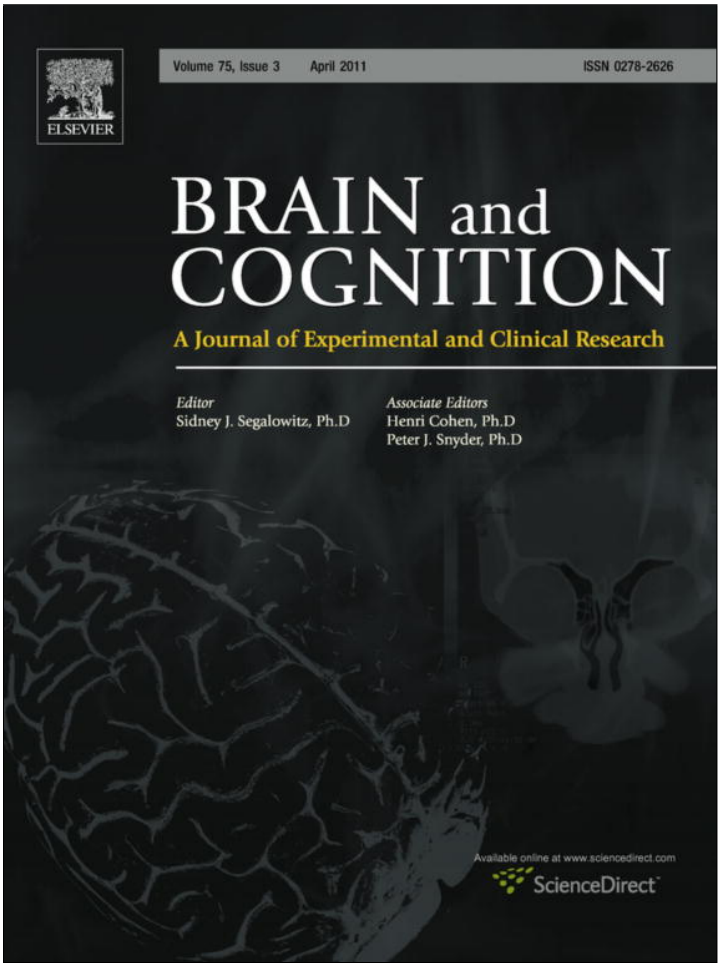
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The effects of mothers' past infant-holding preferences on their adult children's face processing lateralisation

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ABSTRACT

Face processing development is negatively affected when infants have not been exposed to faces for some time because of congenital cataract blocking all vision (Le Grand, Mondloch, Maurer, & Brent, 2001). It is not clear, however, whether more subtle differences in face exposure may also have an influence. The present study looked at the effect of the mother's preferred side of holding an infant, on her adult child's face processing lateralisation. Adults with a mother who had a left-arm preference for holding infants were compared with adults with a mother who had a right-arm holding preference. All participants were right-handed and had been exclusively bottle-fed during infancy. The participants were presented with two chimeric faces tests, one involving emotion and the other one gender. The left-arm held individuals showed a normal left-bias on the chimeric face tests, whereas the right-arm held individuals a significantly decreased left-bias. The results might suggest that reduced exposure to high quality emotional information on faces in infancy results in diminished right-hemisphere lateralisation for face processing.

1. Introduction

Infants will preferentially orient to face-like patterns within hours after birth (e.g. Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991; Valenza, Simion, Macchi Cassia, & Umiltà, 1996), suggesting an innate ability to process faces. However, it takes children years to reach the level of expertise adults have in processing faces. For example, children are able to discriminate faces as well as adults on the basis of face contours at the age of six and on the basis of the spacing of the face elements only at the age of 10 (Mondloch, Le Grand, & Maurer, 2002). According to Mondloch et al. (2002) "the development of configural processing lags behind the development of featural processing and processing based on the external contour of faces (p. 563)". Notwithstanding the extended period of face processing development, the learning process starts right after birth. For example, within a few days new-borns are able to recognise their mothers face when it is presented together with that of a stranger (Pascalis, de Schonen, Morton, Deruelle, & Rabre-Grenet, 1995).

For face recognition to develop normally, infants need to be exposed to faces. Maurer and colleagues have studied the effects of early visual deprivation as a result of bilateral dense cataracts during infancy (Maurer, Lewis, & Mondloch, 2005; Maurer, Mondloch, & Lewis, 2007). When infants are born with this condition, their retinas do not receive patterned visual input for as long as the opaque lenses in their eyes have not been removed or replaced. Even when infants are treated within a few months after birth, some aspects of face recognition abilities fail to develop in later childhood (Le Grand, Mondloch, Maurer, & Brent, 2003; see Maurer et al. (2005), for a review). Whereas individuals, years after having been treated for early cataract, are able to distinguish faces normally on the basis of the external face contour or the forms of the facial features (mouth, nose, eyes), they have difficulty binding together facial features into a holistic gestalt (Le Grand, Mondloch, Maurer, & Brent, 2004) and to take into account the distance relations between the face features (Le Grand et al., 2001, 2004). These abilities depend usually on right-hemisphere processing. Because they do not as a rule develop within the first few months of life when visual deprivation usually occurs, this indicates that early face exposure is important in that it sets up the basic neural architecture in the right-hemisphere for later development of these abilities (cf. Maurer et al., 2007).

Although early face input thus appears to be an important prerequisite for proper face recognition development, it is not known yet whether variations in type or quality of face exposure matter. Of course, variation in face exposure should not, for ethical reasons, be manipulated experimentally, but there are regularly occurring circumstances that may influence the type of face exposure received by some infants. Most people prefer holding an infant to the left side of their body (see for a review, Donnot & Vauclair, 2005), presumably because of their own right-hemisphere

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lateralisation for face perception and because it allows them to better monitor the infant's own facial and other emotional expressions (e.g. Bourne & Todd, 2004; Harris, Almerigi, Carbary, & Fogel, 2001; Vauclair & Donnot, 2005; but see Donnot & Vauclair, 2007). For example, in a study with 287 mother–infant dyads, Salk (1960) found 83% of the right-handed and even 78% of the left-handed mothers to have a left-holding preference.

According to Harris (2010) and Harris et al. (2001) the left-side bias occurs on a test of imagination, as well as with real infants or with dolls and is mostly subconscious. The left-side bias cannot be explained by the heartbeat explanation, the favoured holding position, handedness or femaleness. He hypothesises this bias, "is a product of selective hemispheric arousal accompanying the act (...). The hypothesis supposes that the perception of faces, especially emotional faces, activates neural systems usually predominantly lateralized to the right hemisphere (...), thereby driving attention to the contralateral, or left, side of personal space. Left-side holding thus would be in the direction to which the holder's attention has been endogenously directed by the act of engaging the infant." (Harris et al., 2001, p. 160). More evidence for the attention hypothesis comes from Harris, Cárdenas, Spradlin, and Almerigi (2010) who did find a left visual hemispace bias for dolls but not for books and bags.

The percentage of left-handers who prefer to hold an infant on the right-arm, however, is considerably higher when the task of holding has to be combined with a simple motor task, thereby apparently overruling the face-lateralisation incentive to cradle on the left: Van der Meer and Husby (2006) found as many as 60.7% of the left-handed male and female participants in their study to cradle on the right-arm when asked to also give the "infant" (a doll in their study) a pacifier. Now, the side to which a mother prefers to have her infant during holding and care-taking is likely to determine the view an infant has of its mother's face during much of the time it is awake and near her. That is, left-arm held infants will typically have a better view of the left side of their caregivers' face than right-arm held infants (Hendriks, van Rijswijk, & Omtzigt, 2010). Because, normally, the left side of a face reflects emotions more intensely than the right side (Christman & Hackworth, 1993; Sackeim, Gur, & Saucy, 1978; Borod, St.Clair, Koff & Alpert, 1990; Borod, Haywood, & Koff, 1997), the left-held infant is likely to be provided with a higher quality input of this important information.

Is it probable, however, that the side on which an infant is habitually held can influence its face processing development? The answer to this question must depend largely on the way the infant is fed. Infants under three months of age, for instance, sleep fifteen to sixteen hours on average of each 24-h period (e.g. Michelsson, Rinne, & Paajanen, 1990; Walker & Menaheim, 1994; Wooding, Boyd, & Geddis, 1990). Infants of parents with a conventional Western style of caring, are left awake without contact for about two hours on average (St.James-Roberts et al., 2006, Table 2, London Community). Of the remaining six to seven wakeful contact hours each day, a substantial amount of time is spent on feeding (e.g. 4.1 h for a 10-day old infant; St.James-Roberts et al., 2006, Table 2). In other words, of the limited amount of time young infants are awake and in close proximity to a face most is spend on feeding. When an infant is breast-fed, it is regularly switched from one arm to the other, exposing the infants to two sides of the face about equally. It is not exactly equal because mothers who give breast-feeding tend to feed more from the left than right breast (see Trevathan, 1982). With bottle-feeding, however, switching is not necessary. In the latter case, the mother will have the tendency to hold the infant on her non-dominant arm, in order to keep her dominant hand free for the bottle, therewith exposing her infant mainly to one face side during feeding. Another important difference between bottle-fed and breast-fed infants is that early mother–infant interaction seems to differ. Not only does bottle-feeding last less long than breast-feeding, but it also involves less mutual gazing (see Lavelli & Poli, 1998). Of course, the mother also needs her dominant hand free in other care-taking situations in which the infant lies on its back such as during diaper changing and bathing the infant. This would even increase the proportion of time the bottle-fed infant is seeing its mother's face from one side only.

Given the evidence for rapid face learning in infancy and the existence of a critical period for face processing, as demonstrated by Maurer et al. (2005, 2007) with congenital cataract patients, this could have lasting consequences for face processing development. Note, however, that the exact nature of the critical or sensitive period for face processing is partly unknown, although by inference Nelson (2001) would suggest the first 6–12 months of life. How long this experience must last in order to maintain the ability to recognise faces is even more uncertain. In view of the fact that the right side of the face shows emotional expressions less well than the left side, it was conjectured that bottle-fed individuals of mothers with a right-holding preference have a less well developed face recognition system. There is also an effect on the visual perspective of optical flow depending on whether the infant is fed to the left or right. The mother torso blocks part of the visual field. For left-held infants, the blocked part is in the right visual hemi-field. As a result, there is a right-sided stable foreground and left-sided background flow. Even new-born infants can process the latter type of visual information, because the visual areas representing optical flow and movement are rather well developed at birth. Because the left visual hemi-field projects to the right-hemisphere, this means that the information coming from the visual hemi-field best positioned to see the mother's (moving) face, would be processed by the hemisphere specialised for face processing.

In contrast, for right-held infants the unblocked hemi-field is to the right and the more salient moving stimuli project to the left-hemisphere, the hemisphere less specialised in face processing. The aforementioned observations come from Fritzsche (2003), who described this for breast-fed infants. To a lesser degree, however, this will also hold for bottle-fed infants because bottle-fed infants are less close to their mother's breast than breast-fed infants. This was confirmed in a doll study, which showed that left-holding mothers had a substantially more visible left face half from the infant's point of view than right-holding mothers had of the right face half even when they were looking at the doll (Hendriks et al., 2010). This again suggests that holding an infant on the right-arm provides the infants with less than optimal facial information.

Since the recognition of faces (e.g. Farah, Wilson, Drain, & Tanaka, 1998; Kanwisher, McDermott, & Chun, 1997; Rossion et al., 2000) and facial emotion (e.g., Borod et al., 1990; Campbell, 1982) are considered to be specialised functions of the right-hemisphere, we expected right-held individuals to show a less well pronounced right-hemisphere lateralisation for these functions. The current study was set up to test this assumption.

We presented adults who as an infant had been bottle-fed only (to maximise the influence of holding preference) and who had been either mostly left-held or mostly right-held (see below) with two chimeric faces tests: an emotion and a gender test. Both tests were adapted from previous studies and involved presentations of two images simultaneously, one above the other. The tests were presented in free vision mode (Levy, Heller, Banich, & Burton, 1983), allowing the participant to freely move the eyes over the stimulus before reaching a decision.

In the first experiment, the Emotion test (cf. Levy et al., 1983), the chimeras were constructed from two opposite face halves of the same person, one half expressing happiness and the other half bearing a neutral expression. The purpose of this task was to determine whether right-held individuals show the normal left-bias for perceiving an emotion. As has been repeatedly demonstrated, most people show a left-bias, that is, a tendency to choose the chimera with the facial expression on the left (e.g. Ashwin, Wheelwright, & Baron-Cohen, 2005; Burt & Perrett, 1997; Levy et al., 1983; Luh, Rueckert, & Levy, 1991; Nicholls & Roberts, 2002; Rueckert, 2005). For the second experiment, the Gender test, the two chimeras in each pair were made by combining a female with a male face half. The purpose of this task was to find out whether right-held individuals have a reduced left field bias for gender recognition. A left visual field/right-hemisphere bias has also been identified with alternative versions of the chimeric faces test that have used negative facial emotion and judgements of sex, age, and attractiveness (see Bourne, 2008). The second task was therefore added because studies using gender chimeras also typically find a left-side bias, i.e. an inclination to judge the chimera with the female face-half on the left as appearing more feminine (Burt & Perrett, 1997; Butler et al., 2005; Luh et al., 1991). If a similar effect were to be found with gender chimeras as with emotion chimeras, this would also tell us that the effect would not depend on the processing of facial emotion, emotion processing being largely right-hemisphere lateralised as well, as has been demonstrated in children already as young as 5 years of age (Aljuhanay, Milne, Burt, & Pascalis, 2010). We predicted that right-held in comparison to left-held individuals would show a reduced left-bias for both emotion and gender information in faces, indicating a reduced right-hemisphere lateralisation for face processing and not only for facial emotion.

2. Method

2.1. Participants

Students from the universities in Nijmegen, the Netherlands (Radboud University Nijmegen and HAN University of Applied Sciences) were invited to participate in the study if they were right-handed and, to the best of their knowledge, had been entirely bottle-fed as an infant. Right-handed students with a left-handed mother were particularly encouraged to participate in the study, because we foresaw an underrepresentation of left-handed – and consequently probably right-holding mothers – otherwise, with left-handedness being much less common in the general population. Prospective participants were told they would be presented with visual stimuli on a computer screen, but not that these stimuli were faces. Initially 73 students enrolled in the study. All subjects gave informed consent to participation. The study was approved of by the ethics committee of the Faculty of Social Sciences, Radboud University Nijmegen.

To minimise the possible influence of other factors on face processing development, the participants were further selected on the basis of the information obtained from them and their mothers by means of questionnaires, and depression and handedness scores. The questionnaire for the participants entailed questions about possible visual deficits (e.g. squint, amblyopia, reduced vision in one or two eyes), that for the mothers questions about the neonatal period, the feeding history during the first half year (e.g. bottle-feeding versus breast-feeding, involvement of other caregivers, infant holding-side preference) and possible visual, neurological and/or developmental disorders in their child.

Participants and mothers were also tested for symptoms of depression in present (participants) and past (mothers) by means of the 16 depression items from the Dutch version of the Symptom Checklist-90-R (see Derogatis, 1986; Derogatis, Lipman, Rickels, Uhlenhuth, & Covi, 1974). According to the manual the internal consistency of the depression scale for a sample of participants without psychopathology (normal population) is 0.91; test–retest reliabilities for two periods of one month were 0.76 and 0.86, and for a period of two months 0.72. Both convergent and divergent validity were in the expected direction. Correlations were low for divergent validity and in the medium ranges for convergent validity (Arrindell & Ettema, 2003). Mothers were asked to answer the questions for the post-partum period in retrospect: we felt that a severe post-partum depression was likely to be remembered. The motivation to do so was that maternal depression may in itself have an effect on face processing development (e.g., Striano, Brennan, & Vanman, 2002), because depressed mothers display more flat affect, more negative and less positive facial emotions to their child (e.g. Field, 1992).

Handedness was tested by means of a 10-item handedness questionnaire (Van Strien, 1992), in participants to enable selection of fully right-handed participants and their mothers only to enable selection of either fully right-handed or fully left-handed mothers. The latter was done to increase the likelihood that all mothers, whether right-handed or left-handed, were inclined to bottle-feed by holding the bottle in their dominant hand and the infant on their non-dominant arm, as is the most common pattern of behaviour. Only participants and mothers that were fully right- or left-handed on 10 out of 10 items of the Van Strien checklist were selected.

Thus, the group of left-held participants selected all had right-handed mothers – excluding six candidates with a left-handed mother – and the group of right-held participants all had left-handed mothers – excluding one candidate with a right-handed mother. On the basis of the results of the questionnaires, we excluded the data of a further eleven candidates (and their mothers) from the analyses, mostly for multiple reasons: maternal depression (5), participant depression (4), additional breast-feeding (5), and/or substantial involvement of the father in daily bottle-feeding (3).

Fifty-five participants remained: 25 in the left-held (11 male, 14 female) and 30 in the right-held group (15 male, 15 female). The slightly greater number of right-holding mothers was due to the fact that we had especially urged participants with left-handed mothers to participate. Age did not differ significantly between groups (Left-held: $M = 27.2$, $SD = 5.1$; right-held: $M = 25.3$, $SD = 3.1$, $t(38.381) = 1.59$, $p = .120$). In both groups the mother had been the primary caregiver, had been the sole or main person involved in feeding, and had fully bottle-fed her child from the very beginning.

2.2. Materials

The stimuli for the tests were constructed from photographs selected from a commercially available database (Lundqvist, Flykt, & Öhman, 1998). For the Emotion test we selected the happy and neutral frontal photographs of five male and five female posers. The photographs of each poser were vertically divided and recombined to form two chimeras: one with the happy face half on the left (from the observer's point of view) and the neutral face half on the right and the other chimera combining the remaining face halves. The chimeras were transformed into grey-scale images and an oval cut-out of the chimeras was made to obscure (most of) the hair and neck (see Fig. 1a). The chimeras were then rotated vertically to create mirror images of the originals in addition. The resulting eighty images subtended about 9×7 cm on the screen. On each of the 40 trials, a chimera and its mirror image were presented simultaneously, one above the other. The relative positions of the original and mirror chimeras were counterbalanced and the order of presentation was randomised. The participant's task was to indicate which chimera looked happier. For the Gender test,

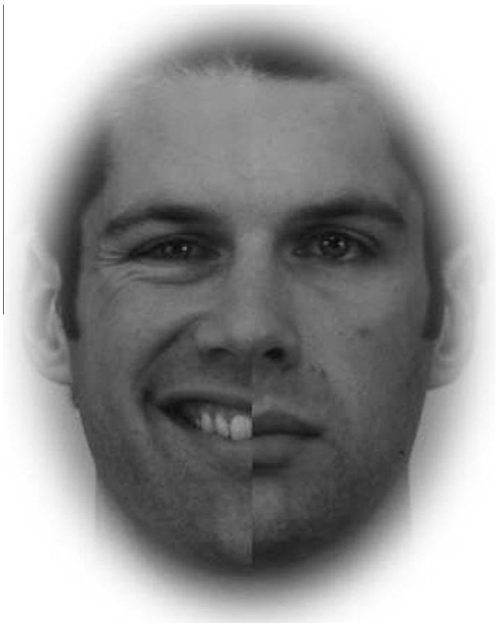

Fig. 1a. Example of emotion chimera.

we selected the neutral expressions of an additional six male and six female posers from the database. The procedure for constructing the chimeras was similar to the one described above, except that now the combined face halves were from two different posers: a male and female poser (see Fig. 1b). The resulting 48 images were presented in 24 trials, with the task of the participant being to indicate which of the two chimeras looked more feminine.

2.3. Procedure

Prospective participants were first tested for handedness. Next, a questionnaire was administered and permission was asked to contact the mother (or father or other caretaker, in case the mother was not available; this happened in none of the cases). If the participant agreed, the mother was contacted immediately and asked whether she would be willing to participate in the study and answer a number of questions about her child. It was explained what the purpose of the study was and that the results would be encoded anonymously. If consenting to participate (which all did), the mother was given a questionnaire and tested for handedness and depressive symptoms post-partum. Next, the participant was subjected to the two face tests, first the Emotion and then the Gender chimeras test. The stimuli were presented on a computer screen by means of the software program Powerpoint (slide-show). The participant gave his/her choice ("top", "bottom" or "don't know") on each trial verbally. The answer was registered by the experimenter and later entered into a computer. Following the procedure of Levy et al. (1983), we calculated for each participant a face encoding asymmetry score by subtracting the number of trials on which the chimera had been chosen with the happy/female side to the left from the trials on which the chimera had been chosen with the happy/female side to the right. The total was then divided by the number of trials on which the participant had reached a decision (i.e. without the trials on which the participant couldn't make a choice; this happened in less than 1% of the trials in the Emotion test and 2% in the Gender test). Thus, a left-bias would be indicated by a negative asymmetry score, a right bias by a positive asymmetry score. The results were then analysed statistically with SPSS. Analyses were carried out with independent *t*-tests, one-tailed, unless otherwise specified.

Fig. 1b. Example of gender chimera.

3. Results

As in prior studies, the participants in the present study – all right-handed – showed a left-bias (depicted by the negative means in Table 1) which was significantly different from zero, in both the Emotion and the Gender test and this was also true when both left-held and right-held participant groups were considered separately.

To test for the effects of mother's holding preference and sex of participants simultaneously, univariate analyses of variance were carried out on the Emotion and the Gender data with infant-holding preference and sex entered as factors. On the Emotion chimeras, participants with a left-holding mother had a significantly larger leftward bias than those with a right-holding mother, $F(1, 51) = 19.96$, $p < .001$ (see Table 1 for means and standard deviations per group and sex). There was no effect of sex ($F = 0$) and no interaction between sex and holding preference ($F = 1.3$).

On the Gender chimeras, individuals with a left-holding mother again had a significantly larger leftward bias than those with a

Table 1
Left-side bias.

	M	*SD*	One-sample *t*-test *H*0 = 0
Emotion chimeras			
Total group (*N* = 55)	−.221	.162	$t(54) = 10.1$, $p < .001$
Left-held (*n* = 25)	−.313	.163	$t(24) = 9.6$, $p < .001$
Females (*n* = 14)	−.294	.190	
Males (*n* = 11)	−.338	.124	
Right-held (*n* = 30)	−.145	.118	$t(29) = 6.73$, $p < .001$
Females (*n* = 15)	−.167	.149	
Males (*n* = 15)	−.123	.074	
Gender chimeras			
Total group (*N* = 55)	−.305	.173	$t(54) = 13.1$, $p < .001$
Left-held (*n* = 25)	−.402	.111	$t(24) = 18.1$, $p < .001$
Females (*n* = 14)	−.384	.085	
Males (*n* = 11)	−.424	.139	
Right-held (*n* = 30)	−.225	.175	$t(29) = 7.02$, $p < .001$
Females (*n* = 15)	−.253	.169	
Males (*n* = 15)	−.197	.183	

right-holding mother, $F(1, 51) = 19.2$, $p < .001$. The effects of sex ($F = .03$) and the interaction between sex and feeding posture ($F = 1.4$) were again not significant Because of the absence of an effect of sex, further data analyses were carried out with independent *t*-tests (one-tailed).

To explore the source of the diminished left-bias average for right-held individuals, we inspected the individual bias scores more closely. All participants with a left-holding mother ($n = 25$) had a leftward bias with both Emotion and Gender chimeras. Most of the participants with a right-holding mother ($n = 30$) also turned out to have a leftward bias with Emotion ($n = 25$) and Gender chimeras ($n = 26$), but reduced and (still) significantly different from the leftward participants (Emotion: left-held: $M = -.313$; $SD = .163$; right-held: $M = -.179$; $SD = .097$; $t(48) = 3.55$, $p < .001$; Gender: left-held: $M = -.402$; $SD = .111$; right-held: $M = -.266$; $SD = .149$). Some of the right-held participants had a rightward or no bias (Emotion: four participants had a rightward bias, one no bias; Gender: two participants had a rightward bias, two no bias).

4. Discussion

A significant leftward bias for face chimeras (emotion and gender) was found for both the left-held and the right-held participant group. The leftward bias for face chimeras replicates earlier findings thereof (e.g. Levy et al., 1983; Luh et al., 1991; Rueckert, 2005). Female and male participants had similar left-biases, as is consistent with some (e.g. Levy et al., 1983; Rueckert, 2005) but not all (Bourne, 2005) earlier studies. More importantly, we found evidence for a reduced leftward bias for face chimeras in individuals who as an infant had been right-held as opposed to left-held by their mothers. This effect was not specific for the perception of emotion since the same bias was also found for the perception of gender. As a result we suggest that side of holding affects face perception in general.

Of course the quality of the stimuli might have affected our results. Note, however, that researchers using different kind of stimuli (printed photo's, photo's on computer monitor, cartoons, stimuli with and without clear transitions between the two face halves) found the same kind of results. The direction and size of the difference between emotion and gender chimeras in the present study was in line with the results of Burt and Perrett (1997) and Butler et al. (2005), but not with Luh et al. (1991) who found a larger effect for emotion than gender. Luh et al. paired a neutral face half with a happy face half, as in the current study. Still, the quality of the pictures could have affected the size of the left visual hemispace bias. The latter might be especially true for the gender test, which is heavily depended on the number and quality of the feminine characteristics in the photos.

As left-held infants have a better view of their mother's most expressive left face half (Hendriks et al., in press), this finding suggests that a reduced left-bias is caused by poorer exposure to faces during infancy. Whether this would be the result of face perception per se could be studied in future research by also assessing perception for stimuli that have been proven not to be sensitive for the left visual hemispace bias, such as assessing object form (Luh et al., 1991), books and bags (Harris et al., 2010) or by presenting stimuli that normally result in a right visual hemispace bias, such as speech reading (Burt & Perrett, 1997).

A reduced leftward bias has also been found in left-handed individuals (Harris et al., 2001; Levy et al., 1983; Rueckert, 2005). One might argue, therefore, that the reduced left-bias in *right-held* participants (with left-handed mothers) was caused, not by their suboptimal view of their mother's face, but by their own atypical pattern of lateralisation resulting from their genetic predisposition. Although this possibility cannot be ruled out, there are two arguments against it. First, the right-held participants were all strongly right-handed (on the handedness test, they were right-handed on 10 out of 10 items), which makes atypical lateralisation due to genetic factors perhaps not so likely for other functions. Second, even truly left-handed individuals (which the present participants, being strongly right-handed, were clearly not) usually show the typical right-hemisphere lateralisation for faces, and, correspondingly, mostly prefer to *cradle* an infant on the left-arm, similar to the right-handed population (e.g. Salk, 1960: 78% of left-handers cradle on the left-arm). In other words, the present results seem difficult to explain with a genetic predisposition account.

There is another potential problem for the interpretation that the present results are caused by impoverished face exposure. That is, if one's holding bias is related to one's own bias on face chimera tests, as has been indicated by some studies (e.g. Bourne & Todd, 2004; Vauclair & Donnot, 2005, but see Donnot & Vauclair, 2007), a mother with a rightward bias might prefer to hold an infant on her right-arm because that would agree with her own lateralisation for the perception of faces and emotions. Consequently, the mother's face half most visible to the infant might be her most expressive face half, even in right-held infants, making it less likely that the present results are attributable to differences in face exposure. Although compelling, this line of reasoning has difficulties of its own. That is, left-handers are *not* lateralised as strongly as right-handers but then simply "reversed". For example, the incidence of the typical pattern of left-hemisphere language dominance is 96% in strong right-handers, whereas only 27% of strong left-handers show the reversed atypical pattern of right-hemisphere language dominance (Knecht et al., 2000). If a similar pattern of incomplete reversed lateralisation holds true for face and/or emotion processing, an infant of a left-holding right-handed mother will still have a much higher chance of being exposed to an optimally expressive face half, than an infant of a right-holding left-handed mother. This interpretation finds further support in a review of facial asymmetry in emotional expression by Borod et al. (1997). Of eight studies in their review that included left-handed posers, six did not find evidence for differences between left-handed and right-handed posers in side of facial expressiveness, and two found a lesser expressiveness of the left face half (i.e. no asymmetry) in left-handers. There was no indication of a better right face-half expressiveness in left-handed posers to match the better left face-half expressiveness in right-handed posers. In others words, there is no reason to believe that right-held infants were exposed to an equally expressive face half as the left-held infants. It is noteworthy, in this respect, that a much higher proportion of right-holding preference has been observed in left-handers that had to combine the holding task with another motor task (Van der Meer & Husby, 2006) than in left-handers that just did the holding task (Donnot & Vauclair, 2005) suggesting that, while bottle-feeding, many left-handers overrule their natural tendency to hold an infant on the left-arm and instead hold it on the right-arm, just to free the dominant left-arm for the bottle. If this were true for some of the left-handed mothers in the present study, this might mean that they indeed had the typical right-hemisphere lateralisation for face processing as most left-handers have and thus indeed exposed their child to their less optimal right face half during bottle-feeding.

One can only guess what it is about being exposed to the normally more expressive side that is so important for enhancing face-recognition skills. In analogy to infant-directed speech which provides the infant with better speech samples, the benefit might come from being exposed to stronger cues. It was Stern (1974) who noted that infant-directed facial expressions, like infant-directed speech, are often more exaggerated, slower in tempo and longer in duration than adult-directed facial expressions. More recently some empirical evidence was found by Chong, Werker, Russell, and Carroll (2003) for specific infant-directed adult facial expressions. They identified three patterns: one that is reminiscent of Stern's 'fish face' and conveys love and concern, one of his 'mock surprise', and a third that seemed to be a special kind of infant-directed smile.

That the intensity of facial expressions plays a role is also evident from studies on mother–infant interactions in which the mother is depressed (Striano et al., 2002; Field, 1992). According to Field (1992), "Depressed mothers typically show flat affect and provide less stimulation as well as less contingent responsivity during early interactions, and their infants show less attentiveness, fewer contented expressions, more fussiness, and lower activity levels" (pp. 52–53).

To conclude, the present results may be taken to suggest that infant exposure to the left as opposed to the right face side of their mother might boost their right-hemisphere lateralisation for face recognition. As the left face side is generally more expressive than the right face side, this suggests that the development of the neuronal architecture for face processing is helped by the emotional expressiveness of the facial input. It appears then that face exposure in infancy does not need to be entirely *absent* as in congenital cataract (cf. Le Grand et al., 2001, 2003) for face processing to be affected: even infants with normal daily face exposure may show atypical face processing later in life, if face exposure quality is suboptimal. If this is indeed the case, this would be an important addition to the congenital cataract studies, because congenital cataract blocks all patterned vision and leads to serious life-long vision problems even in individuals treated in early infancy, leaving the theoretical possibility that the face processing problems caused by congenital cataract result from more general problems with processing visual stimuli instead of being a specific problem limited to faces. It is also possible that side-of-cradling causes "characteristic perceptual asymmetry" (i.e. an asymmetry in favour of the sensory half-field contralateral to the more aroused hemisphere) quite as much as strength of lateralisation. Kim, Levine, and Kertesz (1990) reported that about half of the variation in performance on the Chimeric Faces Test as well as on bilateral tachistosopic discrimination tests is attributable to individual differences in characteristic perceptual asymmetry.

The present findings may be taken to suggest that the developing face processing system is highly sensitive to the type of facial information it is exposed to, as would be consistent with a proposal made by Nelson (2001): "the face recognition system is broadly tuned at birth, but is subsequently 'sculpted' by the kind of exposure it receives."

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