The Left Cradling Bias: An Evolutionary Facilitator of Social Cognition?

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Highlights

1. LCB reflects an evolutionarily old behavioral bias for perceiving social stimuli
2. A pillow with a face symbol, but not a control stimulus elicited a LCB
3. Cradling side of an infant human doll interacted with social ability in children
4. An infant primate doll reversed the LCB
5. LCB reflects population level brain organisation and domain-specific function

Declarations of interest: none

Abstract

A robust left side cradling bias (LCB) in humans is argued to reflect an evolutionarily old left visual field bias and right hemisphere dominance for processing social stimuli. A left visual field bias for face processing, invoked via the LCB, is known to reflect a human population-level right cerebral hemisphere specialization for processing social stimuli. We explored the relationship between cradling side biases, hand dominance and socio-communicative abilities. Four and five year old typically-developing children (N = 98) participated in a battery of manual motor tasks interspersed by cradling trials comprising a(n): infant human doll, infant primate doll, proto-face pillow and no-face pillow. Mean social and communication ability scores were obtained via a survey completed by each child's key teacher. We found a population-level LCB for holding an infant human doll that was not influenced by hand dominance, sex, age or experience of having a younger sibling. Children demonstrating a LCB, did however, obtain a significantly higher mean social ability score compared with their right side cradling counterparts. Like the infant human doll, the proto-face pillow's schematic face symbol was sufficient to elicit a population-level LCB. By contrast, the infant primate doll elicited a population-level right side cradling bias, influenced by both hand dominance and sex. The findings suggest that the LCB is present and visible early in development and is likely therefore, to represent evolutionarily old domain-specific organisation and function of the right cerebral hemisphere. Additionally, results suggest that a LCB requires minimal triggering but can be reversed in some situations, possibly in response to species-type or levels of novelty or stress as perceived by the viewer. Patterns of behavioral biases within the context of social stimuli and their associations with cognitive ability are important for understanding how socio-communication abilities emerge in developing children.

Abbreviations:

Left cradling bias (LCB)

Key words:

behavioral bias, cerebral lateralization, cognition, left cradling bias (LCB)

1. Introduction

At the population-level, approximately 70% of mothers prefer to cradle their infants on the left side of their own bodies regardless of a number of factors including: activity type (e.g., calming, feeding, baby positioning: lateral, upright) (Bourne & Todd, 2004; Bundy, 1979; de Château, Holmberg, & Winberg, 1978; Donnot, 2007; Ginsburg, Fling, Hope, Musgrove, & Andrews, 1979; Hopkins, 2004; Matheson & Turnbull, 1998; Reissland, 2000; Reissland, Hopkins, Helms, & Williams, 2009; Salk, 1973; Sieratzki, Roy, & Woll, 2002; Sieratzki & Woll, 2002, 2004; Thompson & Smart, 1993; Todd & Banerjee, 2016; Tomaszycki, Cline, Griffin, Maestripieri, & Hopkins, 1997; Turnbull & Bryson, 2001; Turnbull & Lucas, 1991, 1996; Turnbull, Rhys-Jones, & Jackson, 2001; Vauclair & Donnot, 2005; Woll & Sieratzki, 2002), mother's handedness (Previc, 1991; Sieratzki & Woll, 1996, 2002; Vauclair & Donnot, 2005; but see van der Meer & Husby, 2006) or mother's culture (Bourne & Todd, 2004; Richards & Finger, 1975). The population-level *left side cradling bias* (LCB) tends to persist for at least the first 12 weeks of the baby's life (Todd & Banerjee, 2016).

1.1 Cerebral Lateralization

The causal nature of the LCB is debated, but the most parsimonious theory relies on cerebral lateralization of function. Cerebral lateralization is the dissociation of specialized processes of left and right hemispheres of the cerebral cortex (for a review see Rogers & Vallortigara, 2013). Because the nerve fibers of the motor cortices are contralaterally innervated, these dominant hemisphere processes can manifest as contralateral motor behaviors (Hellige, 1993). Although quite recently cerebral lateralization and associated contralateral motor biases was thought to be a human unique traits, non-human animal studies suggest that its origins date back to the rise of vertebrates (Rogers & Andrew, 2002; Vallortigara & Rogers, 2005) and possibly even earlier (Anfora et al., 2011; Bell & Niven, 2016; Frasnelli, Vallortigara, & Rogers, 2012). It is theorized that cerebral lateralization of brain function affords advantages to the organism. Strong cerebral lateralization may increase neural efficiency by allowing different functions to operate in parallel across hemispheres, decreasing duplication of functioning across hemispheres and eliminating the initiation of simultaneous and potentially incompatible behavioral responses (Rogers, 2002; Vallortigara, 2000).

Patterns of motor dominances in a wide range of animal species suggest that throughout evolution, the right hemisphere became dominant for urgent responses to the environment (e.g., predators) (e.g., Bonati, Csermely, & Sovrano, 2013; Franklin & Lima, 2001; Koboroff, Kaplan, & Rogers, 2008; Lippolis, Bisazza, Rogers, & Vallortigara, 2002; Martin, Lopez, Bonati, & Csermely, 2010; Rogers, 2000), while the left hemisphere emerged as dominant for routine and structured motor sequencing (e.g., feeding) (e.g., Alonso, 1998; Hopkins, 2007; Rutldige & Hunt, 2003; Westergaard & Suomi, 1996). Through human evolution, these hemispheric dominances (e.g., responding to novel and threatening stimuli) may have provided a platform for more sophisticated human cognitive capabilities (e.g., social emotional behaviors like infant cradling).

Research suggests that humans share a right hemisphere and left gaze bias for face perception (for a review see Demaree, Everhart, Youngstrom, & Harrison, 2005) (e.g., looking time of centrally presented faces) with sheep (Peirce, Leigh, & Kendrick, 2000), dogs and rhesus monkeys (Guo, Meints, Hall, Hall, & Mills, 2009) and chimpanzees (Morris & Hopkins, 1993). Additionally, the left side of the face in both humans and nonhuman primates has been reported to display emotive expression earlier and more intensely than the right side of the face, for example in chimpanzees (Fernandez-Carriba, Loeches, Morcilla, & Hopkins, 2002); macaques: (Hauser, 1993); marmosets: (Hook-Costigan & Rogers, 1998) and baboons (Wallez & Vauclair, 2011). These findings suggest that a human bias for both comprehending and producing facial expressions (identity and emotive expressions) dominated by the right hemisphere is an inherited primate trait. Although this manuscript focuses on the visual channel, human nonverbal, evolutionarily urgent vocalizations (e.g., cries and shouts) associated with threat or danger in the environment, elicit greater right-hemisphere activation compared with the left hemisphere (for a review, see Scott, Sauter, & McGettigan, 2009) suggesting that a right hemisphere dominance for social emotional processing in humans is not specific to a single sensory modality.

Cerebral lateralization of function interpreted through contralateral motor biases allows us to understand better how populations behave in the real world. For example, a left visual preference (right hemisphere) for detecting and monitoring conspecific behavior has ramifications for social positioning during natural human and non-human animal behavior. A study of chimpanzees and gorillas revealed that individuals navigate around conspecifics with a bias for keeping social partners to their left side (Quaresmini, Forrester, Spiezio, & Vallortigara, 2014). The study was later replicated with school children across a range of ages (Forrester, Crawley, & Palmer, 2014). The findings suggest that the right hemisphere may provide an advantage for monitoring the threat levels of conspecifics. However, human social emotional abilities go far beyond locomoting through social spaces. In human (and presumably many non-human animal species) the right hemisphere and left visual field play a critical role in discriminating between social companions and recognition of individuals based on familiarity (for a review, see Vallortigara & Versace, 2017).

1.2 Left Visual Field (LVF) Bias for Human Face Processing

Research suggests that a left visual field (LVF) bias for social stimuli is directly related to human population-level right hemisphere specialization for processing faces. Cognitive and behavioral studies consistently report LVF superiority for processing face stimuli, and these findings align with fMRI and ERP face processing responses, shown to be strongly associated with a LVF and right hemisphere superiority for face stimuli (for a review, see Yovel, 2016). Information presented to the LVF has a direct path to the right hemisphere of the brain and numerous brain imaging studies have reported an anatomically larger fusiform gyrus in the right hemisphere with heightened activation when processing faces compared with non-face stimuli (for a review, see Haxby & Gobbini, 2011). For example, a longitudinal study that implemented both brain imaging (fMRI) and behavioral (eye-tracking) methods demonstrated a positive association between an individual's LVF bias and the strength of right lateralized hemisphere activation during face processing (Yovel, Tambini & Brandman, 2008). The study also indicated that the level of hemispheric bias for face processing remained stable over time. Additional functional imaging research has demonstrated that the right hemisphere is not only dominant for processing faces in general, but it is also selectively dominant for perceiving *human* face identity and strength of facial expressions (Gorno-Tempini & Price, 2001). Clinical studies also support a LVF and right hemisphere advantage for face processing. Individuals with right hemisphere damage demonstrated no LVF advantage and decreased ability to recognize faces (De Renzi, Perani, Carlesim, Silveri & Fazio, 1994). Furthermore, interference in face processing is found when the right (but not the left fusiform gyrus) is disrupted via intracranial electrodes (Jonas et al., 2015; Parvizi et al., 2012). Taken together, these studies converge to suggest that a population-level LVF bias for social stimuli reflects a right hemisphere specialization for attending to and processing social stimuli. As such, visual field biases for faces can act as behavioral markers of anatomical and functional cortical organization of domain specific social processing.

1.3 Social Laterality in Mother Baby Dyads

At no time would it seem more critical for animals to develop social bonds than during the rearing of offspring. Recent research has reported that a myriad of animal species possess social positioning biases, during mother-baby interactions, that favor the right hemisphere and the left eye (Giljov, Karenina, & Malashichev, 2018; Karenina, Giljov, Ingram, Rowntree, & Malashichev, 2017). This orientation of social positioning whilst nurturing offspring has also been identified in great apes (chimpanzees: Nishida, 1993; gorillas: Manning, Heaton, & Chamberlain, 1994). This behavior is likely to be akin to human cradling, supporting an evolutionary continuum of cerebral lateralization for processing social-emotional stimuli.

For the majority of the human population, the LCB facilitates a mutual (mother-baby) right hemisphere advantage for producing and perceiving social signals across visual and auditory social stimuli (Scola & Vauclair, 2010a; Sieratzki & Woll, 2002). The LCB creates a direct route to the right hemisphere through the left visual field of the mother, supporting rapid identification of facial identity and emotional state of the infant (Manning & Chamberlain, 1991). Consequently, the infant is provided with the more expressive left side of the mother's face (Vauclair & Donnot, 2005), which may have the potential to facilitate bonding and social development (Huggenberger, Suter, Reijnen, & Schächinger, 2009). Early social development research suggests that even though neonates have underdeveloped sensory processing channels (Simion, Macchi Cassia, Turati, & Valenza, 2001) faces are still salient stimuli from birth (e.g., Farroni et al., 2005). Regardless of an underdeveloped visual system, neonates preferentially attend to patterns that contain the basic configuration of high-contrast areas of a face (e.g., Johnson, 2007). Moreover, neonates tested at birth demonstrate a preference for faces above other types of stimuli (Bower, 2001; Goren, Sarty, & Wu, 1975; Leppanen, Moulson, Vogel-Farley, & Nelson, 2007; Macchi Cassia, Valenza, Simion, & Leo, 2008; Simion et al., 2001; Umiltà, Simion, & Valenza, 1996; Valenza, Leo, Gava, & Simion, 2006). Johnson, Dziurawiec, Ellis, and Morton (1991) created a schematic illustration of the stimuli that might be optimal for eliciting a face-related preference in neonates. Consistent patterns of results were obtained across investigations of chicks (*Gallus gallus*) and human newborns. These two evolutionarily disparate species demonstrated similar behavioral biases toward face stimuli shortly after hatching or birth, supporting an evolutionary continuity in social orienting (Rosa Salva, Farroni, Vallortigara & Johnson, 2011).

Owing to the rate of cortical development, one might predict that newborns would not benefit from early exposure to visual social stimuli, however, brain imaging findings suggest that neonates may possess face sensitive subcortical neural regions (Johnson, Senju, & Tomalski, 2015; Umiltà et al., 1996), linked to an evolutionarily early predisposition to proto faces. New evidence suggests that basic visual face orienting abilities are in place prenatally as early as 30 weeks of gestations (Reid et al., 2017) and are not dissimilar to the filial responses demonstrated in chicks (Di Giorgio, Loveland, Mayer, Rosa-Salva, Versace, & Vallortigara, 2017). These early behavioral and neural attributes coupled with a reflexive rightward head-turning bias (in the final weeks of gestation through the first six months after birth; Güntürkün, 2003) and a mother's inclination to exhibit a LCB, create ideal conditions for both the infant's survival and developing a social brain.

1.4 Sex, Age and Experience

Evolutionary explanations set up an expectation that the LCB would appear early in ontogeny among both males and females and also without any prior experience of holding infants (e.g. Saling & Bonert, 1983; Todd & Banerjee, 2016). Although the methods used to elicit cradling have been extremely varied across studies, the choice of experimental approach does not appear to influence the robust cradling LCB found in women. However, evidence of a LCB in men has been mixed (Bundy, 1979; Harris, Almerigi, & Kirsch, 2000; Harris, Spradlin, & Almerigi, 2006; Manning, 1991; Nakamichi & Takeda, 1995; Turnbull & Lucas, 1991). Some studies have reported that in men, the LCB is restricted to fathers (Bogren, 1984; Dagenbach, Harris, & Fitzgerald, 1988; Scola & Vauclair, 2010b) and men whose professions required infant care (de Château, 1983). These findings suggests that gender could be an influential LCB factor and additionally that there might be a developmental or experiential component to the LCB. However, to date, it is unclear if any gender bias is mediated by experience or innate predisposition, nor do we understand what exactly it is that makes the LCB emerge in both men and women.

Evidence from cradling studies of girls and boys suggest that a propensity to cradle left is present and visible in children. Girls and boys (aged 2-16 years) demonstrated an LCB using a doll (Pileggi, Malcolm-Smith, & Solms, 2015; Souza-Godeli, 1996; but see de Château & Andersson, 1976). However, Manning and Chamberlain (1991) found that the proportion of left cradling increased with age in girls, only becoming biased to the left by six years of age. In contrast to the findings associated with men suggesting that experience of babies is required to elicit a LCB, boys demonstrated a later developmental trajectory, with a LCB becoming visible not before 16 years of age (de Château & Andersson, 1976).

Across cultures, gender-specific socialisation and family experience might impact the presence of the LCB in young male and female children. In western countries, girls are preferentially socialized to interact with dolls (considered a female-stereotyped toy) from a young age “and may gain formative experience through these interactions” (Todd & Banerjee, 2016). Culturally, boys may be discouraged from interacting with female-stereotyped toys and therefore gain less experience then their female counterparts for developing a cradling bias (Todd, Barry, & Thommessen, 2017). Additionally, experience of sibling care, (as measured by birth order), may also provide important experiences triggering or influencing the strength or propensity for a cradling bias in children. To date, the implementation of non-gender-stereotyped cradling stimuli and the influence of sibling experience have yet to be addressed in systematic fashion to explore how they might contribute to a population-level LCB.

1.5 Motor Biases as a Marker of Cognitive Ability

Motor biases act not only as markers of brain organization, but have also been shown to correlate significantly with subsequent cognitive outcomes (Toga & Thompson, 2003). For instance, at the population-level, strong right hand dominance in children corresponds with the typical development of fine motor skills and subsequent attainment of typical language abilities (left hemisphere dominant; Leask & Crow, 2001). Conversely, weak hand dominance (ambidexterity) is associated with the development of poorer fine motor abilities and weaker language ability (compared with strongly handed individuals) in addition to a rise in neurodevelopmental and mental health disorders (e.g., Rodriguez et al., 2010).

There is currently no evidence suggesting an association between the side of the mother's body on which babies were cradled during the early weeks of infancy and the level of subsequent socio-communicative development. Moreover, population patterns do not necessarily translate to the individual because at the individual level, we cannot be certain of brain organization based on motor biases. However, one retrospective study of healthy adults revealed that individuals who were held with a LCB (derived from family photos) developed a typical left visual field (right hemisphere) bias for responding to chimeric faces, whereas adults that were cradled with a right-arm bias did not (Vervloed, Hendricks, & van den Eijnde, 2011). While all participants could effectively identify the identity and emotional expression of face stimuli, those individuals who were cradled on the left were significantly faster at doing so. The findings suggest that there is significant 'typical' variation in the population and that babies cradled on the left may develop an enhanced right hemisphere bias for processing social emotional stimuli. In fact, one study has even suggested that faces of right-cradlers were less visible from the "infant viewpoint" compared to those of left-cradlers (Hendriks, van Rijswijk, & Omtzigt, 2011). However, at this time it is impossible to reconcile if right side cradled babies were predisposed through heritability (for a genetic account of cradling, see Manning & Denman, 1994) to decreased cerebral lateralization or if the cradling side influenced development.

Although visual and motor biases for social positioning of mother-baby dyads during cradling appear to be rooted in an evolutionarily old right hemisphere advantages for processing social-emotional stimuli, we do not yet understand what features of the baby elicits the LCB in the mother; or if gender, age or experience are contributing factors. Additionally, we seek to better understand better the link between motor biases, cerebral lateralization of function and association with cognitive developmental ability (e.g., Forrester, Pegler, Thomas, & Mareschal, 2014; Lindell & Hudry, 2013).

In the current study, we employed a range of manual motor tasks that explored: hand dominance, cognitive control (impulsivity) and cradling behavior in young typically developing young children. This research takes steps towards addressing some of the gaps in the literature regarding the LCB, motor biases in general and their relationship with cognition. With respect to the cradling results, we predicted: 1) children will demonstrate a preference to hold a doll representing a human infant on their left side, 2) gender, age and experience may influence cradling side bias of the infant human doll; 3) children will demonstrate a preference to hold a non-gender-stereotyped doll (infant primate doll) on their left side because the introduction of the infant primate doll will eradicate socially induced effects of gender, age or experience; 4) no cradling side bias will be found when children hold a control object of the same weight and dimensions as the doll(s) but without social features; 5) the addition of rudimentary facial features to the control object will be sufficient to elicit a left cradling bias in children. With respect to the relationship between motor biases and cognitive ability scores, we predicted: 1) there will be a difference in social ability scores based on cradling side bias and 2) there will be a relationship between the strength of hand dominance for manual motor tasks and communication ability scores.

2. Material and Methods

2.1 Participants

Ninety-eight typically developing children (54 girls, 44 boys) attending reception or year 1 participated in this study (mean age = 69.95 months, SD = 10.64). All children attended a mainstream primary school in central London. Children at this developmental age were chosen because both handedness (e.g., Gudmundsson, 1993) and the cerebral processes associated with hand preference (Bates, O'Connell, Vaid, Sledge, & Oakes, 1986; Fagard & Marks, 2000) have stabilized by then, while also minimizing the amount of time that children have been exposed to socially defined lateralized behaviors. This is also the age used by similar work in this area (e.g., Forrester, Pegler, Thomas, & Mareschal, 2014). For each child, the number of younger siblings living in the home was recorded in order to assess the extent to which exposure to a younger sibling may impact cradling bias.

Table 1. Demographic information of participants

Participant	N	Mean Age in Months	Standard Error	Age Range in Months	Self Report Handedness	Younger Sibling
Girls	54	69.44	1.52	34	7 (L), 47 (R)	17
Boys	44	67.05	1.70	34	8 (L), 36 (R)	9

2.2 Testing Conditions

Children were tested in a small (approximately 2 x 4 metres) quiet room with plain walls. Participants alternated between two testing stations at opposite ends of the room. Each testing station was operated by a different researcher. Each child was presented with three manual-based motor tasks, interspersed with three cradling trials. The tasks were counterbalanced to avoid order effects. Participants began testing at the manual motor station. When the child was at one testing station, the researcher at the other testing station was responsible for coding behavior. The objectivity of coding was high due to the categorical coding of tasks and cradling trials (left, right, correct, incorrect). Inter-rater reliability was performed for 10% of participants, resulting in 100% reliability (r = 1.0).

The number of participants varied across tasks (see section 2.4.1). All children participated in the *Knock and Tap, Peg Board and Card-Lacing* tasks however three children's data from the survey tasks were not completed by key teachers. For cradling trials, only those trials where children followed task instructions and held stimuli in an upright or lateral position were included in analyses. Lower participant numbers for proto-face and no-face pillow stimuli were the result of a between-participant contrast, compared with within-participant contrast for other cradling stimuli (see section 2.4.1).

Table 2 Sample characteristics as a function of task.

Tasks	N	N by Sex	Mean Age (months)	Hand Classification	Younger Siblings
Knock and Tap	98	Girls (54) Boys (44)	69.44 70.40	7 (L), 47 (R) 8 (L), 36 (R)	17 9
Peg Board	98	Girls (54) Boys (44)	69.44 70.40	7 (L), 47 (R) 8 (L), 36 (R)	17 9
Card Lacing	98	Girls (54) Boys (44)	69.44 70.40	7 (L), 47 (R) 8 (L), 36 (R)	17 9
Social Survey Items	95	Girls (53) Boys (42)	69.32 70.74	7 (L), 46 (R) 8 (L), 34 (R)	17 9
Communication Survey Items	95	Girls (53) Boys (42)	69.32 70.74	7 (L), 46 (R) 8 (L), 34 (R)	17 9
Cradling Trials	N	N by Sex	Mean Age (months)	Hand Classification	Younger Siblings
Infant Human Doll	80	Girls (49) Boys (31)	69.96 71.68	6 (L), 43 (R) 6 (L), 25 (R)	17 8
Infant Primate Doll	74	Girls (42) Boys (32)	68.95 70.74	6 (L), 36 (R) 6 (L), 26 (R)	13 7
Proto-Face Pillow	37	Girls (21) Boys (16)	74.91 70.69	3 (L), 18 (R) 3 (L), 13 (R)	7 4
No-Face Pillow	44	Girls (25) Boys (19)	66.32 70.26	4 (L), 21 (R) 3 (L), 16 (R)	7 5

2.3 Manual Motor Tasks

2.3.1 Knock and Tap task:

Each participant began with the *Knock and Tap* task was taken from the NEPSY neuropsychological test battery (Kemp, Kirk, & Korkman, 2001; Korkman, Kirk, & Kemp, 2000). The *Knock and Tap* task was introduced to assess attention and effortful control in young children, as it requires the inhibition of a prepotent action. In this task, the experimenter sat opposite the child (across a table) with hands laid flat on the table. The child was asked to mirror their hand position. Next, the child was asked to indicate their 'favorite hand for writing'. This was taken as indicative of the dominant hand for fine motor actives. There was a 96% concurrence between the child's chosen hand and the hand classification based on the subsequent motor tasks described. The researcher told the child that they would play the game with the indicated (dominant) hand and the other hand (non-dominant) would remain still on the table. The experimenter always conducted the task with the hand that mirrored the child's dominant hand. The researcher provided participants with the following instructions and an accompanying demonstration: "When I knock on the table (closed fist makes contact with the table with an audible sound), you tap on the table (opened palm makes contact with the table with an audible sound). And, if I tap on the table, you knock." Two practice trials were given to make sure that the child understood the task instructions. Fifteen test trials followed as specified in the NEPSY manual (Knock-Knock-Tap-Knock-Knock-Tap-Tap-Knock-Tap-Tap-Knock-Tap-Tap-Tap-Knock). Hesitations were scored as breaks in the flow of the rhythmic trials, and incorrect responses were also recorded.

We used two different manual motor tasks (*Pegboard* and *Card-lacing, see Figure 1)* to assess actual hand dominance. Unimanual actions are typically used to assess hand dominance for fine motor control, thus we introduced the *Pegboard* task. However, unimodal actions (actions that require a single hand to perform an action) are often simple enough that participants may perform the task efficiently with either hand, increasing the likelihood of ambi-preferent scores. Evidence from the laterality literature suggests that bimanual actions (actions that require the use of both hands, such that one hand is holding an object whilst the other hand performs manipulations of the object) demonstrates greater sensitivity as a measure of hand dominance (for a review of hand dominance measures, see Forrester, 2017) Thus, we also introduced the *Card-lacing* task.

2.3.2 Pegboard task:

Participants sat across a table directly opposite the researcher. The researcher produced a white 10 x 10 holed plastic pegboard (*Invicta©* pegboard: 17 x 17 cm, 739 grams). The pegboard and a bowl of multicolored plastic pegs (red, blue, green, yellow) were placed at the child's midline with the pegboard in front of the child and bowl of pegs behind the pegboard from the child's perspective, affixed to the table using Blu Tack©. The pegboard possessed a red outline of a square drawn on the board measuring 6 x 6 holes.

The children were asked to select only red pegs and complete the outline of the 6 x 6 red square. This task required the placement of 20 red pegs. Participants were asked to work as quickly and as accurately as possible. Participants were given a maximum of ninety seconds to complete the task. The researcher scored the number of left handed and right handed peg placements. Errors in the form of: 1) failed attempts to place a peg in a hole and 2) the use of the wrong-colored pegs were recorded. A laterality index scores (LIS) was calculated for each participant using data from the pegboard task. LIS were calculated using the formula [$LI = (R - L)/(R+L)$], with R and L corresponding to the frequency of events resulting in scores ranging between -1.0 and +1.0 where greater positive values reflect an increasing right hand preference and greater negative values represent an increasing left hand preference.

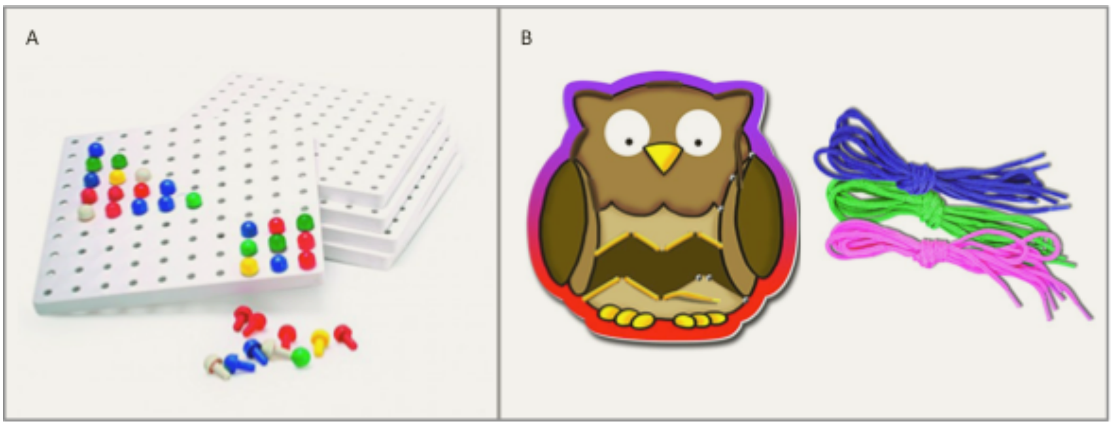

Figure 1. Task stimuli for (A) the Pegboard and (B) Card-lacing tasks.

2.3.3 Card lacing task stimuli

This task was used to assess bimanual coordinated hand dominance. Participants sat at a table, across from the researcher. The researcher provided the child with a lacing card and a jumbo lace with a bound end (*Early Learning Centre© My First Lacing Pictures*). To control for the number and position of holes across participants the same lacing card was used for all participants. Children were instructed to weave the lace through all of the holes in the card. The researcher first provided a demonstration with their own lacing card and did not begin the task until the child had successfully threaded two practice holes. The children were then given ninety seconds to complete as much of the card as possible in no particular order. The number of holes completed and the number of errors (failed attempts to place the head of the lace through a hole) were recorded. LIS scores were also calculated for the card-lacing task.

2.4 Cradling Task

Cradling trials were conducted to assess if children demonstrated a preference for holding different types of social stimuli and a control item with a bias to one side of their body. Cradling stimuli consisted of: an infant human doll, an infant primate (orang-utan) doll, a proto-face pillow and a no-face pillow (Figure 2). All cradling stimuli were altered using fishing weights such that the head portion weighed 2 lbs. and the posterior weighed 1.5 lbs. and the total weight was 5 lbs. All cradling stimuli were 22 inches in length except for the infant human doll, which was 18 inches in length. Doll stimuli wore newborn-sized nappies under unisex, cream-colored one-piece playsuit with a marl-grey pattern. A zip fastening was concealed on the back. The proto-face and no-face pillows were wider at the top than at the bottom and covered with the identical one-piece playsuit fabric and back zip fastening. These stimuli were stuffed with a contained bag of plastic beads positioned in the posterior region to match the posterior region of the dolls. The beads were wrapped in fleece fabric and padded out with polyester cushion filling. The only difference between the proto-face and no-face pillow stimuli was that the proto-face pillow was embellished with a basic configuration of a face, equal to the mean size of the doll stimuli and consistent with the proportions identified by Johnson and collaborators (1991).

Figure 2. Illustrations of (A) the infant human doll, (B) infant primate doll, (C) proto-face pillow and (D) no-face pillow.

2.4.1 Procedure and Behavioral Coding

The cradling task comprised of three trials. Participants began with one of either the proto-face pillow or the no-face pillow. The pillow trial was always presented as the initial cradling trial so that the cradling trials involving the infant human and primate dolls did not ‘contaminate’ these stimuli with a notion of ‘animacy’ or ‘dollness’. Each participant engaged in only one of these conditions because counterbalancing the stimuli would have resulted in some children cradling the proto-face pillow before the no-face pillow. In these cases there was concern that the proto-face pillow would contaminate the subsequent no-face pillow with a quality of ‘animacy’. All participants were then presented with both the infant human and primate dolls in a counterbalanced fashion. The type of pillow used (face vs. no face) was therefore a between-participant contrast, whereas the type of stimulus (pillow, human infant doll or primate infant doll) was a within-participant contrast.

Each cradling trial was conducted with identical procedures to assess whether children would demonstrate a left or right side cradling (see Figure 3). To begin a cradling trial, the child was asked to stand up from the manual motor station, walk to the back of the room and sit in a chair located equidistant from the walls on either side. The researcher then approached the child centrally and said: “I’m going to give you something to hold. Can you take it and hold it like this?" A symmetrical cradling gesture without holding anything was then made (Pileggi et al., 2015; and see panel B, Figure 4). Next, the researcher walked back to the manual motor station with their back to the participant to retrieve the cradling stimulus from a concealed bag under the testing station. The stimulus was held centrally and upright against the researcher's chest so as not to be visible to the participant until the researcher turned back to walk towards the child. The researcher approached the child and extended the stimulus to the child in an upright position towards the child's midline.

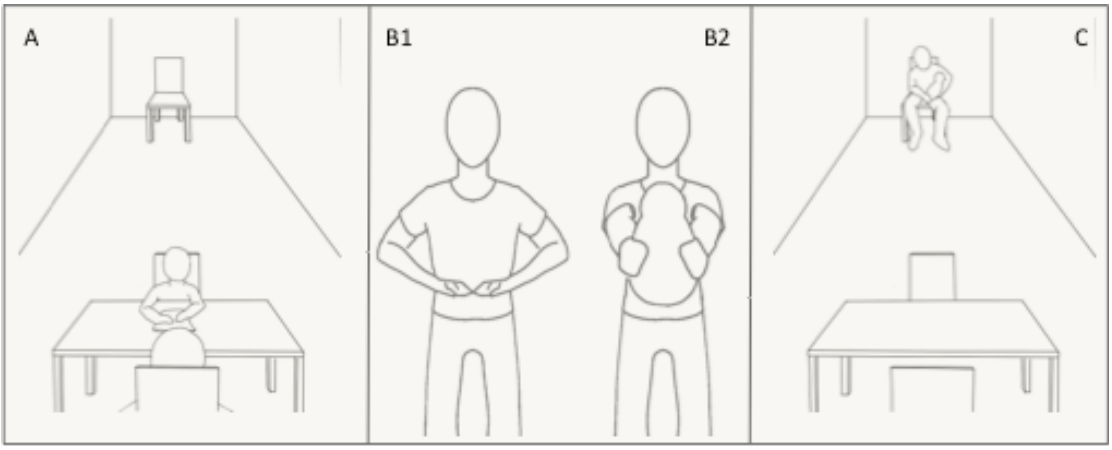

Figure 3. Schema of the testing room layout with the manual motor testing station in the foreground and the cradling station (chair) in the background. Panel A illustrates the child facing the researcher engaged in a task at the manual motor station. Panel B1 illustrates the researcher providing the cradling gesture to the child in advance of producing the cradling stimuli. B2 demonstrates the researcher presenting the cradling stimulus upright and midline to the participant and panel C depicts a successful cradling trial whereby the child cradles a doll in a side-biased lateral or upright position.

If the child did not hold the stimulus in one of the desired positions (lateral or upright), the researcher re-iterated the cradling gesture. When a stimulus had been cradled for approximately 30 seconds, the cradling side was recorded. If the child held the doll in any other position (face down, above the head, on the floor) or rejected the stimulus, the trial was excluded from the analyses below.

2.5 Socio-communication Survey

The key teacher for each child was asked to complete a 14-item socio-communicative survey. The survey was developed specifically for this investigation to provide a basic social ability score (items 2, 3, 5, 7, 9, 11, 13) and a basic communication ability score (items 1, 4, 6, 8, 10, 12, 14) for five year-old children (see Table 4). The survey was scored by the key teacher of each participant using a Likert scale for the categorical descriptions: 'strongly disagree', 'disagree', 'neutral', 'agree' and 'strongly agree'. Categorical selections were transcribed into scores of 1-5 where high scores equated to stronger ability levels. Communication items were developed to reflect speech, language and communication milestones for five year olds. Information about milestones were derived from *Talking Point,* a website about children's speech, language and communication. *Talking Point* is run by I CAN, and receives funding from The Communication Trust. The Communication Trust is a coalition of over 50 not-for-profit organization that support people who work with children in England to support their speech, language and communication needs (SLCN). Social items were developed to reflect social milestones for five year olds. Information about milestones were derived from the United States Center for Disease Control and Prevention's Milestone Tracker: 'Your Child at 5 Years' Social/Emotional checklist.

All descriptive and statistical analyses were conducted using SPSS (Version 24). Alpha was set at 0.05 and all tests were two-tailed.

3. Results

Although 98 children participated in the study, not all children completed all tasks. Table 2 (below) illustrates the number of participants that completed each task, the mean scores for: the manual motor tasks (*Pegboard* and *Card-lacing*), the task for effortful control/impulsivity (*Knock and Tap*) and the frequency of left and right cradling trials for the *Cradling Task* trials (infant human doll, infant primate doll, proto-face pillow, no-face pillow).

Table 2 Group mean scores for each of the 10 study measures.

Manual Motor and Socio-Communicative Tasks	N	Maximum Score	Mean Score	SE
Knock and Tap: Number of Errors	98	15	2.01	.286
Knock and Tap: Number of Hesitations	98	15	1.20	.142
Peg Board: Laterality Index Score	98	-1/+1	.504	.051
Card Lacing Laterality Index Score	98	-1/+1	.476	.054
Social Ability Survey Scores	95	5	4.27	.048
Communication Ability Survey Scores	95	5	4.29	.059
Cradling Trials	N	Trials per Child	Left	Right
Infant Human Doll	80	1	52	28
Infant Primate Doll	74	1	25	49
Proto-Face Pillow	37	1	27	10
No-Face Pillow	44	1	19	25

3.1 Cradling Task

Cradling results are reported in Table 3 and Figure 4. We begin by considering the effects of Gender then turn to considering the impact of motor and stimulus variables on cradling behaviors. Binomial tests were conducted to determine significant cradling side biases.

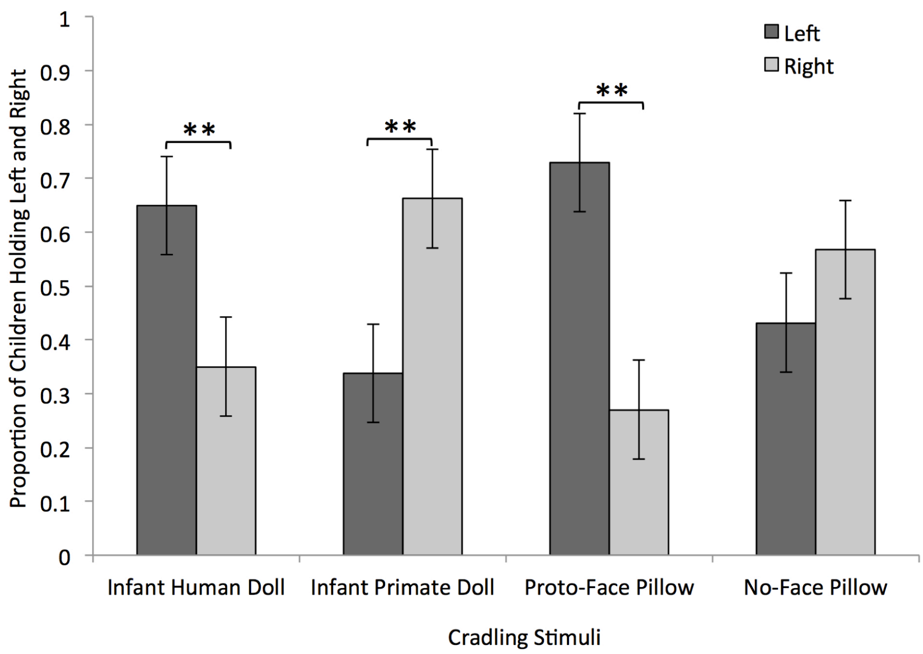

Figure 4. Over all proportion of cradling side for each stimulus type.

3.1.1 Infant Human Doll

Children held the human infant doll significantly more often in a left cradling position than a right cradling position (P < .01). Although there were no significant differences between boys' and girls' cradling behaviors, only Girls showed a significant LCB (P < .05) with the reduced Ns that occur when splitting the sample into two independent groups.

3.1.2 Infant Primate Doll

Children held the infant primate doll significantly more often in a right than in a left cradling position (P < .01). However, boys were significantly more likely than girls to hold the infant primate doll in a right side cradling position (P < .05). Moreover, only boys demonstrated a significant right-sided cradling bias (P < .01) with the reduced participant numbers that occurred when splitting the sample into two independent groups.

3.1.3 Proto Face Pillow

Children held the proto-face pillow significantly more often in a left cradling position than a right cradling position (P< .01). There were no significant differences between Boys' and Girls' cradling behaviors however, only girls demonstrated a significant LCB (P < .05) with the reduced participant numbers that occur when splitting the sample into two independent groups.

3.1.4 No Face Pillow

Neither girls nor boys held the no-face pillow with a significant side bias. Additionally, girls and boys did not differ significantly in their cradling behavior of this stimulus.

No effects of trial order were identified with respect to the condition sequence in which holding stimuli were presented to participants.

Table 3 Frequencies, laterality indices and two-tailed p-values of sign-tests for holding side across cradling conditions broken down by gender.

Condition	Infant Human Doll	Infant Primate Doll	Proto Face Pillow	No Face Pillow
Girls Left	33	18	16	12
Girls Right	16	24	5	13
Laterality Index	-.347	.143	-.524	.040
P-Value	0.0213*	NS	0.0266*	NS
Boys Left	19	7	11	7
Boys Right	12	25	5	12
Laterality Index	-.226	.563	-.375	.263
P-Value	NS	.0021*	NS	NS
Group Left	52	25	27	19
Group Right	28	49	10	25
Laterality Index	-.300	.324	-.460	.136
P-Value	.0097**	.0071**	0.0076**	NS

A chi-squared test of association indicated a significant interaction between holding sides for the infant human and primate dolls, χ^2 (1, N = 67) = 8.735, p = .004. Children who held the infant human doll on the left were equally likely to hold the infant primate doll on the left (n = 21) or right side of their bodies (n = 20). However, children who held the infant human doll on the right were significantly more likely to hold the infant primate doll on the right side (n = 22) compared to the left side (n = 4) of their body.

3.2 Sex, Age and Experience

Statistical analyses indicated that neither school year nor mean age in months interacted with holding side of the human doll for girls. However, a Mann-Whitney *U* test showed that boys who held the infant human doll on the left side of their bodies (Mean = 68.21, SE = 2.42) were significantly younger than boys who held the infant human doll on the right side of their bodies (Mean = 77.17, SE = 2.30) (U = 56, p= .018). A similar pattern was identified for Boys holding the infant primate doll. Boys who held the infant primate doll on their left side (Mean = 63.57, SE = 3.48) were significantly younger than Boys who held the primate doll on their right side (Mean = 72.83, SE = 2.04) (U = 56, p = .040). A Chi-squared test of association, however indicated that boys' holding side and school year were not significant for either the infant human or primate dolls, suggesting that age in months is a more sensitive measure of experience than school year.

Chi-squared tests of association revealed no significant interactions between the holding side of any of the cradling stimuli (infant human doll, infant primate doll, proto-face pillow, no-face pillow) and experience (with or without younger sibling/s). Thus, sibling experience did not appear to moderate cradling behavior in this sample of children.

3.3 Cradling side and Hand Dominance

Cradling side for any of the four kinds of test stimuli was not associated with hand dominance (as measured in the *Knock and Tap* task, nor was it associated with laterality indices (LIS) derived from the *Pegboard task.* A Mann-Whitney *U* test indicated that laterality indices derived from the *Card-lacing* task did associate with cradling bias for the primate doll whereby children who held the infant primate doll on the left were significantly more right-handed (Mean = .689, SE = .074) than children who held the infant primate doll on the right (Mean = .351, SE = .081) ($U=391$, $p=.01$). LIS did not associate with cradling bias for any of the other cradling stimuli.). There were no sex differences across the hand dominance scores.

3.4 Cradling Biases and Socio-communicative Scores

A Pearson test of correlation indicated that mean scores for the social and communicative survey items were highly correlated with each other, $r(95) = .645$, $p < .001$. Additionally, a Pearson test of correlation indicated that social ability scores were positively correlated with the frequency of correct trials from the *Knock and Tap* task $r(95) = .293$, $p = .004$. Communicative ability scores were marginally associated with the number of correct trials in the *Knock and Tap* task $r(95) = .186$, $p < .07$**.** *Knock and Tap* and communicative ability survey scores did not significantly differ between left and right infant human doll cradlers. However, a Mann-Whitney *U* test indicated that children who held the infant human doll with a LCB (n=51) had a significantly higher social ability score (Mean = 4.31, SE.073), compared with those that held the infant human doll on the right (n = 28) (Mean = 4.14, SE.070) ($U=497$, $p = .025$). Finally, infant primate doll, proto-face pillow and no-face pillow stimuli cradling side did not associate with *Knock and Tap* task, social survey or communication survey scores. There were no sex differences across the socio-communicative scores.

Table 4 Social and communication survey items, mean scores, and standard deviations (SD) as a function of cradling the infant human doll on the left and right side.

Item	Statement	Side	N	Mean	SD
1	Can talk about things that have already happened or will happen in the future with a good understanding of time, for example ‘yesterday we went to visit a museum’	Left	51	4.55	0.61
		Right	28	4.36	0.73
2	Wants to please their teacher	Left	51	4.43	0.67
		Right	28	4.18	0.55
3	Is likely to follow rules	Left	51	4.29	0.73
		Right	28	4.00	0.82
4	Can use long and detailed sentences for example “ We went to the park, but we came home because Mary hurt herself”	Left	51	4.41	0.75
		Right	28	4.25	0.89
5	Will share with others on their own accord	Left	50	4.28	0.67
		Right	28	4.18	0.67
6	Can communicate easily with familiar adults and with other children	Left	51	4.45	0.70
		Right	28	4.25	0.89
7	Can tell the difference between real and imaginary/pretend	Left	51	4.47	0.58
		Right	28	4.25	0.65
8	Can speak of imaginary conditions and says things like "I hope....”	Left	51	4.24	0.71
		Right	28	4.07	0.81
9	Likes to sing, dance and act	Left	51	3.94	0.76
		Right	27	3.70	0.54
10	Can take turns in longer conversations and stay on the same topic	Left	51	4.37	0.66
		Right	28	4.14	0.89
11	Prefers to play interactively with others (cooperative play), rather than playing alone (solitary play) or next to others but without interaction (parallel play)	Left	51	4.41	0.61
		Right	28	4.36	0.62
12	Engages in pretend play (e.g., role-playing alone or with others and/or using one object to represent another – for example: “This block is a telephone”.)	Left	51	4.25	0.56
		Right	28	4.07	0.60
13	Engages in eye contact when speaking to others	Left	51	4.55	0.61
		Right	28	4.43	0.57
14	Describes objects and events with lots of detail	Left	50	4.26	0.85
		Right	28	4.14	0.93

Note: Shaded rows denote social items and non-shaded rows denote communication items.

4. Discussion

4.1 Cradling Behavior

Despite the fact that the present results reflect children from an isolated school and could represent a micro-culture specific to this school, the children who participated in this study attended a Central London primary school, which drew from a diverse multicultural catchment area. Moreover, the findings are consistent with previous research across a range of schools and ages (see Jones, 2017). Findings from the present study demonstrated a population-level LCB, supporting an early evolutionary propensity for population-level left visual field and right hemisphere dominance for social-emotional processing (Bourne & Todd, 2004). The presence of an early and visible LCB in children was further supported by results from the proto-face and no-face pillows. The proto-face pillow elicited a population-level LCB while the no-face pillow (control stimulus) did not. The current findings suggest that the salience of the most rudimentary face configuration (e.g., Johnson et al., 1991) is sufficient to elicit a LCB in children. This finding prompts the need for further infant research, to understand the role of cerebral lateralization during typical development. Neonates, from birth, demonstrate a preference for faces above other types of visual stimuli (Bower, 2001; Goren, Sarty, & Wu, 1975; Leppanen et al., 2007; Macchi Cassia et al., 2008; Simion et al., 2001; Umiltà et al., 1996; Valenza et al., 2006), yet no studies have yet to establish if a visual field bias for social stimuli exists early in development.

In direct contrast to our hypothesis, children held the infant primate doll significantly more often in a right versus left cradling position. One possible interpretation of this finding comes from adult cradling studies, which have reported an association between affective symptoms and the strength of the LCB. For example, mothers who held their infants on the right side reported higher stress levels than those holding on the left (Reissland et al., 2009; Vauclair & Scola, 2009). The immediate effect of stress is also associated with right-holding; women who undertook a bilateral cold pressor task, which significantly increased their blood pressure and heart rate, were more likely to hold a doll on the right than controls (Suter, Huggenberger, & Schächinger, 2007). Therefore a decline in, or reversal of, the typical LCB is evidenced in adults undergoing stress, possibly, as Harris (2010) discusses, because positioning the stimulus in the right visual field/left hemisphere of the holder may reflect an “inaction-withdrawal” response rather than approach and engagement.

Cradling the unfamiliar primate doll might have aroused mild anxiety in our participants. Indeed, some boys and girls indicated that they had found the primate doll “scary”. Several children were reluctant or even refused to pick it up, a response not found in the ‘baby doll’ or ‘pillow’ conditions. Whilst we did not envisage that the commercially available primate doll would appear frightening, it was perhaps unexpected in the experimental situation and therefore increased children’s anxiety. Consequently, stress may have been responsible for the increased rates of right side cradling in this condition.

There are other alternative interpretations. It is possible that a LCB is present only for those social stimuli that represent infancy. Todd and Banjeree (2015) reported that the LCB was robust for new mothers the first 12 weeks of their child’s development. However, evidence of a LCB became greatly reduced or disappeared after approximately three months. Babies are born with underdeveloped sensory and motor systems and their survival is reliant on the mother’s perception of their wellbeing. It is possible that children perceived the infant human doll as less than 12 week-old, but perceived the infant primate doll as older than 12 weeks of age. Alternatively, it is possible that the LCB is triggered by species-specific stimuli. A right hemisphere dominance, manifesting as a LVF advantage for social stimuli, may be a response to well-familiarized stimuli. The ‘expertise hypothesis’ suggests that right biased fusiform gyrus activity is positively correlated with the level of speciality of the individual and can be elicited by face and non-face stimuli (Gauthier, Skudlarski, Gore, & Anderson, 2000). Thus, it is possible that since human faces are more familiar than non-human primate faces, the less familiar infant primate doll did not elicit the LCB in children. However, with this interpretation, it should be taken into consideration that the non-conspecific and unfamiliar proto-face pillow *did* elicit a LCB in children rather than a decrease or reversal in LCB.

We found an interaction between cradling sides for the infant human and primate dolls. Children who held the infant human doll on the left were equally likely to hold the infant primate doll on the left or the right. However, children who held the infant human doll on the right were also more likely to hold the infant primate doll on the right. These findings illustrate that child behavior was sensitive to the nature of the cradling stimuli. Furthermore, this pattern of results illustrates the possibility that robust but disparate behavioral phenotypes can emerge in a population of typically developing children.

4.2 Sex, Age and Experience

Holding side for any of the cradling stimuli was not associated with age or experience of having a younger sibling, however sex difference were revealed. Boys demonstrated a weaker LCB than girls for both the infant human doll and the proto face pillow. Although boys held these stimuli proportionately with a left side bias, the results for boys as an independent group were not significant. One interpretation is that these findings represent a question of power and that larger sample sizes may reveal a significant, yet reduced LCB in boys compared with girls. A weaker LCB in boys may be the result from a variety of circumstances including differences in sex, developmental rate and experience. Todd and Banerjee (2016) suggested an effect of gender-stereotyped infant human doll, whereby boys may be less inclined to interact with a baby doll. De Château and Andersson (1976) suggested that girls and boys might have different developmental trajectories such that boys develop an LCB later than girls. Because evidence of a LCB in men has been reported in studies of fathers (Bogren, 1984; Dagenbach et al., 1988; Scola & Vauclair, 2010b) and men whose professions required infant care (de Château, 1983), experience may play a critical role in triggering the LCB. However, in the present study, boys, demonstrated an effect of age that was contrary to the prediction that the occurrence of the LCB would increase with increasing age, as a result of increased experience. Boys, but not girls, demonstrated a significant age difference for left and right side holding of both the infant human doll and the infant primate doll. Boys who held the infant human doll on the left were significantly younger than those who held it on the right. The same was true for boys holding the infant primate doll. The decrease in the LCB with age may reflect boys' increasing disinclination to play with female-gender-typed toys. A meta-analysis conducted by Todd and colleagues (2018) demonstrated that older boys played more with male-gender-stereotyped toys than with female-gender-stereotyped toys compared with younger boys. Future studies should consider longitudinal approaches to disentangle confounds of age, experience and perhaps cultural features (e.g. school, family) that may contribute to holding biases in young boys.

A significant interaction between sex and cradling side for the infant primate doll revealed that boys, but not girls held the infant primate doll with a significant right side cradling bias. In this study the inclusion of a doll representing an infant primate doll was presented as a control stimulus for the possible reluctance of boys to breach gender norms by engaging with a typical 'baby' doll (Todd & Banerjee, 2016). The interpretation of a right side bias for holding the infant primate doll is discussed above, however, the reason why girls revealed a significantly weaker right side bias compared with boys is unclear. The weaker right side cradling bias in girls for the infant primate doll may again result represent a question of power. Larger sample sizes may reveal a significant right side cradling bias in girls, but why it would be weaker than in boys remains to be explored. Further investigations are required to better understand if and when development and experience impacts the strength of a population-level LCB in males and females.

<u>*4.3 Cradling Behavior and Hand Dominance*</u>

Overall, hand classification (self report) and strength (as derived by the *Pegboard* and *Cared-lacing* tasks) were not associated with cradling side of the human infant doll proto-face and no-face pillows. These finding are consistent with previous research demonstrating that neither self-report of hand classification, nor strength of hand dominance (LIS scores) are associated with population-level LCB (Previc, 1991; Sieratzki & Woll, 1996, 2002; Vauclair & Donnot, 2005). Children who were not right handed were equally likely as their right-handed counterparts to hold the infant human doll on the left. Studies of hand dominance report that approximately 70% of left-handed adults and children alike have dominant language processes in the left hemisphere (e.g., Knecht et al., 2000; Szaflarski et al., 2013). These individuals, like 95% of right-handers will possess right hemispheres that are dominant for producing and perceiving social-emotional stimuli. Therefore, the majority of right-handed and left-handed individuals will express a dominant left visual field preference for viewing social stimuli that is influenced by the dominant right hemisphere for processing social-emotional stimuli.

Infant primate cradling side did not interact with hand classification, but did elicit significantly different strength laterality index scores (LIS) for only the *Card-lacing* task. Children who held the infant primate doll with a right cradling bias were significantly more right-handed than children who held the infant primate doll with a LCB. As an example of a bimanual coordination task, the *Card-lacing* task may be revealing the more sensitive measure of hand dominance in children compared with the LIS derived from the *Pegboard task* (e.g., unimanual task) (Fagard & Marks, 2000). One interpretation is that children perceived the infant primate doll as 'less animate' and more of an object. It is possible that the infant primate doll was considered an inanimate object to be held and/or manipulated by the dominant hand. In support of this interpretation, the no-face pillow was also held with a right side bias, although not significantly more than chance in the current sample.

4.4 Cradling Behavior and Socio-Communicative Ability

Holding side for any of the cradling stimuli was not associated with communication survey scores or inhibition scores. In contrast, social ability scores were positively correlated with inhibition scores, such that as social ability scores increased, so did the number of correct trials for the *Knock and Tap* task. This finding suggests that children with higher social ability scores possessed enhanced impulsivity control compared with children with lower social ability scores. Moreover, children who held the infant human doll with a LCB had significantly higher mean social ability scores than children who held the infant human doll with a right cradling bias. Those individuals with a predisposition to employ the left visual field for viewing social stimuli may develop enhanced social processing abilities compared with their right cradling biased counterparts. It is important to note that mean scores for both groups of children were representative of a typically developing population. Thus the difference in mean scores may represent two distinct motor/cognitive phenotypes based on laterality of brain function. Further investigations of behavioral biases may hold the key to a better understanding of the links between brain organization and function. Interestingly, the cradling side of only the infant human doll was associated with social ability scores, suggesting that conspecifics cradled on the left are processed with enhanced salience, potentially resulting in enhanced social ability compared with right side cradlers.

Although previous research draws an association between hand dominance and hemispheric lateralization for language (e.g., Knecht et al., 2000), and reports suggest that as child hand dominance increases, so does verbal ability (Leask & Crow, 2001), we did not find a relationship between hand dominance and the socio-communication survey scores. For the present investigation, we did not test specifically language ability or vocabulary size. It is likely that the communication survey items did not reflect the elements of language production and comprehension that are sensitive to hand dominance for manual motor tasks that are cited in the literature (see Lindell & Hudry, 2013). Moreover, social and communication ability survey scores were strongly positively correlated, suggesting that these measures may not have revealed discrete cognitive domains.

5. Conclusion

Our results suggest that even the most basic face stimuli can elicit population-level LCB in children, preferentially engaging the left visual field and the right hemisphere. The robust cradling behaviors found across stimuli supports an early developmental or innate predisposition for faces (for a review, see Johnson et al., 2015). However, in some cases, unfamiliar or stressful stimuli can cause the LCB to be reversed. Interestingly, the side of holding for *only* the conspecific face stimuli was associated with social ability scores, suggesting that the exposure to *human* faces is important for social cognitive development in children.

The findings from this study may have reach beyond cradling investigations. Research into specific populations with difficulties perceiving faces have found decreased attention to face stimuli (Jones & Klin, 2013) and disrupted right hemisphere activity during face processing (Keehn, Vogel-Farley, Tager-Flusberg & Nelson, 2015). Individuals diagnosed with autistic spectrum disorders have been reported to demonstrate face processing deficits associated with diminished activation of the right fusiform gyrus (for review, see Curby, Willenbockel, Tanaka & Schultz; 2010) and the absence of a LVF bias for face faces in infants (Dundas, Gastgeb & Strauss, 2012). Going forward, a better understanding of the associations between behavioral biases, brain organization/function and cognitive ability during childhood is important identifying and tracking behavioral phenotypes to allow us to make predictions about developmental trajectories across both typical and atypical populations.

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