bottom during familiarization. This is surprising because infants looked at the two faces equally during the familiarization phase. This result suggests that infants could encode the face presented at the top during the familiarization phase more successfully than one at the bottom.

General discussion

The primary purpose of the present study was to examine whether daily exposure to the positional relationship between face and body influenced the emergence of the upper visual field bias for faces, which has been found in adults (Carlei et al., 2017; Fecteau et al., 2000; Felisberti & Currie, 2019; Felisberti & McDermott, 2013; Liu & Ioannides, 2010; Quek & Finkbeiner, 2014; Quek & Finkbeiner, 2016), by comparing the two age groups: 5–6 months as the less exposed group, and 7–8 months as the more exposed group. The results of Experiment 1 revealed that the upper visual field bias for faces was found in 7- to 8-month-olds, but not in 5- to 6- month-olds. This upper visual field bias was specific to faces because bias did not occur with the houses shown in Experiment 2. In Experiment 3, we further explored whether the upper visual field bias for faces had an impact on memory and learning, and found that the face in the upper visual field influenced the learning of individual faces in

7- to 8-month-olds. This result suggests that the face in the upper visual field influenced not only the early stage of intaking visual information, but also later memory retrieval. There is a developmental change in the upper visual field bias for faces between 6 and 7 months, implying that experience with faces in daily life is related to the emergence of upper visual field bias for faces.

As we predicted, the upper visual field bias for faces was observed in 7- to 8-month-olds, suggesting that the experience of perceiving the face and body relationship in daily life is essential for developing an upper visual field bias for faces. The experience with ecological relationship between the face and body (that the face is attached to the body) is accumulated throughout development (Fausey et al., 2016; Jayaraman et al., 2015). Hence, an automatic visual bias toward the face in the upper visual field is formed at approximately 7–8 months. Younger infants aged < 6 months showed no such bias for faces.

A striking result from Experiment 3 showed that the upper visual field bias for faces influenced infants' learning and memory processing. In Experiment 3, two female faces were presented vertically during familiarization, and then two faces were presented horizontally at the right and left positions in the test. Infants showed a novelty preference for the face that was presented at the bottom despite the equal looking time for each face during the familiarization phase. This result implied that infants learned the face in the upper visual field more extensively than in the lower visual field during the learning phase. This is in line with adult studies, which suggest that the location of the face influences memory processing due to faces presented in the upper visual field being encoded more efficiently than those in the lower visual field (Felisberti & McDermott, 2013).

Although it has been debated whether the upper visual field bias for faces is an innate or acquired tendency, the present study revealed that this bias is acquired even in infants. Furthermore, there is a developmental period in which the upper visual field bias for faces emerges between six and seven months. This finding suggests that experience plays a key role in forming the upper visual field bias for faces. What do infants experience during early development? There are two possibilities: one is the experience of voluntarily viewing faces in the upper visual field; and the other is the experience of passive observation of faces as one part of the body. In line with the latter possibility, there is a series of developmental studies showing that body representation develops gradually during this period. Previous studies conducting behavioral and EEG experiments have demonstrated that infants aged 3 months can discriminate between typical and atypical human bodies, and suggest that the sensitivity to structural information of the human body has been acquired at this age (Gliga & Dehaene-Lambertz, 2005; Zieber et al., 2015). At 5 months, infants have been able to distinguish between male and female bodies, reflecting the successful classification of the human body (Hock et al., 2015). Moreover, 9-month-old infants could discriminate between typical and atypical bodies regardless of the type of stimuli, such as the real human body and mannequins, suggesting that older infants have acquired the generalization of human body representation (Heron & Slaughter, 2010). These findings indicate the gradual development of body representation within less than a year. That is, infants showed sensitivity to the structural information of the human body at 3 months, and classified the human body at 5 months, implying the precursor of human body representation. Subsequently, infants aged 9 months can generalize human body representation into other body images, reflecting a more flexible body representation. Experience has caused gradual development of body representation. Considering that 5- to 6-month-olds showed no bias to the face in the upper visual field in the present study, the sensitivity to the human body in 3 months is insufficient for this bias. Instead, a higher level of body representation in older age is necessary for this bias to develop. We suggest that the body representation acquired through the experience of spatial face-body observation leads to the emergence of an upper visual field bias for faces. In future studies, we can further examine the effect of later experience such as childhood and adulthood on the upper visual field bias for faces.

References

Adibpour, P., Dubois, J., & Dehaene-Lambertz, G. (2018). Right but not left hemispheric discrimination of faces in infancy. *Nature Human Behaviour*, *2*, 67–79. https://doi.org/10.1038/s41562-017-0249-4

Carlei, C., Framorando, D., Burra, N., & Kerzel, D. (2017). Face processing is enhanced in the left and upper visual hemi-fields. *Visual Cognition*, *25*, 749–761. https://doi.org/10.1080/13506285.2017.1327466

Chan, A. W. Y., Kravitz, D. J., Truong, S., Arizpe, J., & Baker, C. I. (2010). Cortical representations of bodies and faces are strongest in commonly experienced configurations. *Nature Neuroscience*, *13*, 417–418. https://doi.org/10.1038/nn.2502

de Haas, B., Schwarzkopf, D. S., Alvarez, I., Lawson, R. P., Henriksson, L., Kriegeskorte, N., & Rees, G. (2016). Perception and processing of faces in the human brain is tuned to typical feature locations. *Journal of Neuroscience*, *36*(36), 9289–9302. https://doi.org/10.1523/JNEUROSCI.4131-14.2016

Deruelle, C., & de Schonen, S. (1998). Do the right and left hemispheres attend to the same visuospatial information within a face in infancy? *Developmental Neuropsychology*, *14*(4), 535–554. https://doi.org/10.1080/87565649809540727

de Schonen, S., & Mathivet, E. (1990). Hemispheric Asymmetry in a Face Discrimination Task in Infants. *Child Development*, *61*(4), 1192–1205. https://doi.org/10.1111/j.1467-8624.1990.tb02853.x

Di Giorgio, E., Turati, C., Altoè, G., & Simion, F. (2012). Face detection in complex visual displays: An eye-tracking study with 3- and 6-month-old infants and adults. *Journal* *of Experimental Child Psychology*, *113*(1), 66–77. https://doi.org/10.1016/j.jecp.2012.04.012

Fausey, C. M., Jayaraman, S., & Smith, L. B. (2016). From faces to hands: Changing visual input in the first two years. *Cognition*, *152*, 101–107. https://doi.org/10.1016/j.cognition.2016.03.005

Fecteau, J. H., Enns, J. T., & Kingstone, A. (2000). Competition induced visual field differences in search. *Psychological Science*, *11*(5), 386–393. 10.1111/1467-9280.00275

Felisberti, F. M., & Currie, L. (2019). Asymmetries During Multiple Face Encoding: Increased Dwell Time and Number of Fixations in the Upper Visual Hemifield. *i-Perception*, *10*(1), 1–10. https://doi.org/10.1177/2041669519827974

Felisberti, F. M., & McDermott, M. R. (2013). Spatial location in brief, free-viewing face encoding modulates contextual face recognition. *i-Perception*, *4*(5), 352–360. https://doi.org/10.1068/i0582

Gliga, T., & Dehaene-Lambertz, G. (2005). Structural encoding of body and face in human infants and adults. *Journal of Cognitive Neuroscience*, *17*(8), 1328–1340. 10.1162/0898929055002481

Gliga, T., Elsabbagh, M., Andravizou, A., & Johnson, M. (2009). Faces attract infants' attention in complex displays. *Infancy*, *14*(5), 550–562. https://doi.org/10.1080/15250000903144199

Heron, M., & Slaughter, V. (2010). Infants' responses to real humans and representations of humans. *International Journal of Behavioral Development*, *34*(1), 34–45. doi:10.1177/016502540 9345047

Hock, A., Kangas, A., Zieber, N., & Bhatt, R. S. (2015). The development of sex category representation in infancy: Matching of faces and bodies. *Developmental Psychology*, *51*(3), 346–352. 10.1037/a0038743

Jayaraman, S., Fausey, C. M., & Smith, L. B. (2015). The faces in infant-perspective scenes change over the first year of life. *PLoS ONE*, *10*, e0123780. https://doi.org/10.1371/journal.pone.0123780

Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The Fusiform Face Area: A Module in Human Extrastriate Cortex Specialized for Face Perception. *Journal of Neuroscience*, **1**, 4302–4311. https://doi.org/10.1109/CDC.2005.1583375

Kelly, D. J., Duarte, S., Meary, D., Bindemann, M., & Pascalis, O. (2019). Infants rapidly detect human faces in complex naturalistic visual scenes. *Developmental Science*, *22*(6), e12829. https://doi.org/10.1111/desc.12829

Liu, L., & Ioannides, A. A. (2010). Emotion separation is completed early and it depends on visual field presentation. *PLoS ONE*, 5, e9790. https://doi.org/10.1371/journal.pone.0009790

Quek, G.L. & Finkbeiner, M. (2014). Face-sex categorization is better above fixation than below: Evidence from the reach-to-touch paradigm. *Cognitive Affective Behavioal Neuroscience*, 14, 1407-1419. doi: 10.3758/s13415-014-0282-y.

Quek, G. L., & Finkbeiner, M. (2016). The upper-hemifield advantage for masked face processing: Not just an attentional bias. *Attention, Perception, and Psychophysics*, *78*, 52–68. https://doi.org/10.3758/s13414-015-0965-7

Rawal, A., & Tseng, P. (2020). A Geometrical Account to Explain the Fat-Face Illusion. *i-Perception*, 11. https://doi.org/10.1177/2041669520981094

Rizzolatti, G., Umiltà, C., & Berlucchi, G. (1971). Opposite superiorities of the right and left cerebral hemispheres in discriminative reaction time to physiognomical and alphabetical material. *Brain*, *94*(3), 431–442. https://doi.org/10.1093/brain/94.3.431

Simpson, E. A., Maylott, S. E., Leonard, K., Lazo, R. J., & Jakobsen, K. V. (2019). Face detection in infants and adults: Effects of orientation and color. *Journal of Experimental Child Psychology*, *186*, 17–32. https://doi.org/10.1016/j.jecp.2019.05.001

Sun, Y. H., Ge, L., Quinn, P. C., Wang, Z., Xiao, N. G., Pascalis, O., Tanaka, J., & Lee, K. (2012). A new “fat face” illusion. *Perception*, 41, 117–120. https://doi.org/10.1068/p6906

Sun, Y. H., Quinn, P. C., Wang, Z., Shi, H., Zhong, M., Jin, H., Ge, L., Pascalis, O., Tanaka, J. W., & Lee, K. (2013). Face contour is crucial to the fat face illusion. *Perception*, 42, 488–494. https://doi.org/10.1068/p7439

Teller, D. Y. (1979). The forced-choice preferential looking procedure: A psychophysical technique for use with human infants. *Infant Behavior and Development*, 2, 135–153. https://doi.org/10.1016/S0163-6383(79)80016-8

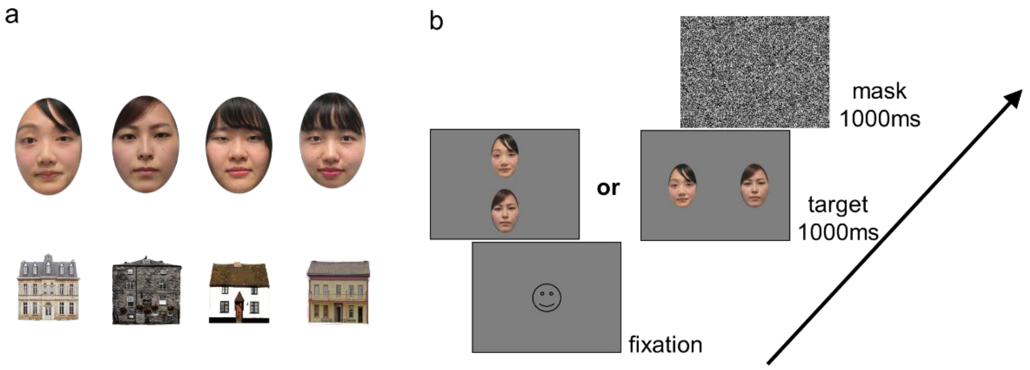
Teller, D. Y. (1997). First glances: The vision of infants. The Friedenwald lecture. *Investigative Ophthalmology and Visual Science*, 38, 2183–2203.

Tomonaga, M. (2015). Fat face Illusion, or Jastrow illusion with faces, in humans but not in chimpanzees. *i-Perception*, 6, 1–5. https://doi.org/10.1177/2041669515622090

Tsurumi, S., Kanazawa, S., Yamaguchi, M. K., & Kawahara, J. (2021). Attentional blink in preverbal infants. *Cognition*, 214, 104749. https://doi.org/10.1167/19.10.108b

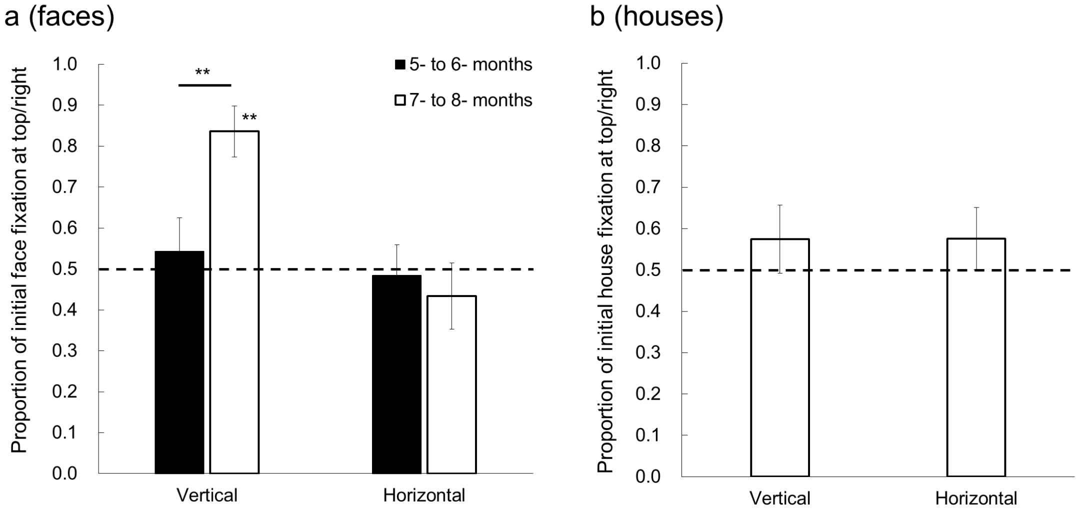
Zieber, N., Kangas, A., Hock, A., & Bhatt, R. S. (2015). Body Structure Perception in Infancy. *Infancy*, *20*(1), 1–17. https://doi.org/10.1111/infa.12064

Figure 1



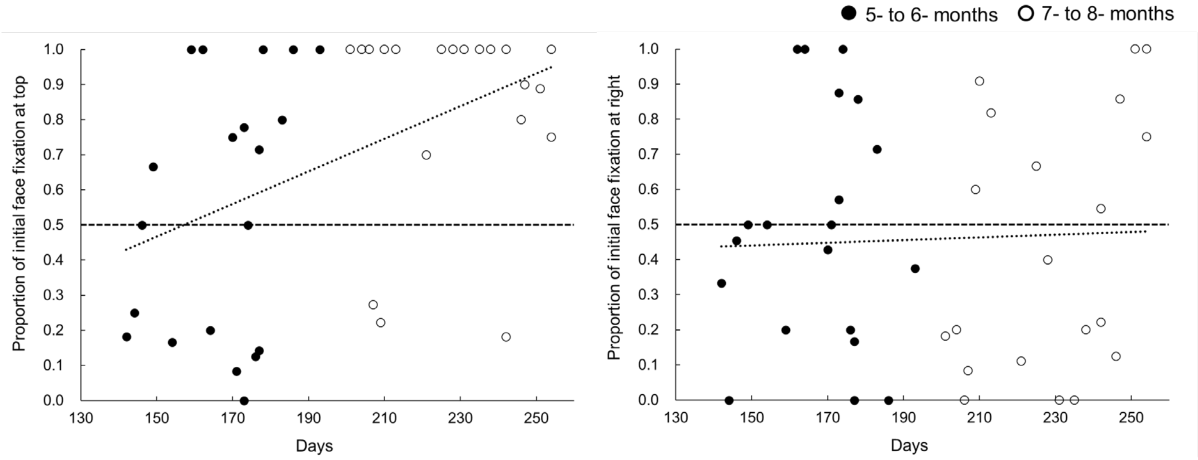
The stimuli in Experiments 1, 2 (a) and illustration of Experimental procedure (b). (a) Four Japanese female faces and house images were used in Experiments. (b) After infants' fixation at the cartoon, two female faces were presented vertically or horizontally for one second, followed by a random dot mask.

Figure 2



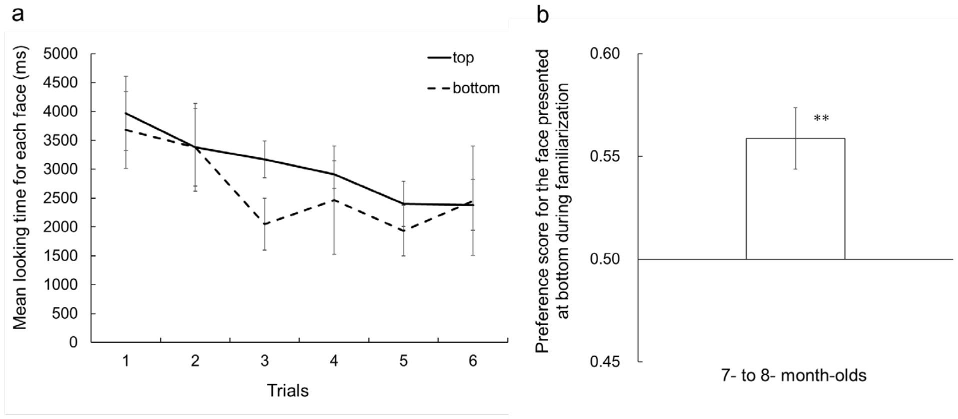
*The proportion of initial fixation at the top and right in (a) Experiments 1 and (b) 2. The horizontal dashed lines represent the chance level (0.5). The bar above chance means that infants tend to look at the top/right, while the bar below chance means that infants tend to look at the bottom/left. (a) A significant difference between ages in the vertical meridian and a significant difference in the vertical meridian in 7–8 months against chance level were found. **p < .01. (b) Only 7- to 8- month-old infants showing upper visual field bias for faces in Experiment 1 were tested in Experiment 2. No significant differences in either the vertical or horizontal meridians were found. Error bars indicate standard error.*

Figure 3



Individual data showing the proportion of initial fixation at the top and right faces in Experiments 1. The left panel is the result of the vertical meridian, and the right panel is that of the horizontal meridian. The horizontal dashed lines represent the chance level (0.5), and dotted lines show a regression line fitted to the data. Positive correlation was observed along the vertical meridian (r = .46), but no such correlation was found along the horizontal meridian (r = .04).

Figure 4



The looking time during the familiarization phase ***(a)*** *and the preference score during the test phase* ***(b)****. Error bars represent standard errors. **p < .01 against chance level (0.5).*