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Direct gaze modulates face recognition in young infants

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Abstract

From birth, infants prefer to look at faces that engage them in direct eye contact. In adults, direct gaze is known to modulate the processing of faces, including the recognition of individuals. In the present study we investigate whether direction of gaze has any effect on face recognition in four-month-old infants. Four-month infants were shown faces with both direct and averted gaze, and subsequently given a preference test involving the same face and a novel one. A novelty preference during test was only found following initial exposure to a face with direct gaze. Further, face recognition was also generally enhanced for faces with both direct and with averted gaze when the infants started the task with the direct gaze condition. Together, these results indicate that the direction of the gaze modulates face recognition in early infancy.

Introduction

Information derived from the face, and especially from the eye region, serves a number of different functions in social interaction, such as triggering a reflexive shift of an observer's visual attention (Driver et al., 1999; Friesen and Kingstone, 1998 and Hietanen, 1999), regulating turn-taking in conversation (Argyle & Cook, 1976), expressing intimacy (Kleinke, 1986, Langton et al., 2000), and inferring mental states (Baron Cohen, 1995). Recent behavioural studies in adults have demonstrated that direct gaze can modulate other aspects of face processing. For example, perceived eye contact can affect both the speed of online gender face judgments and the accuracy of incidental recognition memory of faces (Vuilleumier et al., 2005), and performance in face memory tasks can be influenced by gaze direction both at the encoding and at the retrieval levels (Hood, Macrae, Cole-Davies, & Dias, 2003).

Hood and colleagues tested children between 6 and 7 years of age, and adults on a forced-choice face recognition task in which the direction of eye gaze was manipulated over the course of the initial presentation and subsequent test phase of the experiment. To establish the effects of gaze direction on the encoding and on the retrieval processes, participants were presented with faces displaying either direct or averted gaze and with their eyes closed during the test phase (i.e. encoding manipulation) or with faces presented initially with eyes closed and tested with either direct or averted gaze (i.e. retrieval manipulation). The results demonstrated that direct gaze facilitated the encoding process in both children and adults. Faces with direct gaze also enhanced the retrieval process, although this effect was stronger for adults.

Cognitive neuroscience studies with adults have also revealed modulation of processing resulting from the detection of direct gaze. For example, George et al. (2001), investigated how gaze direction (direct or averted), influences face processing using a gender recognition task. They presented a face with direct or averted gaze, and the face was either a frontal view or tilted at 45 degrees. They observed that specific regions of the fusiform gyrus yielded stronger responses to faces when these looked directly at the subject (regardless the orientation of the head). Since it has been recently shown that the fusiform response can be sensitive to recognition of individuals (Gauthier et al., 2000, 1999; George et al., 1999; Sergent et al., 1994, 1992), and is stronger for attended faces (Wojciulik et al., 1998), the authors concluded that the stronger activity found for faces with direct gaze could be interpreted in terms of enhanced attention and deeper encoding for faces with direct gaze (George et al. 2001). In addition, several electrophysiological studies with adults also found that an occipital-temporal negative peak around 170msec after stimulus onset that is related to face processing (Bentin, Allison, Puce, Perez, & McCarthy, 1996; McCarthy, Puce, Belger, &Allison, 1999) is also sensitive to eye gaze perception (Bentin et al., 1996; Puce, Smith, & Allison, 2000; Senju, Yaguchi, Tojo, & Hasegawa, 2003).

How does this specialization found in adults arise during development? The significance of mutual gaze in the development of human relationships has been shown in many studies, revealing its function to provide information, to regulate adult-infant interaction, to exercise social control and to facilitate task goals from birth (Kleinke, 1986; Blass & Camp, 2001; Farroni et al., 2002). Recently, three converging lines of evidence have emphasized the importance of direct gaze during early infancy. First, newborns prefer to look at faces with direct gaze (Farroni et al. 2002). Second, a period of direct gaze is important for the subsequent cueing of attention in 4-month old infants (Farroni et al., 2003). Third, we (Farroni et al. 2002) found a difference between direct and averted gaze directions at the time and scalp location of a known face-sensitive component of the infant ERP ("infant N170", de Haan et al. 2002). This component of the infant ERP in infants is sensitive to changes in the orientation and species of a face, at least by 12 months of age (Halit et al. 2003). Thus, we hypothesized that direct eye contact enhances the perceptual processing of faces in 4-

month-old infants.
While converging lines of evidence suggest that direct gaze may modulate face processing in young infants, this hypothesis has yet to be directly tested. In the present study, we examined how facial identity and gaze direction may interact early in infancy. As in previous studies reviewed earlier, we investigated whether direct gaze evokes a deeper analysis of other aspects of the person's face such as its identity. Specifically, we predicted that infants that had previously seen a face accompanied by direct gaze would subsequently demonstrate recognition of that face by displaying a novelty preference for an unfamiliar face. In contrast, we predicted no preference when infants initially see a face with averted gaze.

Methods

Participants

Thirty-six babies participated in the experiment and were selected from the family register of Padua. Twelve infants were excluded from the final sample for various reasons: three did not complete testing because of fussiness or drowsiness, and nine were excluded because of technical associated with a failure to calibrate the baby's eyes with the eye tracker. The final sample consisted of twenty-four babies aged between 4-5 months, with a mean age of 4 months and 15 days (range = 115 days to 154 days; 13 male and 11 female).

Apparatus and stimuli

Infants sat in an adapted infant car seat 80 cm distant from a high-resolution computer monitor. The infant's eye level was at the centre of the screen. A cartoon attracted the attention of the infants. The eye movements were recorded by an eye tracker system called Eye Position Detector System (EPDS). This device involved two computers interfaced through a communication serial port (RS232). One computer identified the pupil and recorded eye movements, while the other controlled the experiment, displayed the stimuli and recorded the data. The device was also equipped with a video camera to record the eye movements. Calibration of the eye tracker was achieved when the infants fixated three markers on the screen presented on the top-left, in the centre and on the bottom-right. Re-calibration was performed if required during the experiment. The system is accurate to 0.5° following 3 point calibration. The video camera was centrally positioned on a table under the screen where the stimuli were shown, at 70 cm distant from the infant. The video camera was sensitive to the infrared light components, so a low intensity light setting was created. The EPDS gives two types of outputs: a series of x-y coordinates taken every 40 ms that corresponded to the sequence of the points viewed by the participants on the picture, and a visual pattern, i.e. the eye track on each picture. Three main areas of interest were selected by the experimenter corresponding to the face stimuli (the centre area for the habituation stimulus, and the left and right areas for the face stimuli presented on the periphery). These three areas were considered valid looking points and fixation times were accumulated whenever the infants were looking at them. If the infants looked outside these defined areas no looking times were accumulated. The experimenter could see the stimulus on another screen while the participant was looking toward the picture during the experiment.

During the habituation phase the infants' viewed video clips of a female face with neutral expression and accompanying mouth, hand and finger movements (familiar stimulus). These stimuli were designed to attract attention to the face (videos can be obtained from the authors on request). The stimuli were presented in the centre of the screen during the habituation phase (familiar stimulus) and two static faces (one familiar and one novel) bilaterally presented on a screen during the post habituation phase (see Figure 1). The reason why we used female faces is that they usually are more attractive for young infants and this may maximise attention to the faces during the experiment (see Quinn et al. 2002). In both phases the faces could either have direct or averted gaze. The face subtended a visual angle of 7.2° x 4.9° and the external contour of one eye was about 1° x 0.4°. The eccentricity between the two peripheral stimuli was of 6.4° so that the error range of the eye tracker (0.5°) was not relevant when the infants was looking in between the two stimuli.

Procedure

After the infant was familiarized with the laboratory environment, he or she sat on a car sit in front of the stimulus monitor. A dynamic cartoon was used to attract the infant's attention to different positions of the screen in order to calibrate the baby's saccades. After calibration the trial began and the habituation stimulus appeared.

The experiment was carried out using a visual habituation technique with the infant control procedure (Slater at al., 1985). The infant was judged to have habituated when, from the fourth fixation on, the sum of any three consecutive fixations was 50 percent or less than the total of the first three fixations. When the habituation criterion was reached, the stimulus was automatically turned off and a preference test phase started.

The habituation with the stimulus face was followed by a preference test in which a preference could be expressed between the familiar face and a novel one. The two test stimuli were shown in both left and right positions, the positions being reversed from the first to the second presentation.

There were two different conditions during the habituation phase: condition 1, where the habituation was with a face with a direct gaze, followed by a preference test always with faces with direct gaze (see Fig. 1 a), and condition 2 where a face with an averted gaze (left or right) was used during the habituation phase (see Fig. 1 b), followed by a preference test involving two face with-averted gaze. Both conditions were administered to every infant. The presentation order of the direct or averted gaze conditions was counter balanced across infants with half of them seeing the direct gaze condition first.

Eye movement data were automatically coded from the eye tracker during the experiment. Separate patterns of looking were determined for infants' looking and the fixation time during the habituation phase, and during the preference test phase were measured.

Results

Given that the looking behaviour toward the stimuli was automatically recorded as dependent measures for each infant, total looking times were calculated across the two conditions. A paired samples *t*-test was performed to compare the average total fixation time to reach the habituation criterion for the two faces (i.e., face with direct gaze and face with averted gaze). This comparison revealed that the total fixation time before habituation was significantly longer for the direct gaze condition (72.36s SD = 55.19) than for the averted gaze condition (42.09s SD = 39.27) ($t_{(23)}$ = -2.340, p = .028.)

During the test phase, to test whether the infants were able to recognize the face seen previously, a 2 x 2 ANOVA was performed with the stimulus condition (familiar versus novel) and the gaze direction (direct versus averted) as within-subject factors, and with the habituation fixation time as a covariate to test if the preference for the novel stimulus was influenced by the amount of looking time during habituation (see table 1 for the mean looking times). The ANOVA revealed a significant interaction between stimulus condition and gaze direction ($F_{(1,21)}$ = 4.39; p=.048) demonstrating that the difference in the direction of the gaze between the two conditions lead to a

different behaviour during the preference test. No significant interaction effect of the covariance was found and this result therefore excludes the possibility that our main results are due to a relative lack of attention in one of the two conditions.. A post hoc analysis demonstrated that the infants spent more time looking at the novel face than at the familiar face only in the case of the direct gaze ($t_{(23)}$ = -2.165 p=.041; averted gaze, $t_{(23)}$ =.897, n.s.).
Since half of the infants started the experiment with the direct gaze during the habituation phase, and the other half started with the averted gaze condition, we assessed order effects that may be caused by starting the experiment with the direct gaze face. The result showed an interaction between stimulus condition and order of presentation ($F_{(1, 22)}$ = 5.192; P= .033) demonstrating that those infants who started the experiment with the direct gaze face subsequently tended to prefer the novel face at test regardless of the direction of gaze of the face. This effect was not present in those infants that began with the averted gaze face condition (see Table 2). The order of presentation did not affect the habituation time ($F_{(1, 22)}$ = 1.882; n.s.).

Discussion

If direct gaze enhances face processing in infants we predicted that following exposure to a face with direct gaze infants will subsequently show evidence of having recognized the face (by showing a novelty preference in a paired choice test). Further, no such preference should be observed in infants habituated to a face with averted gaze. This prediction was confirmed. In addition, post-hoc analyses revealed that the order in which the two conditions were presented made a difference. If the experiment began with the direct gaze condition then the averted gaze condition also elicited evidence of subsequent individual recognition. In contrast, if the experiment began with the averted gaze condition, then only the later occurring direct gaze condition resulted in recognition. These effects were not due to differences in looking time between the conditions during the habituation phase.

The results of the present study confirm the hypothesis that direct gaze is an important modulator of face and social information processing early in life. From at least 4 months of age infants show facilitation of cueing of spatial attention, improved individual recognition, and enhancement of neural correlates of face processing, when accompanied, or preceded by, direct gaze. The effects of a period of direct gaze may last for several seconds, or longer. In the gaze cueing experiments of Farroni et.al (2003) a short period of direct gaze had to precede a gaze shift or other motion cue to enable a shift of attention in the infant. In the current study, the effects of direct gaze were longer lasting and extended into the other (averted) gaze condition. Whether this result is primarily due to face recall or face encoding is an issue for future experiments using different testing paradigms (see Hood et al., 2003). Nevertheless, the result could be interpreted as a lack of, or reduced, encoding that subsequently impaired the recognition of faces. This interpretation is supported by the presentation order effect previously discussed. Whether these effects will be observed at younger ages remains to be established in future research.

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Figures and Tables

Figure 1: Stimuli used in the Experiment (half of the subjects saw Figures 1a and the other half Figure1b)

	Mean	**SD**	***N***
NEW DIRECT	10.1	3.6	24
NEW ORIENTED	8.2	4.2	24
FAM. DIRECT	7	3.4	24
FAM. ORIENTED	8	4.2	24

Table 1: Mean total looking time (in seconds) at the New and Familiar faces

	Starting with Direct			**Starting with Oriented**		
	Mean	**SD**	***N***	**Mean**	**SD**	***N***
NEW DIRECT	62	17	12	56	20	12
FAM. DIRECT	38	17	12	44	20	12
NEW ORIENTED	59	21	12	42	20	12
FAM. ORIENTED	41	21	12	58	20	12

Table 2: Percentages and Standard Deviations of direct and averted gaze fixation time during the first and the second presentation