Céline Scola[1]
Jacques Vauclair[1,2]

[1]*Research Center in the Psychology of Cognition Language & Emotion University of Provence 29 Ave. Robert Schuman 13621 Aix-en-Provence Cedex 1, France*
E-mail: jacques.vauclair@univ-provence.fr

[2]*Institut Universitaire de France*

Is Infant Holding-Side Bias Related to Motor Asymmetries in Mother and Child?

ABSTRACT: *Studies have revealed a preference for the left hemibody in infant holding in 65–85% of cases. Several investigations have linked this preference to maternal asymmetries. The main goal of the present study was to assess manual and hemispheric asymmetries in both mother and child and delineate their respective influence on holding-side biases. Holding side was assessed by direct observation, and by use of a questionnaire within populations of mother–child dyads. Maternal asymmetries were handedness and hemispheric specialization for perceiving emotions. Infant asymmetries were fetal position, asymmetric tonic neck reflex (ATNR) at birth and handedness at 19 months of age. To that purpose a longitudinal study has been made with infants observed at 2 and 19 months of age. A significant relationship was found between maternal handedness and holding preferences, but no significant relation was obtained between hemispheric specialization and holding preferences. Fetal position in utero but not ATNR, was significantly related to holding-side preferences. Finally, holding side at 2 months was significantly associated with infants' unimanual preferences. © 2010 Wiley Periodicals, Inc.* Dev Psychobiol 52: 475–486, 2010.

Keywords: *laterality; postural asymmetry; holding-side biases; mother-child relationships; cradling; fetal position; ATNR*

INTRODUCTION

The majority of mothers prefer to hold their young children on the left side of their body when soothing or calming them (e.g., Salk, 1960). This behavior is commonly called holding bias. The holding bias is present (1) in several cultures (e.g., Saling & Cooke, 1984), (2) in nonhuman primates (e.g., Hopkins, 2004), (3) and in both mothers and nonmothers (e.g., Vauclair & Scola, 2009), as well as young girls (e.g., Saling & Bonert, 1983), and even fathers (Scola & Vauclair, 2009). The generality of this behavior has prompted growing interest in the literature and some researchers have attempted to explain the origin of this bias. As holding-side preference is a postural asymmetry, several studies have examined the relationship between the side of holding and the presence of other asymmetries expressed by the mother (e.g., perceptual asymmetries and handedness: Bourne & Todd, 2004; Harris, Almerigi, & Kirsch, 2000; Huggenberger, Suter, Reijnen, & Schachinger, 2009; Manning & Chamberlain, 1991; Vauclair & Donnot, 2005) or by the child (e.g., asymmetric tonic neck reflex or ATNR: Bundy, 1979; Ginsburg, Fling, Hope, Musgrove, & Andrews, 1979; Sieratzki & Woll, 1996).

The aim of this article is to identify the respective relations between these various asymmetries and the newborn holding. For that purpose, four studies were carried out. In the first study, we examined the relationship between holding-side biases and maternal handedness. The second study was concerned with mothers' hemispheric specialization in the perception of emotions, measured at three different times (during pregnancy, immediately after delivery, and 19 months later). The third study focused on the relationship between holding bias, fetal position, and ATNR. Lastly, the fourth study explored the possible relation of the mother's holding-side bias and the child's manual preferences.

One hypothesis that is often advanced to explain the left bias for holding a young child refers to the handedness

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of the holder. Holding her child on the left allows the mother to leave the preferred hand (the right hand in 90% of cases: Annett, 1985) free for performing other activities. Several authors (e.g., Harris et al., 2000; Manning & Chamberlain, 1991; Matheson & Turnbull, 1998; Salk, 1960; Vauclair & Donnot, 2005) have shown that handedness has no significant influence on holding-side preferences. However, these studies also reported that left-handers held young children against their left hemibody in smaller proportions than right-handers (e.g., Harris et al., 2000; Salk, 1960; Vauclair & Donnot, 2005). Given the relatively low percentage of left-handers in the population (~10%), samples of left-handers are often insufficient to show the possible effect of handedness on holding-side biases. Van der Meer and Husby (2006) studied the link between handedness and holding-side biases in a population of 765 men and women of all ages. These authors observed a left holding bias in right-handers and a right holding bias in left-handers. In this study, however, holding amounted to a ''complex bimanual activity,'' as participants were requested to hold a baby doll and simultaneously put a pacifier in its mouth. This means that the infant holding measure was associated with another manual activity that had to be performed at the same time. Thus, the results of this study cannot be taken into account when assessing the relation between handedness and holding-side bias. A recent study by Donnot (2007) is more convincing in this respect. This author tested the holding side within two populations of left-handed women (students and mothers). He showed that the left-handed students preferred holding a young infant on the left side, but that the left-handed mothers had no preference for one side to hold their newborn. The purpose of one of our studies was therefore to replicate some results obtained by Donnot (2007) in a very large sample of mothers in order to have enough left handed mothers.

Another explanation for holding biases is linked to a hypothesis about the cerebral lateralization of emotions. The right hemisphere is known to play a role in the expression and perception of emotional information (e.g., Bryden & Levy, 1983) and could consequently be involved in the regulation of emotional exchanges when a parent holds his or her child. Different investigations (e.g., Bourne & Todd, 2004; Huggenberger et al., 2009; Vauclair & Donnot, 2005) have demonstrated that hemispheric specialization in the perception of facial emotions is correlated with holding-side biases. The main finding is that the left holding bias is linked to enhanced perception of facial emotions in the left visual field, that is, under the control of the right cerebral hemisphere. However, this relation is limited by the fact that the link has only been observed in participants who perceive emotions better in the left visual field, as right-holders do not display a corresponding right visual field bias (Vauclair & Donnot, 2005). Another limitation is that the above-mentioned studies were conducted with nonparents (university students). Thus, Donnot and Vauclair (2007) and Vauclair and Scola (2009) did not observe any significant relationship between perception of either visual or auditory emotions and holding-side preferences in populations of mothers, in marked contrast to the results obtained with student populations (Bourne & Todd, 2004; Vauclair & Donnot, 2005; Harris, Almerigi, Carbari, & Fogel, 2001; Huggenberger et al., 2009).

In addition to maternal asymmetries, the infant/child may also actively influence the holding-side bias, as this postural behavior could be related to several motor asymmetries in the child, such as fetal position and ATNR. The proportion of two-thirds is frequently given for various postural and motor asymmetries in mothers and children: (a) 2/3 of newborns prefer to turn their head to the right when they are in a supine position (ATNR: e.g., Barnes, Cornwell, Fitzgerald, & Harris, 1985), (b) 2/3 of mothers prefer to hold their newborn on the left side of their body (e.g., Harris et al., 2001), and (c) 2/3 of fetuses occupy a left position in the mother's womb (Goodwin & Michel, 1981; Previc, 1991). The frequency of this proportion leads to questions about the relationship that may exist between these different asymmetries.

Ginsburg et al. (1979) suggested that there might be a relationship between holding side and ATNR. The orientation of the child's head might, for example, lead the mother to hold her child preferentially on the left side in order to be facing him/her and thus facilitate interactions. However, the link between ATNR and holding bias is a controversial issue in the literature. While some studies (e.g., Ginsburg et al., 1979; Thompson & Smart, 1993) have reported a significant relationship between ATNR and holding-side preferences, others have found no evidence of any such relationship (e.g., Cornwell, Barnes, Fitzgerald, & Harris, 1985; Dagenbach, Harris, & Fitzgerald, 1988). For their part, Goodwin and Michel (1981) suggested that fetal position might be linked to ATNR, as fetuses that occupy a left position in the mother's womb are thought to turn their head more frequently to the right side after birth when they are in a supine position. Thus, the confirmation of Ginsburg et al.'s hypothesis (1979) of a relationship between holding side and ATNR suggests that fetal position may also influence infant holding patterns. One objective of our study was to identify the relationship between these various asymmetries (fetal position, ATNR, and actual holding side at birth) and holding-side biases expressed by the mother.

The question of the origin of human handedness is complex and unsettled. A number of different hypotheses have been put forward (these will not be described in detail here: for a review, see Hopkins & Rönnqvist, 1998),

referring to a variety of factors, including genetic (oocyte), hemispheric, hormonal and environmental ones (fetal position giving rise to vestibulospinal ATNR, imitation, right-handed environment, etc.). The vestibulospinal, or congenital, hypothesis postulates that the position of the fetus gives rise to motor and hemispheric asymmetries (Previc, 1991). The vestibular receptors of the fetus are unevenly stimulated, according to its position, and this in turn means that the extensor muscles of the neck are unevenly stimulated, thus triggering ATNR. Therefore, asymmetric fetal and neonatal positions will be one of the factors for handedness (Previc, 1991). Van der Meer, Van der Weel, and Lee (1995) showed that asymmetric neonatal head turning induced visuomanual asymmetries in the neonates, who are more likely to move their seen hand than their unseen hand. Other environmental influences on handedness begin at birth. For example, the child may imitate handedness preferences expressed by the mother (e.g., Harkins & Uzgiris, 1991) or by the experimenter (Fagard & Lemoine, 2006). In addition, the holding-side bias may encourage the use of one hand rather than the other and foster hemispheric asymmetry for gaze. An infant held on the left side has his/her right hand placed close to the mother's body; the infant also has a clearer view of the mother's left hemiface and can therefore perceive her facial emotions better with the right cerebral hemisphere. Thus, holding bias may, to some extent, be responsible for the handedness of the child. The goal of Study 4 was therefore to verify the possible relation between holding bias, 19 months after birth, and the child's handedness.

Current research on holding-side biases (e.g., Reissland, Hopkins, Williams, & Helms, 2009; Scola, Arciszewski, & Vauclair, submitted; Scola & Vauclair, 2009) aims to enhance understanding of the holding-side bias by taking emotional variables (maternal depression and anxiety) into consideration. However, the relation with asymmetric behavioral variables (mother's and child's handedness, hemispheric specialization, and ATNR) and holding-side preferences has yet to be clarified. The main objective of the present study was therefore to assess the respective influence of these various asymmetries and the interrelations between them. It seems important to consider at the same time asymmetries of mothers and children, because children could actively participate in the holding by their own posture, like mothers do (Negayama et al., 2010).

GENERAL METHODOLOGY

Holding Measures

Holding bias was measured by direct observation, supplemented by the use of a questionnaire. For the observation, the mother was instructed as follows: ''Pick your baby/child up as you would if he/she were feeling distressed or if he/she had started crying. Now, show me how you would hold him/her in your arms.'' This instruction is currently used for the assessment of the holding bias (e.g., Donnot, 2007; Donnot & Vauclair, in press; Harris et al., 2001; Vauclair & Scola, 2008, 2009). The preferential holding side was then recorded, before administering the questionnaire (this observation was regarded as the first item of the holding questionnaire). The questionnaire consisted of five questions assessing the holding side in different situations (for more details about the questionnaire, see Vauclair & Scola, 2009).

The observation was always performed before presenting the holding questionnaire. As mothers' responses to the questionnaire perfectly matched the observational records, we calculated only one holding score. When the infant was held against the left hemibody, we scored -1 and when the infant was held against the right hemibody, we scored $+1$.

Evaluation of the Mother's Handedness

Maternal handedness was assessed by the Edinburgh Handedness Questionnaire (Oldfield, 1971). This questionnaire determines whether participants are more or less right-handed, left-handed, or ambidextrous. It consists of 10 items, yielding a laterality score of between -10 and $+10$.

Evaluation of the Child's Handedness

Infant handedness was assessed by means of five tasks: two unimanual tasks and three bimanual tasks. For each task, the child was seated at a table with marks on the top for positioning the hands and a cross in the center where the objects were to be placed. These marks were designed to retain the infant's attention when the experimenter placed the objects on the cross in the center and also served to ensure that the objects were the same distance away from both the child's hands. Three trials were run for each task. If the right hand was used, a score of $+1$ was assigned and if the left hand was used, the score was -1.

- *Task 1*: Simple unimanual task. The child was told to pick up a small stuffed toy placed before him/her.
- *Task 2*: Complex unimanual task. The child was told to take a small stuffed toy out of a narrow glass held by the experimenter.
- *Task 3*: Simple bimanual task. The child was told to take a small stuffed toy out of a narrow glass which he/she had to hold. The hand that took the stuffed toy was deemed to be the active hand. The glass was placed in

such a way that the toy could only be removed if the glass was held in one hand.
- *Task 4*: Bimanual task and strength. The child was told to pull a plastic teddy bear out of a cylinder. The active hand was the one that pulled the teddy bear out.
- *Task 5*: Bimanual task and accuracy. This task was based on the test tube used to study nonhuman primates (e.g., Vauclair, Meguerditchian, & Hopkins, 2005). An opaque plastic tube open on two sides (15 cm in length and 1.5 cm in diameter) was used. Food (chocolate) was inserted in the tube at both ends and the tube was then placed in front of the child. The child was told to hold the tube and to use a finger to obtain the food. The finger used was deemed to be the preferred hand.

For each infant two quotients of laterality were calculated, one for unimanual handedness (tasks 1 and 2) and another for bimanual handedness (tasks 3, 4, and 5).

Assessment of the Child's Postural Asymmetries

Evaluation of the Fetal Position. Administrative restrictions in French maternity hospitals prevented us from gaining access to the mothers' medical records. In this study, the nature of the fetal position was therefore obtained by directly asking the mothers. During delivery, mothers are systematically informed by midwifes about the position of the fetus. It was explicitly stated that mothers should only provide this information if they were sure it was accurate.

Evaluation of the ATNR. The child was laid in a supine position and the experimenter (CS) positioned herself in the child's vertical axis so as not to influence the orientation of the child's head. For the same reason, the mother positioned herself beyond the child's visual field, behind the experimenter. The head was maintained in the central axis, and then immediately released. Although time has not been registered, it was observed that the newborn maintained its head position in the minutes following release. The side to which the child turned his/her head was recorded (Thompson & Smart, 1993). If the child turned his/her head to the right, the score of $+1$ was assigned and if the child turned his/her head to the left the score of -1 was given. ATNR was recorded within 2–3 days of birth.

Evaluation of Asymmetry in the Perception of Emotions

Asymmetries in the visual perception of emotions were measured by means of the chimeric faces task (CFT) designed by Bourne and Todd (2004). This task consists of the presentation of faces composed of two hemifaces with two different expressions (smiling and neutral). The purpose of this task is to detect the participant's dominant visual field in the recognition of facial emotions. Ten pairs of faces were presented, and for each trial, participants were shown two faces (A and B) on a computer screen, one directly above the other, for 4 s. For example, if the upper face (A) was composed of a smiling hemiface on the right and a neutral hemiface on the left, the bottom face (B) was its mirror image, with the half-smiling face on the left and the neutral one on the right. Participants were asked to say which face looked the most pleasant or smiling, "A" or "B."

Participants

The four studies reported in this article were administered to six different samples of participants. Alongside a novel sample of 123 participants were participants who had been enrolled in previously published (Vauclair & Scola, 2008, 2009) or recently submitted studies (Scola et al., submitted). However, it is important to note that the data presented in the present article have never been published. The published or submitted material concerned the impact on holding-side biases of variables other than asymmetry (e.g., affective variables such as anxiety and depression) rather than the variables of asymmetry (hemispheric, ATNR, and fetal position) and laterality (mother's and child's handedness), which constitute the focus of the present article.

Statistical Analysis

The statistical data processing was performed using SPSS. Linear regressions were used to measure the effects of the different asymmetry variables (maternal handedness, hemispheric specialization in the perception of emotions, fetal position, ATNR, and infant handedness) on holding-side preferences (a nominal variable with two modalities: right vs. left). The linear regressions were preferred to chi-square analyses because this method allowed us to use the complete data set and to consider simultaneously more than two variables. Primiparity and age of the mothers have been recorded but they had no effect on holding side and asymmetries. These analyzes are not reported here for more readability.

STUDY 1. HOLDING BIAS AND MOTHER'S HANDEDNESS

The objective was to test the relation between handedness and maternal preferences for one particular holding side. Various authors (e.g., Harris et al., 2000; Matheson & Turnbull, 1998) have tested this hypothesis in different

populations but have failed to demonstrate any significant link between laterality and holding side, despite a slight reduction in the latter in left-handers. While these investigations were performed on populations of non-parents, Donnot (2007) compared the holding-side biases of two populations of left-handed women: mothers and students. This author found that a left holding bias was present in this students' population but not in the mothers' sample. Left-handed mothers displayed no holding bias either on the left side or the right side, whereas right-handed mothers preferentially held their children on the left side. The aim of the present study was thus to verify the role of handedness on holding-side preferences within a population of mothers.

Participants

Two hundred sixty mothers were observed in a single session in the first 6 days after delivery ($M = 3.24$). One hundred forty-four of these participants had been observed in a previous study (Vauclair & Scola, 2008) and 116 participants were added for the purposes of the present study. All participants were studied in four 4 maternity hospitals in the Marseille area over a period of 3 years. The average age of the mothers was 30.2 years and 46.5% of them were primiparous.

Method

Holding-side bias was assessed by direct observation and by questionnaire (see the General Methodology Section). The assessment of the mothers' handedness using the Oldfield questionnaire (1971) revealed that 11% ($N = 29$) of them were left-handed and 89% were right-handed, which is consistent with the literature (Annett, 1985). There were no ambidextrous mothers in our sample.

Results and Discussion

The results showed that 71.1% of the mothers preferred to hold their newborn on the left side of their body. The distribution of this sample indicates that right-handed mothers predominantly held on the left side, while left-handed mothers had no side preference for holding their infants (Tab. 1).

The binomial regression model showed that maternal handedness explains significantly holding-side bias: $b = -.956$, $SE = .400$, $\beta = .384$, $p = .017$. A mother's handedness could thus explain her side preference for holding her child. It should be recalled that handedness has been found to have no significant link with holding-side biases in populations of students (e.g., Harris et al., 2000). It also has no relation among fathers (Scola & Vauclair, 2009). However, the mother's handedness explains the side on which she holds her child, but as shown by the descriptive statistics, we can observe that it is only in the right-handed sample. The explanation of holding side by handedness is not sufficient itself, because if it did, then left-handed mothers should have expressed a right holding bias.

Table 1. Distribution (Number) of Holding-Sides Biases According to Handedness

	Left holding side	Right holding side
Left-handed mothers	15	14
Right-handed mothers	170	61

STUDY 2. HOLDING-SIDE BIAS AND MOTHER'S HEMISPHERIC SPECIALIZATION

The goal of the second study was to test the relation between hemispheric specialization in the perception of emotions by future mothers or mothers and holding-side bias. Recent studies (Donnot & Vauclair 2007; Vauclair & Scola, 2009) of mothers after delivery have failed to find any relation between emotion perception and holding bias, in contrast to studies of student populations (e.g., Vauclair & Donnot, 2005; Huggenberger et al., 2009). Different hypotheses have been put forward to explain these differences, such as the effect of hormonal factors or the nature of the child/adult relationship. Thus, the lack of a link between hemispheric specialization and holding bias could be related to hormonal changes after childbirth. According to Hausman and Güntürkün (2000), hormonal changes in the female cycle may cancel perceptual asymmetries. It also seems important to consider the nature of the relationship between held and holder. Students who hold a doll cannot be compared to mothers holding their newborn. These two behaviors do not involve the same degree of attention, investment, etc., and it is thus not surprising to observe different results in these two contexts. The objective of this study was to verify the effect of asymmetries in the perception of emotions on holding bias in different samples of mothers studied at three different times: during pregnancy, just after delivery and when the child had reached the age of 19 months. In the three samples there was about 10% of left-handers (between 7.9% and 11.3%), and for each analysis handedness has been controlled for with the linear regression.

Study During Pregnancy

Participants. Eighty-one future mothers were studied during pregnancy ($M = 6.2$ months). A detailed analysis

of the results obtained on 76 of these mothers is provided in Scola and Vauclair (2009). Five additional future mothers were added in the present study. The average age of the mothers was 29.85 years and 65.78% of these mothers were nulliparous.

Method. Holding bias was assessed by questionnaire. Note that this questionnaire has been validated in several previous studies (e.g., Donnot, 2007; Donnot & Vauclair, 2007, in press; Vauclair & Scola, 2009). The aim was to find out how future mothers thought they would hold their children. Hemispheric specialization in the perception of emotions was measured by means of the CFT designed by Bourne and Todd (2004).

Results. The results showed that 72% ($n = 59$) of future mothers declared that they would hold their newborn on the left side of their body. Likewise 65.4% of future mothers displayed a preference for perceiving emotions in their left visual field, 27.2% displayed a preference for the right visual field, and 7.4% of future mothers had no preference for either visual field. An analysis of these results revealed an absence of any significant association between hemispheric specialization and holding side, $b = .020$, $SE = .018$, $\beta = 1{,}020$, $p = .275$. Hemispheric specialization in the perception of emotions assessed during pregnancy therefore has no significant effect on the way future mothers think they will hold their children in their arms.

Study Carried Out Just After Delivery

Participants. For this study, 123 mothers were studied in three maternity hospitals between 3 and 6 days after delivery. The mothers had an average age of 31 years and 49.6% of them were first-time mothers.

Method. Holding side was measured by observation and by questionnaire. Hemispheric specialization in the perception of emotions was assessed by means of the CFT designed by Bourne and Todd (2004).

Results. Results showed that 69.1% ($n = 85$) of mothers preferred to hold their newborn on the left side of their body in the days following delivery. Likewise 42.3% of mothers perceived emotions better in their left visual field, while 37.4% displayed a preference for the right visual field. During this postnatal period, nearly 20.3% of mothers had no preference for either visual field. The analysis of results failed to reveal any significant effect of hemispheric specialization on holding-side bias, $b = .048$, $SE = .089$, $\beta = 1.050$, $p = .584$. Hemispheric specialization in the perception of emotions, measured a few days after birth, therefore has no significant effect on a mother's infant-holding side.

Study Carried Out 19 Months After the Birth of the Child

Participants. In this study, 43 mothers were studied in their homes when their children had an average age of 19 months. These mother–infant dyads were being followed longitudinally for 2 years (Scola et al., submitted). However, the results on the variables examined in the present article have not been reported before. Mothers were aged 29.8 years on average and 65.1% of them were primiparous.

Method. Holding side was measured by observation and by questionnaire, while hemispheric specialization in the perception of emotions was measured using Bourne and Todd's CFT (2004).

Results. The results showed that 62.8% ($n = 27$) of mothers preferred to hold their children on the left side of their body, even when the latter had reached the age of 19 months. Likewise 41.9% of future mothers perceived emotions better in the left visual field and 37.2% in the right visual field. During this session, 20.9% of mothers had no preference for either visual field. The results failed to reveal any significant effect of hemispheric specialization on holding-side bias, $b = -.156$, $SE = .122$, $\beta = .856$, $p = .200$. Therefore, hemispheric specialization in the perception of emotions, assessed when the children have reached the age of 19 months, has no significant effect on the mothers' preferred holding side.

Discussion of Study 2. The link between hemispheric specialization in the perception of emotions and infant holding was found not to be significant in a population of mother–child dyads, regardless of the period. These results are consistent with findings for other populations of mothers (Donnot & Vauclair, 2007; Vauclair & Scola, 2009), but not for the general population (e.g., Bourne & Todd, 2004; Harris et al., 2001; Huggenberger et al., 2009; Lucas, Turnbull, & Kaplan-Solms, 1993; Vauclair & Donnot, 2005).

STUDY 3. HOLDING BIAS AND ASYMMETRIES IN THE FETUS AND NEWBORN

This study examined the relationship between fetal and neonatal asymmetries (i.e., fetal position in the womb and ATNR) and holding-side bias. Various studies have tested the hypothesis of a relationship between holding bias and ATNR (e.g., Ginsburg et al., 1979; Thompson &

Smart, 1993), but some of the reported results are contradictory and our study was therefore designed to settle this question one way or the other. In addition, as other studies had demonstrated a relationship between fetal position and ATNR (Previc, 1991), the objective of the present study was also to clarify whether the way in which the fetus is positioned in the womb is linked with maternal holding preferences.

Participants

This study involved 92 mother–child dyads studied in three maternity hospitals between 3 and 6 days after delivery. These mothers were from the same sample as the 123 mothers observed in Study 2 (session just after birth). However, 29 mothers were removed from the sample either because the mothers did not know the fetal position of their child or because ATNR could not be observed in the child. The mothers had an average age of 28.7 years and 55.2% of them were primiparous.

Method

Holding side was analyzed by observation and by questionnaire. The children's ATNR was observed (Thompson & Smart, 1993) and information about their previous fetal position was provided by the mothers (for more details of this measurement, see the General Methodology Section).

Results and Discussion

The results indicated that (1) 73.9% of the mothers preferred to hold their newborn against their left hemibody, (2) 51.1% of the fetuses were positioned on the left side of their mother's womb, and (3) 53.3% of the newborns preferentially turned their head to the left a few days after birth. A significant effect of fetal position on infant holding-side preference was found, $b = .505$, $SE = .252$, $\beta = 1{,}658$, $p = .045$. Fetal position therefore appears to explain the mother's preferred holding side. Fetuses positioned on the left in their mother's womb were more often held on the left side in their mother's arms (see Tab. 2).

As no significant effect was observed between holding side and ATNR, $b = .332$, $SE = .247$, $\beta = 1{,}394$, $p = .178$, holding side was deemed not to be dependent upon the child's asymmetrical tonic neck reflex (see Tab. 3).

Table 2. Distribution (Numbers and Percentages) of Holding-Side Biases According to Fetal Position

	Left holding side	Right holding side
Left position in womb	39 (82.9%)	8 (17.1%)
Right position in womb	29 (64.4%)	16 (35.6%)

Table 3. Distribution (Numbers and Percentages) of Holding-Side Biases According to ATNR

	Left holding side	Right holding side
Left ATNR	39 (79.6%)	10 (20.4%)
Right ATNR	29 (67.4%)	14 (32.6%)

The results highlighted a significant relationship between fetal position and holding side, but not between ATNR and holding side. Fetal position may therefore be related to mother's holding bias after the child's birth.

STUDY 4. HOLDING SIDE AND INFANT HANDEDNESS

One of the various hypotheses put forward to explain the origin of handedness is environment-based (e.g., Fagard, 2001; Hopkins & Rönnqvist, 1998). According to this hypothesis, an asymmetry in infant holding could promote the use of one particular hand and consequently affect the development of hand preference in the child. This environmental factor may thus be one of the components in the development of handedness. For example, Harkins and Michel (1988) demonstrated that if there is any parental influence on children's laterality, it must come from the mother. We know that (1) mothers usually hold their child more frequently than fathers and (2), as reported in Study 1, mothers' handedness has an effect on their holding-side bias. In this study, it should however be noted that we are not attempting to ascribe handedness to holding-side bias, as the origin of handedness is dependent on several factors and this trait is multidimensional (Hopkins & Rönnqvist, 1998). Rather, the purpose of this study was to describe the relationship between these two types of asymmetry.

Participants

Forty mothers took part in this study, which was conducted in the mothers' homes with their children when the latter were 2 and 19 months of age. These mother–infant dyads were studied longitudinally for 2 years as part of another study (Scola et al., submitted) but the results on the variable examined in the present article (infant handedness) are novel. The average age of the mothers was 28.6 years and 62.5% of them were primiparous.

Method

Holding side was evaluated by observation and by questionnaire during both sessions. Statistical analyses were focused on holding-side biases at 2 months. While holding bias can influence handedness, the holding patterns recorded when the children were 2 months old were probably more representative than those displayed when the child was 19 months of age, as holding occurs less often at 19 months that at 2 months. The children's handedness was assessed by five tasks described above. Their indexes of laterality were analyzed separately for uni- and bimanual preferences.

Results and Discussion

The results showed that 63.4% of mothers preferred to hold their children on the left side of their body, even when they were 19 months old. Seventeen percent of the children preferred to use their left hand for unimanual activities and 23.7% for bimanual activities (see Tab. 4).

The results failed to reveal any significant link between bimanual laterality and holding side, $b = -.009$, $SE = .175$, $\beta = -.081$, $p = .609$. Nor was there any significant link for unimanual laterality, although more children who were held on the right side tended to be left-handers (25%) compared with those who were held on the left (14%), $b = -.287$, $SE = .159$, $\beta = -.274$, $p = .079$. In short, the results revealed the existence of a slight effect of holding-side bias on unimanual hand preferences at 19 months of age. However, no relation was found for bimanual tasks (see below for an extended discussion).

GENERAL DISCUSSION

Various authors (e.g., Bogren, 1984; Harris et al., 2001; Sieratzki & Woll, 1996) have sought to understand the origin and function of the holding-side bias. As their conclusions differ, according to population and evaluation methods, the main objective of the present studies was to investigate the effects of various asymmetries on holding-side biases in the mother–child dyad. Taken together, the four studies described here show that a mother's preference for a particular holding side is associated with her handedness. They also show that there is no link between hemispheric specialization in the recognition of emotions and her choice for one holding side, whatever the period (before or after delivery). As for children, while there is a significant relationship between fetal position and holding-side biases, there is no such relationship between ATNR and holding-side biases. We also showed that the holding-side bias may affect the development of the child's unimanual hand preferences. This result needs to be examined in greater depth, as no effect of holding-side bias was observed for bimanual handedness and there was only a trend for unimanual reaching. We should therefore assume that handedness patterns are unstable during the first 3 years of life (e.g., Corbetta & Thelen, 1999; Fagard, Spelke, & von Hofsten, 2009).

The idea that holding-side bias might be explained with reference to handedness was first postulated in Salk's pioneering study (1960). While several subsequent studies (e.g., Donnot and Vauclair, 2007; Harris et al., 2000) have played down the role of handedness in the determination of holding-side biases, they have nonetheless shown that the proportion of left-handers who held on the left side is smaller than that of right-handers (e.g., Harris et al., 2000; Salk, 1960). Donnot (2007) tested samples of left-handers. This author showed that left-handed students who held a doll demonstrated the typical left holding bias (like it is reported in right-handed populations). While left-handers mothers did not hold mainly their newborn on the left side, Study 1 confirmed the same influence of handedness on a mother's preference for holding her newborn. The binomial regression analysis shows that right handedness explain significantly the left holding side bias. However, while a left holding bias was observed in right-handed mothers, no equivalent holding bias was seen in left-handed mothers, who displayed no preference for either side. It would therefore appear that the sole factor of handedness is not sufficient for determining the holding side bias among left-handed mothers. It should be pointed out that no study has ever demonstrated a reversal of holding side (right holding bias) in populations of left-handers. Note also that left-handed people are often found to be less strongly lateralized than their right-handed peers when performing activities designed to assess both manual preference and manual performance (e.g., Doyen, Duquenne, Nuques, & Carlier, 2001;

Table 4. Distribution (Numbers) of Infant Handedness According to Task

Handedness for each task	Task 1	Task 2	Task 3	Task 4	Task 5
Right hander	32	33	28	23	23
Left hander	6	8	9	10	11
No preference	2	0	2	5	3
Missing value	1	0	2	3	4

Schmidt, Oliveira, Rocha, & Abreu-Villaca, 2000). Left-handers have to adapt to a right-handed world and therefore exhibit greater flexibility in using their hands. It is likely that left-handed mothers are better able to hold their infant on both sides. It is also interesting to observe that the influence of handedness on holding-side bias seems to depend on the nature of the population under scrutiny and on the type of relationship established between the holder and the held. Donnot (2007), for instance, failed to detect any effect of handedness in a population composed of students. Scola and Vauclair (2009) also reported an absence of effect among new fathers, whereas in the present study, an effect was clearly present among mothers.

The influence of hemispheric specialization on holding-side bias has been demonstrated repeatedly (e.g., Bourne & Todd, 2004; Donnot and Vauclair, 2005; Harris et al., 2001; Huggenberger et al., 2009). It seems that this influence is more pronounced in a general population than among mothers with their newborns. Using the CFT, some studies (e.g., Donnot & Vauclair, 2007; Vauclair & Scola, 2009) have even demonstrated an absence of influence of hemispheric specialization in the recognition of facial emotions on holding-side preferences in a population of mothers. As seen above, this difference could be explained by hormonal (Hausman & Günturkün, 2000) and/or the nature of the child/adult relationship (Donnot & Vauclair, 2007). Hausman and Güntürkün (2000) highlighted a link between variations in asymmetries for performing a face discrimination task and hormonal changes during the ovarian cycle, which could reduce the dominance of the left visual field in the perception of emotions in the CFT. An alternative explanation rests on the type of relationship established between the holder and the held. A student with a doll is not faced with the same constraints as a new mother holding her infant. For the former, the holding is passive, while for the latter, the holding is active and mutual adjustment takes place between mother and child (Vauclair & Scola, 2009). The differences between these two situations may well account for the observed differences in the putative role of the right hemisphere.

The present study showed that hemispheric specialization has no effect on holding-side bias, regardless of the period. This result tends to invalidate the hormonal hypothesis (Hausman & Güntürkün, 2000) and instead favors the relational one. Holding her child on her left side is an adaptive behavior for the mother and this behavior involves many more factors than the mere perception of emotions by one cerebral hemisphere. This idea is reinforced by the fact that the processing of emotions by the right hemisphere is not stable, as it can depend on the mother's emotional state (Heller & Nitschke, 1998). In addition, when a mother holds her child in order to soothe him or her, this behavior is not exclusively a question of emotion detection (via the right hemisphere) because the mother also has to take the context into consideration in order to understand and interpret the signals of her child's crying. It would be unrealistic to assume that the context in which a mother tries to console her child only triggers her right cerebral hemisphere. In the artificial doll-holding situation, the holder does not know the context or the child, etc. and the level of attentiveness is very different from that of a mother who is concretely interacting with her newborn. These contextual differences could explain the differential impact of the right hemisphere on holding side within the general population and within a population of mothers.

The influence of ATNR on holding-side bias is a controversial issue in the literature. We report in our study that ATNR had no link with the holding-side biases. This lack of relation may have a number of different causes. Firstly, ATNR was assessed only once, 4 days following the birth of the child, and by simple observation. It is therefore possible that this measure was not representative of the child's preferred head orientation. It would have been interesting to observe ATNR using multiple measures over time in order to obtain a more reliable and accurate assessment of this behavior. Secondly, some studies (e.g., Cornwell, Fitzgerald, & Harris, 1985; Michel & Goodwin, 1979) have shown that the orientation of the child's head is linked to his or her state (e.g., awake, crying, or screaming), but this variable was not taken into account in our study. It would therefore also be interesting to have a systematic method for evaluating ATNR (e.g., Rönnqvist & Hopkins, 1998). Thirdly, if the orientation of the child's head has an effect on holding side, it is probably because it allows the mother to hold her child in such a way that the latter is looking either toward her or toward the environment, depending on the situation. In this specific context, holding position should also be part of the equation, when analyzing the relationship between ATNR and holding side. Indeed, according to the position in which they are placed (e.g., horizontal or vertical), and the direction of their ATNR, children can orient their head either outwards or towards their mother. Therefore, the design of our study prevents us from concluding that ATNR has no effect on holding-side bias. A more accurate measurement of ATNR needs to be combined with an analysis of both holding side and holding position.

Previc (1991) based his theory of the origin of brain lateralization on the rule of the fetal position. As seen above, most fetuses are positioned on the left side of the womb during the third trimester of pregnancy. This asymmetric position is thought to generate stimulation differences between the left and right sides of the fetus and thus to influence different expressions of lateralization. In our study, an effect of fetal position in the womb was

observed on holding-side bias, namely the positioning in the womb (left side) was the same as the holding-side bias recorded after delivery. This is the first time that such a relation has been demonstrated. One could assume that the position of the fetus triggers an unbalanced posture in the mother during pregnancy, that would lead to a postural asymmetry. This postural asymmetry may lead the mother to adopt a left holding bias after delivery. It is also interesting to note that a left orientation of the fetus in the womb is considered to be optimal for normal delivery, as a right position is likely to cause more complications during childbirth (Previc, 1991). It also just so happens that a left holding bias after birth is regarded as more appropriate than a right bias. Salk (1973) reported that a right holding bias following postpartum separation is associated with maternal anxiety or depression (see also Reissland et al., 2009; Vauclair & Scola, 2008, 2009; Weatherill et al., 2004). Although it is still premature to draw any definite conclusions about this link, further studies on this issue should contribute to a better understanding of holding-side bias and its determinants.

Studies of young children have shown that handedness is unstable before 2–3 years of age (e.g., Corbetta & Thelen, 1999; Fagard et al., 2009). However, the first demonstration of manual asymmetry, namely thumb-sucking (Hepper, Shahidullah, & White, 1991), begins in the womb, a finding that has favored the study of handedness at an early age. The origin of handedness nevertheless remains uncertain, and several investigators (e.g., Fagard, 2001; Hopkins & Rönnqvist, 1998) have stressed its complexity and multidimensional nature. Among the different hypotheses about the role of the child's environment, Fagard (2001) has suggested that holding-side biases may partly explain infant handedness. Thus, preferences for one holding side could lead to a disparity in the development of manual skills, leading the infant to prefer the use of one hand (e.g., the right) rather than the other. Our study revealed the existence of a slight effect of holding-side biases on unimanual hand preferences at 19 months of age, but any effect for preferences expressed in bimanual tasks. Bimanual coordination only becomes clearly observable in the second year (e.g., Michel, Ovrut, & Harkins, 1985). Our result therefore needs to be confirmed by other studies and by an assessment of uni- and bimanual handedness during child development. This result nonetheless lends a degree of plausibility to the hypothesis that postural asymmetry in holding a young child contributes to handedness.

The effect of hemispheric and postural asymmetries on holding-side biases needs to be investigated further from a longitudinal perspective, focusing on the nature of the relationship between the holder and the held. Mothers' lateralized behaviors, as well as those of their newborn, should also be evaluated more systematically in order to gain a more accurate explanation for the origin of holding-side biases and a better understanding of the purpose of these biases.

NOTES

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