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The shared signal hypothesis: Effects of emotion-gaze congruency in infant and adult visual preferences

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In this study, 4-month-old infants' and adults' spontaneous preferences for emotional and neutral displays with direct and averted gaze are investigated using visual preference paradigms. Specifically, by presenting two approach-oriented emotions (happiness and anger) and two avoidance-oriented emotions (fear and sadness), we asked whether the pattern of emotion–gaze interaction suggested by the shared signal hypothesis (SSH) would also be found with this paradigm. Both age groups demonstrated an ability to discern the approach- and avoidance-oriented emotions, matching them with direct and averted gaze, respectively. Nonetheless, infants showed a greater sensitivity for the congruent emotion-gaze combination in the approach-oriented emotions, while adults were equally sensitive to the gaze-expression congruence for both the approach- and avoidance-oriented emotions. In a follow-up experiment, infants showed no preference for direct or averted gaze in the context of neutral faces. We conclude that the SSH may have validity from infancy, gradually extending from approach-oriented emotions to avoidance-oriented emotions over the course of development.

Over the last thirty years many studies have investigated the development of the ability to discriminate and recognize faces, and to process their internal features, such as eye gaze, expression, and identity. One topic that has been relatively neglected, however, is how specific combinations of eye gaze and emotional expression interact. In one study with adults, Adams and Kleck (2005) presented neutral faces with direct and averted gaze to adults who were asked to rate the faces on four emotion scales (anger, fear, sadness, and joy). Gaze direction was found to influence the perceived emotion conveyed by the neutral faces; participants attributed anger and joy to neutral faces

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with direct gaze, and fear and sadness to faces with an averted gaze. These expression-gaze combinations have also been observed with different testing methods (Adams & Kleck, 2003, 2005), leading these authors to suggest that emotional expressions and gaze direction interact, and contribute to basic behavioural motivations to either approach or avoid. Their hypothesis, the Shared Signal Hypothesis (SSH), postulates that when gaze direction is combined with the intent communicated by a specific expression, it will enhance the perception of that emotion. In this case, joyful and angry expressions are categorized as 'approach-oriented emotions', and so are usually accompanied with direct gaze. Fearful and sad expressions are categorized as 'avoidance-oriented emotions', and so are more easily categorized when accompanied with averted gaze.

Recent studies suggest that sensitivity to such combinations of expression and gaze may emerge early in life. For example, newborns prefer happy faces when accompanied with direct gaze (Farroni, Menon, Rigato, & Johnson, 2007; Rigato, Menon, Johnson, & Farroni, 2011), and the visual event-related potentials of 4- and 7-month-olds are modulated by expression–gaze interactions for angry and happy faces with direct gaze (Hoehl & Striano, 2008; Rigato, Farroni, & Johnson, 2010; Striano, Kopp, Grossmann, & Reid, 2006).

In the current study, 4-month-old infants' and adults' spontaneous preferences for emotional displays were investigated using visual preference paradigms. The purpose of the study was to investigate whether gaze direction modulates the preference for certain emotional expressions, since these characteristics co-occur in the context of a face. Further, we asked whether the pattern of emotion-gaze combinations proposed by the SSH would also be found with this paradigm, and whether this theory can account for data from infants as well as adults. Based on the SSH, stimuli were classified as either 'congruent' (e.g., happy with direct gaze; fearful with averted gaze) or 'incongruent' (e.g., happy with averted gaze; fearful with direct gaze).

Although most infant preferential looking paradigms measure total looking time, in this study we focused on measures of the first look (that is, direction and duration of the first look of each trial). Although differences in total looking times have been recognized as providing evidence of discrimination between stimuli, it has been suggested that the duration of the first look is even more sensitive to stimulus differences than total looking time over a long interval (McCall, 1971). In addition, adults' total looking times are likely to be influenced by higher level questions about the experimental design that might compromise spontaneous responses. Indeed, several adult studies have focused more on the first look of each trial rather than total looking time (e.g., Manns, Stark, & Squire, 2000; Snyder, Blank, & Marsolek, 2008). In order to collect comparable data from the two age groups in this study, we therefore decided to adopt first look measures for the infants as well as the adults.

Based on the SSH, we expected adults to demonstrate a preference for congruent displays, which are thought to be the most familiar stimuli (Adams and Kleck, 2005). Further, based on the prior infant studies, we predicted that infants would prefer to look at congruent combinations for approach-oriented emotions (happy and angry faces accompanied with direct gaze) but not at congruent avoidance-oriented emotion.

EXPERIMENTS 1 (ADULTS) AND 2 (INFANTS)

Method

Participants

Twelve adults (four male) aged between 22 and 46 years old (mean age 30 years), volunteered for Experiment 1. Thirty-five infants, aged between 112 and 139 days (mean age 127 days), were recruited using the Babylab database at Birkbeck College and participated in Experiment 2. Sixteen of these infants were excluded (seven due to fussiness, six due to a strong side bias – they turned more than 85% of the time in one direction – and three due to technical errors), leaving a final sample of 19 infants (nine male). All infants were born full term (37–41 weeks) and were in the normal range for birth weight. The testing took place only if the infant was awake and in an alert state. Informed consent was obtained from the parents.

Apparatus and stimuli

Participants sat in a chair (adults) or in an adapted infant car seat (infants) 65 cm in front of a high-resolution computer monitor (50″), within an acoustically shielded and dimly lit room. Their eye level was aligned with the centre of the screen, and participants' gaze was recorded using a video camera mounted below the monitor and centred on the participant's face. Participants were presented with faces displaying different facial expressions (happy, fearful, angry, sad) with direct and averted gaze. The visual angle of the face stimuli was $15^\circ \times 13^\circ$ in all experiments. The pictures were female models selected from the MacBrain Face Stimulus Set (Tottenham, Borscheid, Ellertsen, Marcus, & Nelson, 2002). In order to display different gaze directions, pictures were modified with Adobe Photoshop 7.0. Inter-trial stimuli of colourful dynamic cartoons were displayed between 800 and 1,600 ms, ensuring that participants' gaze was directed to the centre of the screen before the next slide was presented. Rectangular areas of interest (AOIs) were defined manually around each face stimulus, using ClearView software. The dependent variables were recorded using a camera and a Tobii X-50 eye tracking system (Tobii Technology, Stockholm, Sweden) to record participants' eye movements.

Four different face identities were used throughout the experiments. The Tobii X-50, which comes with a 50″ monitor, allowed us to display four face stimuli at a time (of the same model), preserving their natural size. Calibration was achieved when the participant fixated five markers on the screen presented at the top and bottom corners, and at the centre of the screen. Small dynamic cartoon pictures were used to calibrate for the infants, and a blue circle for the adults. Gaze data were recorded at 50Hz. Adults were instructed to simply look at the faces presented on the screen.

Design and procedure

After calibration, each trial began with a dynamic cartoon at the centre of the screen. Four faces were displayed for 2.5 s in Experiment 1 (adults) and 12 s in Experiment 2 (infants) (see Figure 1). The four stimuli were the same face identity, all displaying either the approach-oriented expressions (happy and angry), or the avoidance-oriented

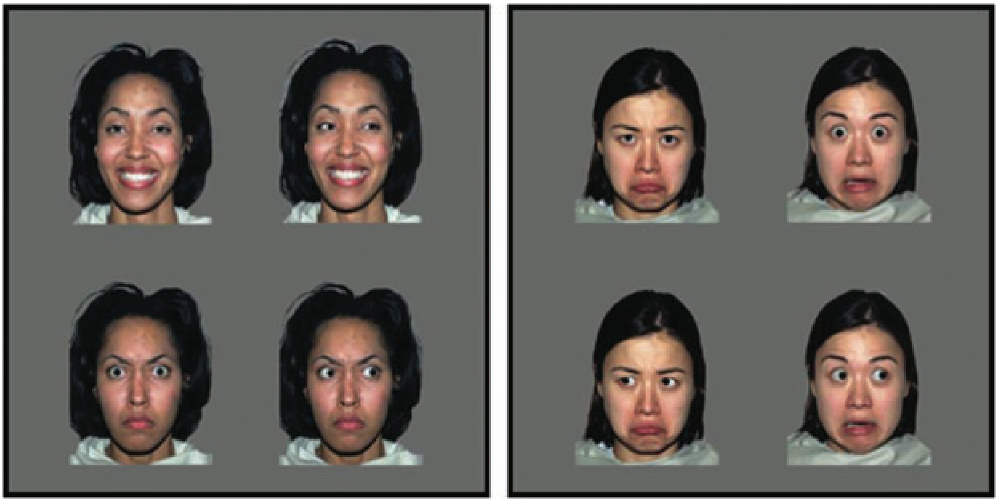

Figure 1. Example of stimuli used in Experiments 1 and 2. On the left, faces displaying approach-oriented emotions (happiness and anger); on the right, faces displaying avoidance-oriented emotions (sadness and fear).

expressions (fearful and sad). Half of the faces were accompanied with direct gaze, the other half with averted gaze. For both approach- and avoidance-oriented slides face identities varied. Each category of slide (approach or avoidance) was pseudo-randomly presented eight times, for a total of 16 trials, or for as long as the infants were willing to look at the screen. In all the experiments, the averted gaze direction (left or right) and the position of the stimuli on the screen (left or right, top or bottom) were counterbalanced across the trials.

Analysis

The dependent variables measured were the direction and the duration of the first look. This is the first fixation for each trial towards one of the AOIs in each slide. In all the experiments, the direction of the first look was calculated by performing chi-square tests for congruent–incongruent expressions, direct–averted gaze direction, gaze direction in approach- and avoidance-oriented emotions, and for each facial expression. Further, a sign test for the congruent–incongruent conditions was also performed. Two ANOVAs were performed in order to analyse the duration of the first look. Firstly, a 4×2 ANOVA with facial expressions (happy, fearful, angry, sad) and gaze direction (direct, averted) as within-subject factors and, secondly, a 2×2 ANOVA with emotions (approach oriented, avoidance oriented) and gaze direction (direct, averted) as within-subject factors were carried out. Bonferroni correction was used for multiple comparisons. Further, *t*-test comparing congruent (happy and angry with direct gaze, fearful and sad with averted gaze) versus incongruent (happy and angry with averted gaze, fearful and sad with direct gaze) emotional expressions was performed.

Results

EXPERIMENT 1 (ADULTS)

Direction of the first look

Non-parametric chi-square tests showed that adults made their first look significantly more to incongruent ($M = 9.3$) than to congruent ($M = 6.8$) displays ($\chi^2(1, N = 12) = 4.688, p = .03$) (see Table 1). This finding is also confirmed by a sign test on the individual data ($Rcrit = 2, p < .05$), which revealed that nine of 12 participants looked first more frequently at one of the incongruent displays. Also, adult participants looked significantly more at approach-averted ($M = 4.9$) than approach-direct displays ($M = 3.1$) ($\chi^2(1, N = 12) = 5.042$, $p = .025$), and in particular to angry-averted ($M = 2.7$) compared with angry-direct displays ($M = 1.25$) ($\chi^2(1, N = 12) = 6.149, p = .013$).

Duration of the first look

A 4×2 ANOVA with facial expression (happy, angry, fearful, sad) and gaze direction (direct, averted) as within subjects factors showed an interaction of these two factors ($F(3,33) = 6.069$, $p = .002$). Pairwise comparisons revealed that adults looked significantly longer at angry-averted displays ($M = 1170$ ms, $SD = 1092$ ms), compared with angry-direct ($M = 409$ ms, $SD = 438$ ms) ($t(11) = -3.229$, $p = .002$), fearful-averted ($M = 711$ ms, $SD = 764$ ms) ($t(11) = -2.564, p = .026$) and sad-averted displays ($M = 540$ ms, $SD = 442$ ms) ($t(11) = -2.706, p = .020$). In addition, adults looked longer at fearful-direct ($M = 824$ ms, $SD = 568$ ms) and sad-direct displays ($M = 841$ ms, $SD = 849$ ms), than at angry-direct displays ($t(11) = 3.326, p = .007$; $t(11) = 2.243, p = .046$). A 2×2 ANOVA with facial expression (approach, avoidance) and gaze direction (direct, averted) as within subjects factors confirmed an expression–gaze interaction ($F(1,11) = 11.09$, $p = .007$). Successive analyses revealed that adult participants looked longer at approach-averted displays ($M = 935$ ms, $SD = 708$ ms) than at either approach-direct ($M = 581$ ms, $SD = 520$ ms) ($t(11) = -2.859, p = .016$), or avoidance-averted displays ($M = 626$ ms, $SD = 543$ ms) ($t(11) = 3.616, p = .004$) (see Table 1), and looked longer at avoidance-direct ($M = 832$ ms, $SD = 675$ ms) compared with approach-direct displays ($t(11) = -2.498$, $p = .030$). Further, adults looked longer at the incongruent displays ($M = 884$ ms, $SD = 673$ ms) than at the congruent ones ($M = 603$ ms, $SD = 468$ ms) ($t(11) = -3.330, p = .007$).

Table 1 . Duration and direction of the first look to the emotional displays in Experiment 1 (adults)

Measures of the first look		Duration (ms) Mean	Duration (ms) Standard deviation	Direction (*n*) Mean
Approach	Direct	581	520	3.1
	Averted	935	708	4.9
Avoidance	Direct	832	675	4.3
	Averted	626	543	3.7
Congruent		603	468	6.8
Incongruent		884	673	9.3

Discussion

In accord with the SSH, adults associated specific emotional expressions with specific gaze directions. However, contrary to our prediction, adults looked first and for longer at the incongruent emotions, that is, approach-oriented expressions with averted gaze and avoidance-oriented expressions with direct gaze. Based on a recent study on visual preference in adults (Park, Shimojo, & Shimojo, 2010), we were expecting a preference for the most familiar faces, that is, the congruent emotional displays (Adams & Kleck, 2005). However, differences in method between the studies may have led to the differing results; the Park *et al*. study was a sequential preference-judgment task, while the present study presented stimuli simultaneously. Nevertheless, this study shows clear evidence of gaze and expression integration. By testing infants with the same paradigm and stimuli, the next experiment aimed to investigate the development of this perceptual integration of gaze and expression.

EXPERIMENT 2 (INFANTS)

Direction of the first look

The frequencies of the first look only differed to the approach-oriented emotions slides ($\chi^2(1, N = 19) = 3.699, p \leq .05$), showing that infants oriented more to happy ($M = 4.4$) than to angry expressions ($M = 3.2$). The frequency of the first look to congruent and incongruent emotions did not differ significantly (see Table 2).

Duration of the first look

A 4 × 2 ANOVA with facial expression (happy, angry, fearful, sad) and gaze direction (direct, averted) as factors within subjects showed a significant effect of expression ($F(3,54) = 2.674, p \leq .05$). This revealed longer looking times to happy expressions ($M = 2834$ ms, $SD = 2989$ ms), followed by fearful ($M = 2491$ ms, $SD = 2365$ ms), angry ($M = 2103$ ms, $SD = 2623$ ms), and sad ($M = 1662$ ms, $SD = 2065$ ms) expressions. Further analysis showed that within the approach-oriented emotions slide, infants looked more at happy-direct ($M = 3604$ ms, $SD = 3947$ ms), than happy-averted ($M = 2063$ ms, $SD = 2469$ ms) ($t(18) = 2.434, p = .026$), and than angry-direct displays ($M = 1663$ ms, $SD = 1663$ ms) ($t(18) = 2.439, p = .025$). Within the avoidance-oriented emotions slide, infants looked more at fearful-averted ($M = 2905$ ms, $SD = 2957$ ms), than fearful-direct ($M = 2076$ ms, $SD = 2001$ ms) ($t(18) = -2.047, p \leq .05$), or sad-averted displays

Table 2. Duration and direction of the first look to the emotional displays in Experiment 2 (infants)

Measures of the first look		Duration (ms) Mean	Duration (ms) Standard deviation	Direction (*n*) Mean
Approach	Direct	2634	2740	4.1
	Averted	2303	3135	3.5
Avoidance	Direct	1944	2248	3.6
	Averted	2209	2111	3.9
Congruent		4842	4519	8
Incongruent		4247	5144	7.1

(M = 1512 ms, SD = 1775 ms) ($t(18) = 2.486$, $p = .023$). A 2 × 2 ANOVA with facial expression (approach, avoidance) and gaze direction (direct, averted) as factors within subjects showed a trend towards an expression effect ($F(1,18) = 3.561$, $p = .075$), revealing longer looking times to approach- (M = 2468 ms, SD = 2740 ms) than avoidance-oriented emotions (M = 2076 ms, SD = 2248 ms) (see Table 2).

Discussion

Infants oriented more frequently and looked for longer at happy expressions than angry ones, confirming previous studies that measured total looking times (Grossmann, Striano, & Friederici, 2007; La Barbera, Izard, Vietze, & Parisi, 1976). Happy expressions are also preferred by babies at birth, and are the expressions most usually experienced by infants as they commonly precede social interaction (Farroni *et al*., 2007). Therefore, it is likely that the infants immediately recognized them as familiar and socially relevant stimuli. This is also in line with Vaish's hypothesis (Vaish, Grossman, & Woodward, 2008) that young infants show a positivity bias, generally preferring positive emotional expressions.

Further, infants' first looks were longer for happy expressions with direct gaze, validating the congruence between these two features suggested by the SSH. In accord with this theory, infants were also sensitive to the expression-gaze congruence in fearful faces, looking longer to these expressions with averted gaze, when compared with sad expressions. Therefore, it seems that the visual preference often found for fearful faces in older infants (see for example, Nelson & Dolgin, 1985), is already developing at 4 months of age.

COMPARISON BETWEEN EXPERIMENT 1 AND 2

In order to delineate a possible developmental trajectory of expression–gaze interactions, comparisons between the results obtained from adults and those obtained from infants were carried out. The data were transformed to percentages by dividing the duration of the first look spent towards congruent displays by the duration of the first look spent towards the stimuli presented (congruent and incongruent displays). Non-parametric independent samples tests (Mann–Whitney U) were run comparing the emotional displays.

Results

Direction of the first look

Infants oriented more frequently than adults towards the congruent displays ($z = -2.423$, $p = .015$; infants 52.5%, adults 42.2%), and correspondingly adults oriented more frequently than infants towards the incongruent displays. Also, infants oriented more than adults towards the approach-direct expressions ($z = -2.130$, $p = .033$; infants 27.2%, adults 19.3%), whereas adults oriented more than infants towards the approach-averted expressions ($z = -2.650$, $p = .008$; infants 23.5%, adults 30.7%). The two groups did not differ in the direction of the first look for the avoidance-oriented displays (Direct gaze: $z = -.841$, $p = .400$; infants 24%, adults 27.1%; Averted gaze: $z = -1.170$, $p = .242$; infants 25.3%, adults 22.9%).

Duration of the first look

Infants looked longer than adults at the congruent emotional arrays ($z = -2.433$, $p = .015$; infants 53.4%, adults 40.9%), and correspondingly adults looked longer than infants at the incongruent arrays. Specifically, infants looked longer than adults at approach-direct (i.e., congruent) displays ($z = -2.352$, $p = .019$; infants 27.7%, adults 18.4%), while adults looked longer than infants at approach-averted (i.e., incongruent) displays ($z = 2.636$, $p = .008$; infants 23%, adults 32.8%). The two groups did not differ in the duration of the first look for the avoidance-oriented displays (Direct gaze: $z = -1.379$, $p = .168$; infants 23.6%, adults 28.3%; Averted gaze: $z = -1.379, p = .168$; infants 25.7%, adults 20.6%).

Discussion

While infants tended to respond with longer and more frequent first looks to congruent displays, adults' first looks were directed more often to the incongruent ones. This effect was mainly due to gaze variation in approach-oriented emotions; infants preferred approach-oriented expressions with direct gaze, whereas adults preferred approach-oriented expressions with averted gaze. Both groups demonstrated their greater response to happy and angry faces, suggesting that the perception of such emotional signals may rely not only on the general face configuration, but also on the specific gaze direction displayed. Therefore, in both infants and adults, gaze variation in approach-oriented expressions may be more relevant than in avoidance-oriented expressions. Thus, those facial expressions that are directed towards ourselves may be the most critical to decode.

In the next experiment infants were presented with a classic visual preference paradigm, in which pairs of faces were presented. This third experiment was run to allow a more direct comparison between direct and averted gaze within the same emotional expression, to ascertain whether infants will show a preference for a specific combination of gaze and expression in each emotional display.

EXPERIMENT 3

Method

Participants

Twenty-nine infants, aged between 110 and 137 days (mean age 122 days), were recruited using the Babylab database at Birkbeck College. After excluding 13 of them (three due to fussiness, four due to a strong side bias, three babies for technical errors, and three for not reaching the trial criterion – performing at least one trial per condition), the final sample consisted of 17 infants (seven male). All infants were born full term (37–41 weeks) and were in the normal range for birth weight. The testing took place only if the infant was awake and in an alert state. Informed consent was obtained from the parents.

Apparatus and stimuli

The laboratory setting was the same as the previous experiments. For this experiment, however, a Tobii 1750 (Tobii Technology, Stockholm, Sweden) was used to record the eye movements of the infants, and they were presented with two faces at a time of the same model on a 17″ computer monitor.

Figure 2. Example of stimuli used in Experiment 3. Pairs of faces displaying the same emotional expression and different gaze direction.

Design and procedure

In Experiment 3, a pair of face stimuli was displayed for 8 s (Figure 2). Both the faces were the same model displaying the same facial expression, one accompanied with direct gaze and the other with averted gaze. Each facial expression (happy, fear, anger, sadness) was pseudo-randomly presented four times, every time with a different facial identity, for a total number of 16 trials or for as long as the infants were willing to look at the screen.

Analysis

The analyses were carried out as in Experiments 1 and 2.

Results

Direction of the first look

Chi square tests showed that infants oriented significantly more frequently to congruent ($M = 8.8$) than incongruent emotion-gaze combinations ($M = 6.8$) ($\chi^2(1,N = 17) = 3.859$, $p \leq .05$) (see Table 3). In addition, a sign test confirmed that significantly more infants looked first at the congruent ($N = 11$) than at the incongruent ($N = 4$) facial displays ($Rcrit = 4$, $p < .05$). Further, they oriented to approach-direct ($M = 4.8$) more than approach-averted ($M = 3.1$) ($\chi^2(1,N = 17) = 5.365$, $p = .02$), and to angry-direct ($M = 2.5$) than angry-averted displays ($M = 1.4$) ($\chi^2(1,N = 17) = 4.587$, $p = .03$).

Duration of the first look

The 2 $\times$ 2 ANOVA with expression (approach, avoidance) and gaze direction (direct, averted) as within subjects factors reported a significant expression–gaze interaction ($F(1,15) = 6.223$, $p = .025$) (see Table 3). Further comparisons showed that infants looked significantly longer at the direct gaze ($M = 870$ ms, $SD = 260$ ms) than averted gaze direction ($M = 524$ms, $SD = 309$ ms) ($t(15) = 2.904$, $p = .011$) within

Table 3. Duration and direction of the first look (ms) to the emotional displays in Experiment 3

		Duration (ms)		Direction (*n*)
Measures of the first look		Mean	Standard deviation	Mean
Approach	Direct	870	260	4.8
	Averted	524	309	3.1
Avoidance	Direct	751	347	3.7
	Averted	814	520	4
Congruent		842	213	8.8
Incongruent		637	239	6.8

the approach-oriented emotions. Further, comparing the approach- and the avoidance-oriented emotions, both accompanied with averted gaze, a trend to look more at the avoidance-oriented emotions came out ($t(15) = -2.007$, $p = .063$). The comparison between congruent and incongruent displays was significant ($t(15) = -2.494$, $p = .025$), showing longer looking time at the congruent ($M = 842$ ms, $SD = 213$ ms) than at the incongruent displays ($M = 637$ ms, $SD = 239$ ms).

Discussion

Infants preferred to look longer and more frequently at approach-oriented emotions with direct gaze rather than averted gaze. Their first look was directed not only towards happy and angry expressions with direct gaze more than with averted gaze, but also towards congruent than incongruent emotions. Also, significantly more babies oriented to congruent than to incongruent emotions. Overall, the findings provide evidence of an early integration of expression and gaze, which allows the infant to detect the congruence/incongruence of these features within a face. Specifically, infants preferred those faces that displayed a congruent arrangement. Nonetheless, a gaze effect was found only in approach-oriented emotions, as infants looked at them for longer and more often when they were accompanied with direct gaze. A possible reason is the experience that infants have with happy faces with direct gaze from birth (Farroni *et al.*, 2007). However, this explanation cannot account for the expression of anger, as infants at 4 months of age have not usually been exposed to this kind of emotional expression (Malatesta & Haviland, 1982). Thus, it is more likely that when direct gaze is combined with angry and happy expressions, it enhances the perception of these emotions, as suggested by the SSH, whether they are familiar or not. The evidence that averted gaze does not significantly enhance the perception of the avoidance-oriented emotions may be partially explained by the fact that infants looked more frequently at faces with direct than with averted gaze. Alternatively, fearful and sad expressions are either equally relevant or not interesting stimuli for the infants at this age. In fact, according to Vaish (Vaish *et al.*, 2008), it is not until older ages that infants show a negativity bias, and infants as young as 4 months are still more attracted by positive stimuli. However, in Experiment 2, infants discriminated between fearful and sad expressions, preferring the fearful ones. Thus, even if young infants generally prefer positive expressions, they are also already able to discriminate between negative expressions. In conclusion, this experiment shows that infants are able to detect expression-gaze congruence, and that they particularly prefer the approach-oriented emotions accompanied with direct gaze.

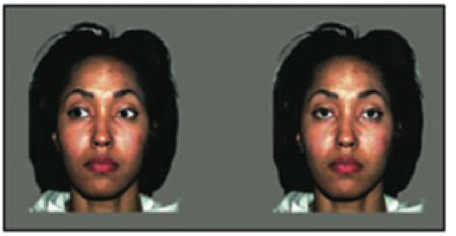

Figure 3. Example of stimuli used in Experiment 4. Pair of faces displaying a neutral expression with direct and averted gaze.

EXPERIMENT 4

This follow-up experiment addresses the question of whether infants show a visual preference for certain gaze directions when accompanied by neutral faces. Infants were shown two neutral face stimuli that differed in gaze direction and were tested in a classic visual preference paradigm (Figure 3). As previous work has shown that newborns prefer to look at neutral faces when accompanied with direct gaze, and that such stimuli enhance brain activation in response to faces in infants at the same age tested in the present study (Farroni, Csibra, Simion, & Johnson, 2002), a preference for this combination of gaze and expression was expected.

Method

Participants

Thirteen infants, aged between 123 and 148 days (mean age 136 days), were recruited to the University of Padua, Department of Psychology from a list provided by the register of births office of Padua. After excluding two of them (one due to a strong side bias, and one for technical errors), the final sample consisted of 11 infants (six male). All infants were born full term (37–41 weeks) and were in the normal range for birth weight. The testing took place only if the infant was awake and in an alert state. Informed consent was obtained from the parents.

Apparatus and stimuli

Infants sat in an adapted infant car seat at a distance of 65 cm from a high-resolution computer monitor (17″), within an acoustically shielded and dimly lit room. Infant's eye movements were recorded by a video camera mounted above the screen, and subsequently coded by two coders naïve as to the experimental condition (inter-rater reliability for 10% of the total participants, Cohen's kappa = 0.90 for the direction of fixation and 0.89 for the duration of fixation). Three different face identities were used, and infants were presented with pairs of the same identity at the same time.

Design and procedure

Pairs of neutral faces were presented in two blocks of six trials each, for a total number of 12 trials, or for as long as the infants were willing to look at the screen. The averted gaze direction (left or right) and the position of the stimuli on the screen (left or right, top or bottom) were counterbalanced across the trials.

Analysis

The direction of the first look was calculated as in the previous experiments. The duration of the first look was analysed by running *t*-tests comparing the gaze direction (direct vs. averted).

Results

Direction of the first look

A chi-square test showed that infants did not orient significantly more frequently to direct than averted gaze ($\chi^2(1, N = 11) = 0.001, p = .97$; Direct gaze: $M = 5.8$; Averted gaze: $M = 5.7$).

Duration of the first look

Contrary to the prediction, *t*-test comparing the duration of the first look to direct and averted gaze did not reveal significant differences ($t(10) = -.735, p = .479$; Direct gaze: $M = 6984$ ms, $SD = 3513$ ms; Averted gaze: $M = 8279$ ms, $SD = 4680$ ms).

Discussion

In contrast to our prediction, 4-month-olds did not prefer the face accompanied with direct gaze when compared to one with averted gaze. One explanation is that a neutral expression is ambiguous to interpret, and less commonly experienced in live social interactions. Therefore, infants may not associate it with a particular gaze direction. However, the evidence that newborns do prefer neutral faces with direct gaze when compared with averted gaze (Farroni *et al*., 2002) suggests that at birth gaze direction is more salient than the emotional expression displayed. In contrast, at older ages expression, and possibly the interaction between expression and gaze, becomes more salient than eye gaze alone in determining a preference. Nevertheless, it is worth noting that at 4 months, direct gaze in neutral faces facilitates the neural processes associated with the earliest encoding of a face (Farroni *et al*., 2002). Therefore, while the present behavioural data indicate that 4-month-old infants do not seem to discriminate between direct and averted gaze, event-related potentials evidence reveals that the neural process underlying these two stimuli is differentiated.

GENERAL DISCUSSION

In the current study, adults and 4-month-old infants were presented with combinations of expressions and gaze direction, and their eye movements were recorded in order to detect their visual preference. Adults were predicted to look at the most familiar face stimuli, that is, congruent approach displays. In contrast to this, we found they looked first at the incongruent face stimuli, that is, approach-oriented expressions with averted gaze and avoidance-oriented expressions with direct gaze. This result was interpreted in terms of the novelty for adults of viewing incongruent gaze–expression combinations (Adams & Kleck, 2005). On the other hand, infants preferred the congruent displays; they looked longer at happy expressions with direct gaze among the approach-oriented emotions, and fearful expressions with averted gaze among the avoidance-oriented emotions. The preference for happy faces confirms previous results from infant studies that such stimuli are preferred from birth (Farroni *et al.*, 2007) and that this preference is preserved for an extended period during development, particularly when compared to angry faces (Grossmann *et al.*, 2007). The association of the happy expression with direct gaze is consistent with the SSH. This hypothesis is also supported by the preference we observed in infants for fearful faces with averted gaze. To this point, the SSH may explain our results, albeit only partially for infants. The difference between the two age groups may reflect an effect of familiarity of the congruent combinations, which attracted the infant attention, and an effect of novelty of the incongruent combinations, which held the adult attention because of their ambiguity.

In the third experiment, infants were shown only two faces displaying the same emotional expression but with different gaze directions. Infants preferred those faces that displayed a congruent arrangement. Nonetheless, a gaze effect was found only in approach-oriented emotions, which were preferred with direct gaze. This finding converges well with recent studies that found enhanced ERPs for happy and angry expressions with direct gaze in 4- and 7-month-olds (Hoehl and Striano, 2008; Rigato *et al.*, 2010; Striano *et al.*, 2006).

The fourth study investigated whether infants showed a visual preference for a certain gaze direction also in neutral faces. In contrast to our prediction, and to previous findings (Farroni *et al.*, 2002), infants did not prefer faces with direct gaze. One explanation is that a neutral expression is ambiguous for infants, and they may not therefore associate a particular gaze direction with it. Alternatively, it might be that, at this age, eye gaze direction in isolation does not play a strong role in determining visual preference, as it does at birth, and instead facial expressions are greater determinants of preference. It is also possible that coding looking times manually in this experiment was a less sensitive measure than using eye trackers in other experiments.

Other methodological limitations of the present study also need to be taken into account. For instance, we used measures of the first look as opposed to total looking time. This was done in order to compare the findings from the two different populations since adult studies usually avoid total looking time measures due to the top-down cognitive processes that may become engaged (e.g., Manns *et al.*, 2000; Snyder *et al.*, 2008). However, the first look may not be the ideal measure to determine cognitive processes with infant populations, and total looking time may need to be considered in future studies. Future research is also needed to clarify the infant preference for fearful faces with averted gaze, since this was observed in only one experiment, and to further investigate development of the negativity bias suggested by Vaish *et al.* (2008). Finally, the fact that this study used static face stimuli is an important consideration, to the extent that it remains unclear how appropriate it may be to infer from our results about real-life settings, where more dynamic emotional expressions are encountered.

In summary, the current study demonstrated that both adults and infants discriminate the approach- and avoidance-oriented emotions, matching them with direct and averted gaze respectively, in line with the SSH. Nonetheless, infants showed a greater sensitivity to gaze direction in the approach-oriented emotions and, in one experiment, also in one of the avoidance-oriented emotions (fearful) by expressing a visual preference for the congruent displays, while adults detected the congruence/incongruence in all the approach- and avoidance-oriented emotions by looking at the incongruent displays. To conclude, our findings suggest that the SSH may apply from infancy, with a gradual extension from approach-oriented emotions to the avoidance-oriented emotions.

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