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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

33 **Abstract**

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

58

59 **Abbreviations:**

60 Left cradling bias (LCB)

61

62 **Key words:**

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

64 **1. Introduction**

65 At the population-level, approximately 70% of mothers prefer to cradle their infants
66 on the left side of their own bodies regardless of a number of factors including: activity
67 type (e.g., calming, feeding, baby positioning: lateral, upright) (Bourne & Todd, 2004;
68 Bundy, 1979; de Château, Holmberg, & Winberg, 1978; Donnot, 2007; Ginsburg, Fling,
69 Hope, Musgrove, & Andrews, 1979; Hopkins, 2004; Matheson & Turnbull, 1998;
70 Reissland, 2000; Reissland, Hopkins, Helms, & Williams, 2009; Salk, 1973; Sieratzki,
71 Roy, & Woll, 2002; Sieratzki & Woll, 2002, 2004; Thompson & Smart, 1993; Todd &
72 Banerjee, 2016; Tomaszycski, Cline, Griffin, Maestripieri, & Hopkins, 1997; Turnbull &
73 Bryson, 2001; Turnbull & Lucas, 1991, 1996; Turnbull, Rhys-Jones, & Jackson, 2001;
74 Vauclair & Donnot, 2005; Woll & Sieratzki, 2002), mother's handedness (Previc, 1991;
75 Sieratzki & Woll, 1996, 2002; Vauclair & Donnot, 2005; but see van der Meer & Husby,
76 2006) or mother's culture (Bourne & Todd, 2004; Richards & Finger, 1975). The
77 population-level *left side cradling bias* (LCB) tends to persist for at least the first 12
78 weeks of the baby's life (Todd & Banerjee, 2016).

79

80 1.1 Cerebral Lateralization

81 The causal nature of the LCB is debated, but the most parsimonious theory relies on
82 cerebral lateralization of function. Cerebral lateralization is the dissociation of
83 specialized processes of left and right hemispheres of the cerebral cortex (for a review
84 see Rogers & Vallortigara, 2013). Because the nerve fibers of the motor cortices are
85 contralaterally innervated, these dominant hemisphere processes can manifest as
86 contralateral motor behaviors (Hellige, 1993). Although quite recently cerebral
87 lateralization and associated contralateral motor biases was thought to be a human
88 unique traits, non-human animal studies suggest that its origins date back to the rise
89 of vertebrates (Rogers & Andrew, 2002; Vallortigara & Rogers, 2005) and possibly
90 even earlier (Anfora et al., 2011; Bell & Niven, 2016; Frasnelli, Vallortigara, & Rogers,
91 2012). It is theorized that cerebral lateralization of brain function affords advantages
92 to the organism. Strong cerebral lateralization may increase neural efficiency by
93 allowing different functions to operate in parallel across hemispheres, decreasing
94 duplication of functioning across hemispheres and eliminating the initiation of
95 simultaneous and potentially incompatible behavioral responses (Rogers, 2002;
96 Vallortigara, 2000).

97

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

109

110 Research suggests that humans share a right hemisphere and left gaze bias for face
111 perception (for a review see Demaree, Everhart, Youngstrom, & Harrison, 2005) (e.g.,
112 looking time of centrally presented faces) with sheep (Peirce, Leigh, & Kendrick, 2000),
113 dogs and rhesus monkeys (Guo, Meints, Hall, Hall, & Mills, 2009) and chimpanzees
114 (Morris & Hopkins, 1993). Additionally, the left side of the face in both humans and
115 nonhuman primates has been reported to display emotive expression earlier and
116 more intensely than the right side of the face, for example in chimpanzees (Fernandez-
117 Carriba, Loeches, Morcilla, & Hopkins, 2002); macaques: (Hauser, 1993); marmosets:
118 (Hook-Costigan & Rogers, 1998) and baboons (Wallez & Vauclair, 2011). These findings
119 suggest that a human bias for both comprehending and producing facial expressions
120 (identity and emotive expressions) dominated by the right hemisphere is an inherited
121 primate trait. Although this manuscript focuses on the visual channel, human
122 nonverbal, evolutionarily urgent vocalizations (e.g., cries and shouts) associated with
123 threat or danger in the environment, elicit greater right-hemisphere activation
124 compared with the left hemisphere (for a review, see Scott, Sauter, & McGettigan,
125 2009) suggesting that a right hemisphere dominance for social emotional processing
126 in humans is not specific to a single sensory modality.

127

128 Cerebral lateralization of function interpreted through contralateral motor biases
129 allows us to understand better how populations behave in the real world. For
130 example, a left visual preference (right hemisphere) for detecting and monitoring
131 conspecific behavior has ramifications for social positioning during natural human and
132 non-human animal behavior. A study of chimpanzees and gorillas revealed that
133 individuals navigate around conspecifics with a bias for keeping social partners to their
134 left side (Quaresmini, Forrester, Spiezio, & Vallortigara, 2014). The study was later
135 replicated with school children across a range of ages (Forrester, Crawley, & Palmer,
136 2014). The findings suggest that the right hemisphere may provide an advantage for
137 monitoring the threat levels of conspecifics. However, human social emotional
138 abilities go far beyond locomoting through social spaces. In human (and presumably
139 many non-human animal species) the right hemisphere and left visual field play a
140 critical role in discriminating between social companions and recognition of
141 individuals based on familiarity (for a review, see Vallortigara & Versace, 2017).

142

143 1.2 Left Visual Field (LVF) Bias for Human Face Processing

144 Research suggests that a left visual field (LVF) bias for social stimuli is directly related
145 to human population-level right hemisphere specialization for processing faces.
146 Cognitive and behavioral studies consistently report LVF superiority for processing
147 face stimuli, and these findings align with fMRI and ERP face processing responses,
148 shown to be strongly associated with a LVF and right hemisphere superiority for face
149 stimuli (for a review, see Yovel, 2016). Information presented to the LVF has a direct
150 path to the right hemisphere of the brain and numerous brain imaging studies have
151 reported an anatomically larger fusiform gyrus in the right hemisphere with
152 heightened activation when processing faces compared with non-face stimuli (for a
153 review, see Haxby & Gobbini, 2011). For example, a longitudinal study that
154 implemented both brain imaging (fMRI) and behavioral (eye-tracking) methods
155 demonstrated a positive association between an individual's LVF bias and the strength
156 of right lateralized hemisphere activation during face processing (Yovel, Tambini &
157 Brandman, 2008). The study also indicated that the level of hemispheric bias for face
158 processing remained stable over time. Additional functional imaging research has
159 demonstrated that the right hemisphere is not only dominant for processing faces in

160 general, but it is also selectively dominant for perceiving *human* face identity and
161 strength of facial expressions (Gorno-Tempini & Price, 2001). Clinical studies also
162 support a LVF and right hemisphere advantage for face processing. Individuals with
163 right hemisphere damage demonstrated no LVF advantage and decreased ability to
164 recognize faces (De Renzi, Perani, Carlesim, Silveri & Fazio, 1994). Furthermore,
165 interference in face processing is found when the right (but not the left fusiform gyrus)
166 is disrupted via intracranial electrodes (Jonas et al., 2015; Parvizi et al., 2012). Taken
167 together, these studies converge to suggest that a population-level LVF bias for social
168 stimuli reflects a right hemisphere specialization for attending to and processing social
169 stimuli. As such, visual field biases for faces can act as behavioral markers of
170 anatomical and functional cortical organization of domain specific social processing.

171

172 1.3 Social Laterality in Mother Baby Dyads

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

182

183 For the majority of the human population, the LCB facilitates a mutual (mother-baby)
184 right hemisphere advantage for producing and perceiving social signals across visual
185 and auditory social stimuli (Scola & Vauclair, 2010a; Sieratzki & Woll, 2002). The LCB
186 creates a direct route to the right hemisphere through the left visual field of the
187 mother, supporting rapid identification of facial identity and emotional state of the
188 infant (Manning & Chamberlain, 1991). Consequently, the infant is provided with the
189 more expressive left side of the mother's face (Vauclair & Donnot, 2005), which may
190 have the potential to facilitate bonding and social development (Huggenberger, Suter,
191 Reijnen, & Schächinger, 2009). Early social development research suggests that even

192 though neonates have underdeveloped sensory processing channels (Simion, Macchi
193 Cassia, Turati, & Valenza, 2001) faces are still salient stimuli from birth (e.g., Farroni
194 et al., 2005). Regardless of an underdeveloped visual system, neonates preferentially
195 attend to patterns that contain the basic configuration of high-contrast areas of a face
196 (e.g., Johnson, 2007). Moreover, neonates tested at birth demonstrate a preference
197 for faces above other types of stimuli (Bower, 2001; Goren, Sarty, & Wu, 1975;
198 Leppanen, Moulson, Vogel-Farley, & Nelson, 2007; Macchi Cassia, Valenza, Simion, &
199 Leo, 2008; Simion et al., 2001; Umiltà, Simion, & Valenza, 1996; Valenza, Leo, Gava, &
200 Simion, 2006). Johnson, Dziurawiec, Ellis, and Morton (1991) created a schematic
201 illustration of the stimuli that might be optimal for eliciting a face-related preference
202 in neonates. Consistent patterns of results were obtained across investigations of
203 chicks (*Gallus gallus*) and human newborns. These two evolutionarily disparate
204 species demonstrated similar behavioral biases toward face stimuli shortly after
205 hatching or birth, supporting an evolutionary continuity in social orienting (Rosa Salva,
206 Farroni, Vallortigara & Johnson, 2011).

207

208 Owing to the rate of cortical development, one might predict that newborns would
209 not benefit from early exposure to visual social stimuli, however, brain imaging
210 findings suggest that neonates may possess face sensitive subcortical neural regions
211 (Johnson, Senju, & Tomalski, 2015; Umiltà et al., 1996), linked to an evolutionarily
212 early predisposition to proto faces. New evidence suggests that basic visual face
213 orienting abilities are in place prenatally as early as 30 weeks of gestations (Reid et al.,
214 2017) and are not dissimilar to the filial responses demonstrated in chicks (Di Giorgio,
215 Loveland, Mayer, Rosa-Salva, Versace, & Vallortigara, 2017). These early behavioral
216 and neural attributes coupled with a reflexive rightward head-turning bias (in the final
217 weeks of gestation through the first six months after birth; Güntürkün, 2003) and a
218 mother's inclination to exhibit a LCB, create ideal conditions for both the infant's
219 survival and developing a social brain.

220

221 1.4 Sex, Age and Experience

222 Evolutionary explanations set up an expectation that the LCB would appear early in
223 ontogeny among both males and females and also without any prior experience of

224 holding infants (e.g. Saling & Bonert, 1983; Todd & Banerjee, 2016). Although the
225 methods used to elicit cradling have been extremely varied across studies, the choice
226 of experimental approach does not appear to influence the robust cradling LCB found
227 in women. However, evidence of a LCB in men has been mixed (Bundy, 1979; Harris,
228 Almerigi, & Kirsch, 2000; Harris, Spradlin, & Almerigi, 2006; Manning, 1991; Nakamichi
229 & Takeda, 1995; Turnbull & Lucas, 1991). Some studies have reported that in men, the
230 LCB is restricted to fathers (Bogren, 1984; Dagenbach, Harris, & Fitzgerald, 1988; Scola
231 & Vauclair, 2010b) and men whose professions required infant care (de Château,
232 1983). These findings suggests that gender could be an influential LCB factor and
233 additionally that there might be a developmental or experiential component to the
234 LCB. However, to date, it is unclear if any gender bias is mediated by experience or
235 innate predisposition, nor do we understand what exactly it is that makes the LCB
236 emerge in both men and women.

237

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

247

248 Across cultures, gender-specific socialisation and family experience might impact the
249 presence of the LCB in young male and female children. In western countries, girls are
250 preferentially socialized to interact with dolls (considered a female-stereotyped toy)
251 from a young age “and may gain formative experience through these interactions”
252 (Todd & Banerjee, 2016). Culturally, boys may be discouraged from interacting with
253 female-stereotyped toys and therefore gain less experience than their female
254 counterparts for developing a cradling bias (Todd, Barry, & Thommessen, 2017).
255 Additionally, experience of sibling care, (as measured by birth order), may also provide

256 important experiences triggering or influencing the strength or propensity for a
257 cradling bias in children. To date, the implementation of non-gender-stereotyped
258 cradling stimuli and the influence of sibling experience have yet to be addressed in
259 systematic fashion to explore how they might contribute to a population-level LCB.

260

261 1.5 Motor Biases as a Marker of Cognitive Ability

262 Motor biases act not only as markers of brain organization, but have also been shown
263 to correlate significantly with subsequent cognitive outcomes (Toga & Thompson,
264 2003). For instance, at the population-level, strong right hand dominance in children
265 corresponds with the typical development of fine motor skills and subsequent
266 attainment of typical language abilities (left hemisphere dominant; Leask & Crow,
267 2001). Conversely, weak hand dominance (ambidexterity) is associated with the
268 development of poorer fine motor abilities and weaker language ability (compared
269 with strongly handed individuals) in addition to a rise in neurodevelopmental and
270 mental health disorders (e.g., Rodriguez et al., 2010).

271

272 There is currently no evidence suggesting an association between the side of the
273 mother's body on which babies were cradled during the early weeks of infancy and
274 the level of subsequent socio-communicative development. Moreover, population
275 patterns do not necessarily translate to the individual because at the individual level,
276 we cannot be certain of brain organization based on motor biases. However, one
277 retrospective study of healthy adults revealed that individuals who were held with a
278 LCB (derived from family photos) developed a typical left visual field (right
279 hemisphere) bias for responding to chimeric faces, whereas adults that were cradled
280 with a right-arm bias did not (Vervloed, Hendricks, & van den Eijnde, 2011). While all
281 participants could effectively identify the identity and emotional expression of face
282 stimuli, those individuals who were cradled on the left were significantly faster at
283 doing so. The findings suggest that there is significant 'typical' variation in the
284 population and that babies cradled on the left may develop an enhanced right
285 hemisphere bias for processing social emotional stimuli. In fact, one study has even
286 suggested that faces of right-cradlers were less visible from the "infant viewpoint"
287 compared to those of left-cradlers (Hendriks, van Rijswijk, & Omtzigt, 2011). However,

288 at this time it is impossible to reconcile if right side cradled babies were predisposed
289 through heritability (for a genetic account of cradling, see Manning & Denman, 1994)
290 to decreased cerebral lateralization or if the cradling side influenced development.

291

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

300

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

318

319 **2. Material and Methods**

320

321 2.1 Participants

322 Ninety-eight typically developing children (54 girls, 44 boys) attending reception or
323 year 1 participated in this study (mean age = 69.95 months, SD = 10.64). All children
324 attended a mainstream primary school in central London. Children at this
325 developmental age were chosen because both handedness (e.g., Gudmundsson,
326 1993) and the cerebral processes associated with hand preference (Bates, O'Connell,
327 Vaid, Sledge, & Oakes, 1986; Fagard & Marks, 2000) have stabilized by then, while also
328 minimizing the amount of time that children have been exposed to socially defined
329 lateralized behaviors. This is also the age used by similar work in this area (e.g.,
330 Forrester, Pegler, Thomas, & Mareschal, 2014). For each child, the number of younger
331 siblings living in the home was recorded in order to assess the extent to which
332 exposure to a younger sibling may impact cradling bias. Please see Table1.

333

334 **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

335

336 2.2 Testing Conditions

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

347

348 The number of participants varied across tasks (see section 2.4.1). All children
 349 participated in the *Knock and Tap*, *Peg Board* and *Card-Lacing* tasks however three
 350 children’s data from the survey tasks were not completed by key teachers. For cradling
 351 trials, only those trials where children followed task instructions and held stimuli in an
 352 upright or lateral position were included in analyses. Lower participant numbers for
 353 proto-face and no-face pillow stimuli were the result of a between-participant
 354 contrast, compared with within-participant contrast for other cradling stimuli (see
 355 section 2.4.1). Please see Table 2.

356

357 **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)	69.44	7 (L), 47 (R)	17
		Boys (44)	70.40	8 (L), 36 (R)	9
Peg Board	98	Girls (54)	69.44	7 (L), 47 (R)	17
		Boys (44)	70.40	8 (L), 36 (R)	9
Card Lacing	98	Girls (54)	69.44	7 (L), 47 (R)	17
		Boys (44)	70.40	8 (L), 36 (R)	9
Social Survey Items	95	Girls (53)	69.32	7 (L), 46 (R)	17
		Boys (42)	70.74	8 (L), 34 (R)	9
Communication Survey Items	95	Girls (53)	69.32	7 (L), 46 (R)	17
		Boys (42)	70.74	8 (L), 34 (R)	9
Cradling Trials	N	N by Sex	Mean Age (months)	Hand Classification	Younger Siblings
Infant Human Doll	80	Girls (49)	69.96	6 (L), 43 (R)	17
		Boys (31)	71.68	6 (L), 25 (R)	8
Infant Primate Doll	74	Girls (42)	68.95	6 (L), 36 (R)	13
		Boys (32)	70.74	6 (L), 26 (R)	7
Proto-Face Pillow	37	Girls (21)	74.91	3 (L), 18 (R)	7
		Boys (16)	70.69	3 (L), 13 (R)	4
No-Face Pillow	44	Girls (25)	66.32	4 (L), 21 (R)	7
		Boys (19)	70.26	3 (L), 16 (R)	5

358

359 2.3 Manual Motor Tasks

360

361 2.3.1 Knock and Tap task:

362 Each participant began with the *Knock and Tap* task was taken from the NEPSY
 363 neuropsychological test battery (Kemp, Kirk, & Korkman, 2001; Korkman, Kirk, &
 364 Kemp, 2000). The *Knock and Tap* task was introduced to assess attention and effortful
 365 control in young children, as it requires the inhibition of a prepotent action. In this

366 task, the experimenter sat opposite the child (across a table) with hands laid flat on
367 the table. The child was asked to mirror their hand position. Next, the child was asked
368 to indicate their 'favorite hand for writing'. This was taken as indicative of the
369 dominant hand for fine motor activities. There was a 96% concurrence between the
370 child's chosen hand and the hand classification based on the subsequent motor tasks
371 described. The researcher told the child that they would play the game with the
372 indicated (dominant) hand and the other hand (non-dominant) would remain still on
373 the table. The experimenter always conducted the task with the hand that mirrored
374 the child's dominant hand. The researcher provided participants with the following
375 instructions and an accompanying demonstration: "When I knock on the table (closed
376 fist makes contact with the table with an audible sound), you tap on the table (opened
377 palm makes contact with the table with an audible sound). And, if I tap on the table,
378 you knock." Two practice trials were given to make sure that the child understood the
379 task instructions. Fifteen test trials followed as specified in the NEPSY manual (Knock-
380 Knock-Tap-Knock-Knock-Tap-Tap-Knock-Tap-Tap-Knock-Tap-Tap-Tap-Knock).
381 Hesitations were scored as breaks in the flow of the rhythmic trials, and incorrect
382 responses were also recorded.

383

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

395

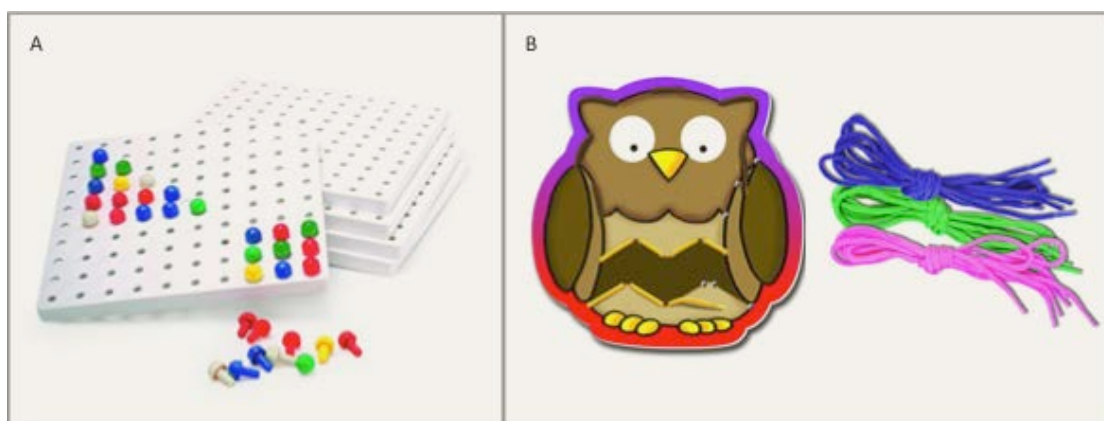
396 *2.3.2 Pegboard task:*

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

404

405 The children were asked to select only red pegs and complete the outline of the 6 x 6
406 red square. This task required the placement of 20 red pegs. Participants were asked
407 to work as quickly and as accurately as possible. Participants were given a maximum
408 of ninety seconds to complete the task. The researcher scored the number of left
409 handed and right handed peg placements. Errors in the form of: 1) failed attempts to
410 place a peg in a hole and 2) the use of the wrong-colored pegs were recorded. A
411 laterality index scores (LIS) was calculated for each participant using data from the
412 pegboard task. LIS were calculated using the formula $[LI = (R - L)/(R+L)]$, with R and L
413 corresponding to the frequency of events resulting in scores ranging between -1.0 and
414 +1.0 where greater positive values reflect an increasing right hand preference and
415 greater negative values represent an increasing left hand preference.

416



417

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

419

420 2.3.3 Card lacing task stimuli

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

432

433 2.4 Cradling Task

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

451



452

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

455

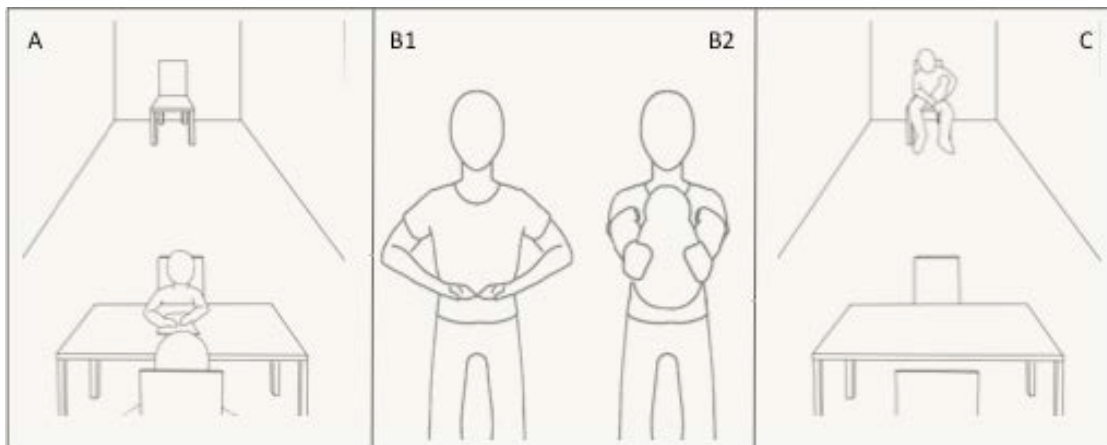
456 *2.4.1 Procedure and Behavioral Coding*

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

469

470 Each cradling trial was conducted with identical procedures to assess whether children
471 would demonstrate a left or right side cradling (see Figure 3). To begin a cradling trial,
472 the child was asked to stand up from the manual motor station, walk to the back of
473 the room and sit in a chair located equidistant from the walls on either side. The
474 researcher then approached the child centrally and said: “I’m going to give you
475 something to hold. Can you take it and hold it like this?” A symmetrical cradling
476 gesture without holding anything was then made (Pileggi et al., 2015; and see panel
477 B, Figure 4). Next, the researcher walked back to the manual motor station with their

478 back to the participant to retrieve the cradling stimulus from a concealed bag under
479 the testing station. The stimulus was held centrally and upright against the
480 researcher's chest so as not to be visible to the participant until the researcher turned
481 back to walk towards the child. The researcher approached the child and extended the
482 stimulus to the child in an upright position towards the child's midline.
483



484

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

493

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

499

500 2.5 Socio-communication Survey

501 The key teacher for each child was asked to complete a 14-item socio-communicative
502 survey. The survey was developed specifically for this investigation to provide a basic

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

518

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

521

522 **3. Results**

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

529

530

531 **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

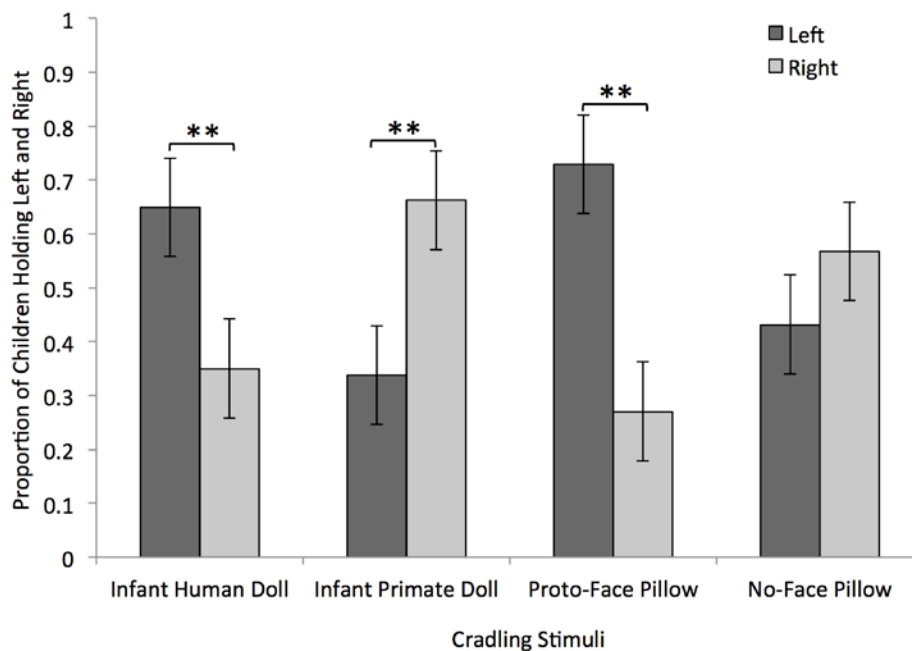
Peg Board: Laterality Index Score	98	-1/+1	.504	.051
Card Lacing Laterality Index Score	98	-1/+1	.476	.054
Social Ability Survey Scores	95	5	4.27	.048
Communication Ability Survey Scores	95	5	4.29	.059
Cradling Trials	N	Trials per Child	Left	Right
Infant Human Doll	80	1	52	28
Infant Primate Doll	74	1	25	49
Proto-Face Pillow	37	1	27	10
No-Face Pillow	44	1	19	25

532

533 3.1 Cradling Task

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

538



539

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

541

542 3.1.1 Infant Human Doll

543 Children held the human infant doll significantly more often in a left cradling position
 544 than a right cradling position ($P < .01$). Although there were no significant differences

545 between boys' and girls' cradling behaviors, only Girls showed a significant LCB ($P <$
546 $.05$) with the reduced Ns that occur when splitting the sample into two independent
547 groups.

548

549 *3.1.2 Infant Primate Doll*

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

556

557 *3.1.3 Proto Face Pillow*

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

563

564 *3.1.4 No Face Pillow*

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

567

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

570

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

573

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

574

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

582

583 3.2 Sex, Age and Experience

584 Statistical analyses indicated that neither school year nor mean age in months
585 interacted with holding side of the human doll for girls. However, a Mann-Whitney U
586 test showed that boys who held the infant human doll on the left side of their bodies
587 (Mean = 68.21, SE = 2.42) were significantly younger than boys who held the infant
588 human doll on the right side of their bodies (Mean = 77.17, SE = 2.30) ($U = 56, p =$
589 .018). A similar pattern was identified for Boys holding the infant primate doll. Boys
590 who held the infant primate doll on their left side (Mean = 63.57, SE = 3.48) were
591 significantly younger than Boys who held the primate doll on their right side (Mean =
592 72.83, SE = 2.04) ($U = 56, p = .040$). A Chi-squared test of association, however
593 indicated that boys' holding side and school year were not significant for either the
594 infant human or primate dolls, suggesting that age in months is a more sensitive
595 measure of experience than school year.

596

597 Chi-squared tests of association revealed no significant interactions between the
598 holding side of any of the cradling stimuli (infant human doll, infant primate doll,

599 proto-face pillow, no-face pillow) and experience (with or without younger sibling/s).
600 Thus, sibling experience did not appear to moderate cradling behavior in this sample
601 of children.

602

603 3.3 Cradling side and Hand Dominance

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

613

614 3.4 Cradling Biases and Socio-communicative Scores

615 A Pearson test of correlation indicated that mean scores for the social and
616 communicative survey items were highly correlated with each other, $r(95) = .645$, $p <$
617 $.001$. Additionally, a Pearson test of correlation indicated that social ability scores
618 were positively correlated with the frequency of correct trials from the *Knock and Tap*
619 task $r(95) = .293$, $p = .004$. Communicative ability scores were marginally associated
620 with the number of correct trials in the *Knock and Tap* task $r(95) = .186$, $p < .07$. *Knock*
621 *and Tap* and communicative ability survey scores did not significantly differ between
622 left and right infant human doll cradlers. However, a Mann-Whitney *U* test indicated
623 that children who held the infant human doll with a LCB ($n=51$) had a significantly
624 higher social ability score (Mean = 4.31, SE.073), compared with those that held the
625 infant human doll on the right ($n = 28$) (Mean = 4.14, SE.070) ($U=497$, $p = .025$). Finally,
626 infant primate doll, proto-face pillow and no-face pillow stimuli cradling side did not
627 associate with *Knock and Tap* task, social survey or communication survey scores.
628 There were no sex differences across the socio-communicative scores. Please see
629 Table 4.

630

631 **Table 4** Social and communication survey items, mean scores, and standard deviations
 632 (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 Right	51 28	4.55 4.36	0.61 0.73
2	Wants to please their teacher	Left Right	51 28	4.43 4.18	0.67 0.55
3	Is likely to follow rules	Left Right	51 28	4.29 4.00	0.73 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 Right	51 28	4.41 4.25	0.75 0.89
5	Will share with others on their own accord	Left Right	50 28	4.28 4.18	0.67 0.67
6	Can communicate easily with familiar adults and with other children	Left Right	51 28	4.45 4.25	0.70 0.89
7	Can tell the difference between real and imaginary/pretend	Left Right	51 28	4.47 4.25	0.58 0.65
8	Can speak of imaginary conditions and says things like "I hope...."	Left Right	51 28	4.24 4.07	0.71 0.81
9	Likes to sing, dance and act	Left Right	51 27	3.94 3.70	0.76 0.54
10	Can take turns in longer conversations and stay on the same topic	Left Right	51 28	4.37 4.14	0.66 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 Right	51 28	4.41 4.36	0.61 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 Right	51 28	4.25 4.07	0.56 0.60
13	Engages in eye contact when speaking to others	Left Right	51 28	4.55 4.43	0.61 0.57
14	Describes objects and events with lots of detail	Left Right	50 28	4.26 4.14	0.85 0.93

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

635

636 **4. Discussion**

637

638 **4.1 Cradling Behavior**

639 Despite the fact that the present results reflect children from an isolated school and
 640 could represent a micro-culture specific to this school, the children who participated
 641 in this study attended a Central London primary school, which drew from a diverse
 642 multicultural catchment area. Moreover, the findings are consistent with previous
 643 research across a range of schools and ages (see Jones, 2017). Findings from the
 644 present study demonstrated a population-level LCB, supporting an early evolutionary
 645 propensity for population-level left visual field and right hemisphere dominance for

646 social-emotional processing (Bourne & Todd, 2004). The presence of an early and
647 visible LCB in children was further supported by results from the proto-face and no-
648 face pillows. The proto-face pillow elicited a population-level LCB while the no-face
649 pillow (control stimulus) did not. The current findings suggest that the salience of the
650 most rudimentary face configuration (e.g., Johnson et al., 1991) is sufficient to elicit a
651 LCB in children. This finding prompts the need for further infant research, to
652 understand the role of cerebral lateralization during typical development. Neonates,
653 from birth, demonstrate a preference for faces above other types of visual stimuli
654 (Bower, 2001; Goren, Sarty, & Wu, 1975; Leppanen et al., 2007; Macchi Cassia et al.,
655 2008; Simion et al., 2001; Umiltà et al., 1996; Valenza et al., 2006), yet no studies have
656 yet to establish if a visual field bias for social stimuli exists early in development.

657

658 In direct contrast to our hypothesis, children held the infant primate doll significantly
659 more often in a right versus left cradling position. One possible interpretation of this
660 finding comes from adult cradling studies, which have reported an association
661 between affective symptoms and the strength of the LCB. For example, mothers who
662 held their infants on the right side reported higher stress levels than those holding on
663 the left (Reissland et al., 2009; Vauclair & Scola, 2009). The immediate effect of stress
664 is also associated with right-holding; women who undertook a bilateral cold pressor
665 task, which significantly increased their blood pressure and heart rate, were more
666 likely to hold a doll on the right than controls (Suter, Huggenberger, & Schächinger,
667 2007). Therefore a decline in, or reversal of, the typical LCB is evidenced in adults
668 undergoing stress, possibly, as Harris (2010) discusses, because positioning the
669 stimulus in the right visual field/left hemisphere of the holder may reflect an “inaction-
670 withdrawal” response rather than approach and engagement.

671

672 Cradling the unfamiliar primate doll might have aroused mild anxiety in our
673 participants. Indeed, some boys and girls indicated that they had found the primate
674 doll “scary”. Several children were reluctant or even refused to pick it up, a response
675 not found in the ‘baby doll’ or ‘pillow’ conditions. Whilst we did not envisage that the
676 commercially available primate doll would appear frightening, it was perhaps
677 unexpected in the experimental situation and therefore increased children’s anxiety.

678 Consequently, stress may have been responsible for the increased rates of right side
679 cradling in this condition.

680

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

699

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

708

709 4.2 Sex, Age and Experience

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

739

740 A significant interaction between sex and cradling side for the infant primate doll
741 revealed that boys, but not girls held the infant primate doll with a significant right

742 side cradling bias. In this study the inclusion of a doll representing an infant primate
743 doll was presented as a control stimulus for the possible reluctance of boys to breach
744 gender norms by engaging with a typical 'baby' doll (Todd & Banerjee, 2016). The
745 interpretation of a right side bias for holding the infant primate doll is discussed above,
746 however, the reason why girls revealed a significantly weaker right side bias compared
747 with boys is unclear. The weaker right side cradling bias in girls for the infant primate
748 doll may again result represent a question of power. Larger sample sizes may reveal a
749 significant right side cradling bias in girls, but why it would be weaker than in boys
750 remains to be explored. Further investigations are required to better understand if
751 and when development and experience impacts the strength of a population-level LCB
752 in males and females.

753

754 4.3 Cradling Behavior and Hand Dominance

755 Overall, hand classification (self report) and strength (as derived by the *Pegboard* and
756 *Cared-lacing* tasks) were not associated with cradling side of the human infant doll
757 proto-face and no-face pillows. These finding are consistent with previous research
758 demonstrating that neither self-report of hand classification, nor strength of hand
759 dominance (LIS scores) are associated with population-level LCB (Previc, 1991;
760 Sieratzki & Woll, 1996, 2002; Vauclair & Donnot, 2005). Children who were not right
761 handed were equally likely as their right-handed counterparts to hold the infant
762 human doll on the left. Studies of hand dominance report that approximately 70% of
763 left-handed adults and children alike have dominant language processes in the left
764 hemisphere (e.g., Knecht et al., 2000; Szaflarski et al., 2013). These individuals, like
765 95% of right-handers will possess right hemispheres that are dominant for producing
766 and perceiving social-emotional stimuli. Therefore, the majority of right-handed and
767 left-handed individuals will express a dominant left visual field preference for viewing
768 social stimuli that is influenced by the dominant right hemisphere for processing
769 social-emotional stimuli.

770

771 Infant primate cradling side did not interact with hand classification, but did elicit
772 significantly different strength laterality index scores (LIS) for only the *Card-lacing*
773 task. Children who held the infant primate doll with a right cradling bias were

774 significantly more right-handed than children who held the infant primate doll with a
775 LCB. As an example of a bimanual coordination task, the *Card-lacing* task may be
776 revealing the more sensitive measure of hand dominance in children compared with
777 the LIS derived from the *Pegboard task* (e.g., unimanual task) (Fagard & Marks, 2000).
778 One interpretation is that children perceived the infant primate doll as 'less animate'
779 and more of an object. It is possible that the infant primate doll was considered an
780 inanimate object to be held and/or manipulated by the dominant hand. In support of
781 this interpretation, the no-face pillow was also held with a right side bias, although
782 not significantly more than chance in the current sample.

783

784 4.4 Cradling Behavior and Socio-Communicative Ability

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

803

804 Although previous research draws an association between hand dominance and
805 hemispheric lateralization for language (e.g., Knecht et al., 2000), and reports suggest

806 that as child hand dominance increases, so does verbal ability (Leask & Crow, 2001),
807 we did not find a relationship between hand dominance and the socio-communication
808 survey scores. For the present investigation, we did not test specifically language
809 ability or vocabulary size. It is likely that the communication survey items did not
810 reflect the elements of language production and comprehension that are sensitive to
811 hand dominance for manual motor tasks that are cited in the literature (see Lindell &
812 Hudry, 2013). Moreover, social and communication ability survey scores were strongly
813 positively correlated, suggesting that these measures may not have revealed discrete
814 cognitive domains.

815

816 **5. Conclusion**

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

825

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

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840

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845

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