Hand preference and manual midline crossing in 12-month-old infants

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Previous research has found that hand preference can be detected reliably in infants as young as 6 months of age through the use of reach-grasp tasks. While many studies have targeted their efforts at discerning hand preference in infants younger than 12-months of age, a lack of knowledge about hand preference during the ages of 1-2 years remain. The aim of the present study was to investigate whether 12-month-old infants demonstrate a clear hand use preference during unimanual reaching and grasping. Participants consisted of 54 healthy, full term 12-month-old infants (+2/-2 weeks). Goal objects were placed at a reachable distance, in front of the infants and randomly allocated to either left, midline or right positions. Infant hand choices and the success of each grasp were coded offline from video recordings made of the reach-grasp sessions and an overall lateralisation index (LI) was calculated later for each infant. The results demonstrated that the 12-month-old infants were generally right-preferred. Additionally, almost double the frequency of grasps were accounted for by right hand grasps. Further, a significant right hand preference was found when children reached across the midline to grasp objects. The findings imply that hand preference may be readily observed in the prehension activities of 12-month-old infants, and particularly prominent when reaching across the midline.

Most healthy human adults have a clear hand preference when it comes to everyday manual tasks. The term “handedness” is used to define individual preference for a particular hand, when engaged in unimanual tasks (Annett, 1970; Scharoun & Bryden, 2014). Coren and Porac (1977) suggested that there is a relatively stable, right to left handedness ratio; approximately, 90% to 10% in the adult human population. Strong right hand preference has not only been reported in Western continents such as Central Europe and North America but internationally, including samples taken from populaces in Asia, Africa and the Middle East (Coren & Porac, 1977; Scharoun & Bryden, 2014). The ratio of left handers may still vary between countries and different socio-cultural environments (Annett, 2002). However, to date, most studies have consistently reported a vast majority of right handers in their population (Fagard, 2013) and none have revealed a majority of left handers (Annett, 2002).

There are few strong consensual agreements about the background and origins regarding the development of handedness (Fagard, 2013; Janssen, 2004; McManus, 2004). The division in opinion debate on whether an individual or a combination of factors are underlying the high proportion of right handers in the population and the subsequent development of hand preference. The discussion thus far, has included arguments from social and environmental influences such as the cross-cultural bias of left handers, biological effects such as postural asymmetry, head orientation in utero and the possibility of genetics on the subsequent outcome of later handedness in the human adult population (Fagard, 2013). Biological and genetic discussions have been motivated by observations found in nature showing that lateralised behaviours and functions such as hand preference are not solely exclusive to humans; instances of lateralised behaviours have also been reported among primates and animals at the population level (Annett, 2002; Hepper, McCartney & Shannon, 1998).

Indeed, several more recent studies have supplemented evidence for a paradigm supporting a biological link for hand preference. Instances of asymmetric and lateralised behaviour can be observed as early as in utero, long before exposure to the exterior environment. For example, Hepper, McCartney and Shannon (1998) found that around 8-10 weeks of the gestation period, a majority of fetuses (85%) exhibited a greater preference for right arm movements. Hepper, Shahidullah and White (1991) also found that in a sample of the 282 fetuses at 15 gestational weeks, the majority (92%) sucked their right thumb. When a subsample from these studies were tested again 12 years later, the authors found that all of the right-hand, thumb suckers had become right handers, whereas 67% of the left-hand, thumb suckers had become left handers (Hepper, McCartney & Shannon, 1998; Hepper, Shahidullah & White, 1991; Fagard, 2013). Studies such as these promote the notion that, at least in part, features of handedness may be triggered and advance into development through biological means (Fagard, 2013).

Studying handedness in infants has been motivated by accumulated evidence suggesting that hand preference can be identified during early infancy. Furthermore, as hand preference is a feature of motor development associated to changes in brain asymmetry, it also considered as one of the potential factors that determine a child’s cognitive development (Knecht et al., 2000; Johnston et al., 2013). As such, research on child development has focused some of its efforts on factors such as hand preference. Considering that hand preference may influence later development, there is some importance in the assessment of favourable and unfavourable, social, health-related implications and the cognitive developments that may possibly arise later in maturity as a result of this association (Johnston et al., 2009). Whilst right handedness is associated with normal cognitive development and the normal brain function asymmetries associated in language lateralisation, mixed preference and non-
right handedness has been associated with atypical cognitive abilities (Heilman, 2005; Johnston et al., 2009; Johnston et al., 2013; Michel, Tyler, Ferre & Sheu, 2006). Studies of disturbances in typical functional asymmetries have reported non-right handedness being associated with early brain damage (Domellöf, Johansson & Rönnqvist, 2011). For example, a relation between in-uterine alcohol exposure and the consequent abnormalities in the development of functional asymmetries including hand preference (Domellöf et al., 2009). Studying hand preference during infancy may thus both provide a rich set of information on the debate of how handedness manifests, and constitute an early indicator for (a)typical development (Schauron & Bryden, 2014; Nelson, Konidaris & Berthier, 2014).

Several research efforts have attempted to map the development of lateralised behaviors in human infants. Tools, in the form of handedness questionnaires have traditionally been employed in the assessment of hand preference. The verbal requirements and a mandatory familiarity of the items and tasks typically brought up in such questionnaires, reveal weaknesses in the testing applicability for very young children, despite attempts to bypass these issues with supplementary aid given by accompanying adults. Additionally, handedness questionnaires are limited in their efficacy to provide developmental information (Schauron & Bryden, 2014). Likewise, earlier paradigms, notions and beliefs on infant handedness are being challenged. By shifting our efforts to study handedness in infants by means of prehensile activity studies, described also as reach-task studies, we may continue to contribute and improve our understanding of the hemispheric functional asymmetry and interhemispheric communication associated with the development of this movement skill (Michel et al., 2006; Berthier & Keen, 2006).

Through action, infants are able to learn about their environments, doing so at an especially rapid pace (Corbetta & Bojczyk, 2002). This experience is marked by an extremely fast rate of growth in infants, coupled with the consequent, physiological changes that occur. These physical changes are characterised by immense increases, for instance seen in the length and mass of the developing infant arms (Berthier, 2011). Between the ages of 3-4 months, infants perform successful forward extended reaches (Corbetta & Bojczyk, 2002; Cunha et al., 2015; von Hofsten, 1991). However, the quality of infant reaching movements observed in the initial 3-4 months are far from that found in adults (Cunha et al., 2015). Nonetheless, towards six months of age, shortly after the onset of prehensile movements, infants have become increasingly better trained and exercised to their surroundings. A prevailing idea is that as the infants continue to grow, increases associated with the biological maturation that has taken place allows infants to better utilise visually guided control to direct reach-grasp movement into the immediate surroundings, resembling adult-like movement and goal directed-perception (Morange & Bloch, 1996; Melzer et al., 2012).

Ferre and colleagues (2010) mention that there is a growing number of studies providing evidence for hand preference developing in very young infants. These studies contradict the opposing view from past literature suggesting a thorough difficulty and unreliability for endeavours to identify patterns of handedness during the developmental course of early infancy. A number of previous investigators asserted that infant handedness regularly subjects to change, only stabilising around the ages of 3-4 years or later in child development, closer to school age (McManus, 2004; Janssen, 2004; Schauron & Bryden, 2014; Campbell et al., 2015). Contrarily, Michel and colleagues (2006) argue that the evidence suggesting an instability and unreliability of identifying handedness amongst infants is unsatisfactory. A notable study by Nelson, Campbell and Michel (2013) revealed that right hand preference was consistent amongst 39% of infants at 6-14 months; growing to 76% by 18-24 months,
with 21% showing left hand preference. These results imply the presence of a stable hand preference during early infancy (Nelson, Campbell & Michel, 2013).

Studies have also shown that infants as young as between 7 and 13 months old, exhibit signs of stable hand preference in skills such as grasping (Michel, Sheu & Brumley, 2002; Michel et al., 2006). In addition, cases from previous studies have demonstrated that hand preference can be detected and reliably assessed, as early as 6 months into their first year of life (Butterworth & Hopkins, 1993; as cited by Schauron & Bryden, 2014) Examples such as the data from Michel and colleagues (2006) suggest that further study and investigation of infant hand preference patterns between this sensitive, 7-13 month period, could potentially help inform us about the nature in which handedness manifests during the earlier stages in development. In agreement with this view, Ferre et al. (2010) have continued to suggest that the shifts in hand use preference between 6-14 months and reaching may reflect changing in the development of the manual skills.

An interesting phenomenon revealed in infant preliminary reach behaviour is that they are primarily composed of ipsilateral motion (von Hofsten, 1991). Nonetheless, reaching across contralaterally, for objects appears quickly. The progress of contralateral reaching often emerges around 18-20 weeks, denoting a child's increased ability in examining and interacting with the immediate surroundings (Provine & Westerman, 1979; Corbetta & Bojczyk, 2002; Marschik et al., 2008). The emergence of this characteristic in reach behaviour has been associated with a great shift of control, now being committed to the corpus callosum to handle the processes. It has been suggested that this shift in control allows for a better adept interhemispheric communication, corresponding with the increased skill in these movements (Scharoun & Bryden, 2014). The relevance of this is from the notion that the maturation of the corpus callosum could have a role in both hand preference development and bimanual coordination (Scharoun & Bryden, 2014). Collectively, this has led to the emergence of ideas that speculate that the development of the ability to successfully cross the midline may play an important part in the development of a later hand preference (Fagard, Spelke & von Hofsten, 2009; Scharoun & Bryden, 2014).

Crossing the midline is seen when one moves a body part into the contralateral side space i.e. reaching across the central longitudinal axis or midline, with the arm, for the object of interest (Cermak, Quintero & Cohen, 1980). Schauron and Bryden (2014) point out that successful midline reaches necessitate inhibition of the ipsilateral movements, as to ensure focus on the contralateral activity. Contralateral midline reaching can be witnessed when infants begin to reach. For prehension activity however, only with age-related experience can midline reaching improve (Schauron & Bryden, 2014). Midline crossing is an infrequent phenomenon, considering that most typically developing young infants have a tendency to reach laterally presented objects with the hand of the same side (Fagard, 1998; Fagard, Spelke & von Hofsten, 2009). Thus far, midline crossing has been fairly well documented from the age of two (Stillwell, 1987). Understanding the development of manual midline crosses and its relation to hand preference is, as of yet, unclear and limited (Fagard, Spelke & von Hofsten, 2009). It may be of interest to study manual midline crosses in young infants in order to increase our understanding of how the development and relation to hand preference takes place.

To sum up, while there is still controversy whether a consistent hand preference can be assessed in infants younger than 2 years of age, recent research suggest that instances of early hand preference are featured and able to be assessed not long after voluntary prehensile
movement emerge in infants, using simple experimental procedures (Schauron & Bryden, 2014; Nelson, Campbell & Michel., 2013). Michel and colleagues (2006) maintain that there is a possibility to assess hand preference in reaches. The authors quote that many studies have reported patterns of predictability in the hand preferences of objective reaching among 7-13 month infants, adding that competence and a stability in reach skill improves from 6-13 months (Michel, 2002; Michel et al., 2006).

Between 4-12 months, both contralateral reaching and goal directed preferential hand use tasks, see increased improvements and implementation (Morange & Bloch, 1996). Due to the rapid development of reaching, 6-month-old infants are expected to perform adequately stable reaching movements in an adequately stable manner. Midline crossing performances begin to occur between 4-7 months (van Hof, van der Kamp & Savelsbergh, 2002). Additionally, kinematic studies have shown that sufficient practice has been acquired at 8 months, to endow smoother, singular reaches, analogous to the movements found in older children and adults (Berthier, 2011). The ability to reach and grasp by crossing the midline and spontaneous midline crossing are associated with a maturation leap of the corpus callosum by the end of the first year (Bishop, 1990). By 12 months, midline crosses become more frequent, with the higher prevalence of right hand to left direction crosses (Rönnqvist & Domellöf, 2006).

Continuing from the information outlined above, the present study aimed to further explore the characteristics in the reach movements of healthy, typically developing, 12-month-old infants, whilst undertaking unimanual reach-grasp tasks. We can expect that at 12 months of age, infants will be able both to perform successful reaching-grasping and to perform midline crossing in reach activities. Whether or not infants at this age demonstrate a more consistent hand use preference in these actions is uncertain. The following research questions were posed with regards to hand preference characteristics among 12-month-old infants during unimanual reaching and grasping movements.

1) Is there an overall right handed preference in the study population?
2) Is there a higher frequency of right than left hand grasps across the reaching tasks?
3) Do the infants demonstrate a hand preference when performing manual midline crossing?
4) In terms of acquiring the object, are there more successes in the grasps performed by right hand midline crosses than grasps performed by left hand midline crosses?

Method

Participants

Within the framework of a larger study conducted through Umeå University Hospital, Sweden (Timby et al., 2014), a total of 160 videotapes with testing sessions of full term infant boys and girls aged 12 months (+/- 2 weeks) had been acquired. All infants had first been assessed by the Bayley Scales of Infant and Toddler Development, Third edition (Bayley-III) (Bayley, 2006), followed by an assessment of hand preference. All participating infants were healthy, full term deliveries with no known sensory, motor or neurological impairments and had been born at Umeå University Hospital.
For the present study, a sub-sample of 58 infants 28 boys; 26 girls were randomly selected to be included in the analyses regarding the hand preference assessment from the video tapes. However, nine of the videos had been compromised as the recorded data were corrupted or missing, leading to their elimination from the study. To amend this loss, six new participants were included into the set of the study. Of these, one participant had to be excluded due to a data loss of the video session prior to coding. The final study sample thus comprised of a total of 54 infants (28 boys; 26 girls). Information about the study had previously been provided to the parent/guardians of the infants by Timby et al. (2014). Written parental consent had also been acquired for all infants that had been included in the present study. The study in which the data was collected had been approved by the Regional Ethical Review Board in Umeå.

**Materials**

*Recording apparatus.* A Canon XM-1 video camcorder, set up from the side, had been used to record the sessions onto mini DV tapes, allowing offline observation and coding of ipsilateral and contralateral reaches performed by the infant participants.

The goal objects in the reach-tasks were toy ducks in three colours (yellow, red, blue). These were the same objects included in the fine motor assessment within the Bayley-III (Bayley, 2006). Thus, the goal objects are considered age-appropriate, attractive to infants at 12 months and easy to grasp with one hand. Additionally, this aimed to prevent any possible influences on hand selection through the object properties (Schauron & Bryden, 2014).

![Figure 1. Illustration of the experimental set-up.](image-url)
Design and Procedure

A dedicated testing room in the hospital had been allocated for all infants in the study to be tested individually. Infants were first familiarised with the testing conditions and the researcher. Then infants were seated on their parent or guardian's lap, directly in front of the experimenter who administered the experiment. The parents had been informed to minimise any interference that they may potentially place in the experiment thereby, affecting the reach-grasp performances of the infants.

Experimental sessions. The goal objects were presented one at a time on a white A3 size paper, placed directly in front of the infant. The A3 paper was used to designate a graspable distance for the seated infants, in relation to the placement of the object. Three potential positions were allocated for the infant; either at left, right or the midline position with a distance of 12 cm between each position of the object (See Figure 1). A total of up to 12 trials were possible for the infants to complete. To improve the possibility that infants completed the full set of trials, toys were interchanged amongst the various different positions. This was done as quickly as possible, in order to make sure that the child proceeded and completed the full set of trials and to minimise the chance of interruptions to the experiment due to a loss of motivation or interest.

Coding reach-grasp hand choice of video sessions

Following data collection, the video recordings of the infants were used to code the sessions onto score sheets. Score sheets would denote scores for the hand that had been used for each of the grasping object’s positions. This was used to attribute a lateralisation score for each of the infant’s reaching movements. For each item, infants had a choice between using their left, right or both hands, as they were not constrained in any way, during the session. Secondary observations aimed to differentiate between the hands that had been used during the grasping actions.

Cases in which, both hands appeared to be used, required the video footage to be re-examined. This ensured the selection of the hand that had first made contact and grasped the object. In such instances, grasps could only be granted a unimanual grasp score, if a reasonable delay between the contact of the object and each hand had been detected. Alternately, if no delay or a sufficiently miniscule delay appeared, a bimanual grasp would be scored for the reach-grasp task. Finally, a lateralisation index was calculated for each infant using their performance and hand selection on the reach-grasp unimanual tasks. This was done by use of an algorithm generating a lateralisation index from -1 (left hand preference) to +1 (right hand preference).

All grasps performed with both hands were scored as 0. Grasps performed at the left position were scored as -1 for a left hand (LH) grasp, and 2 for a right hand (RH) grasp. Grasps performed at the midline position were scored as -1.5 for a LH grasp and 1.5 for a RH grasps. Those at the right position were scored as -2 for a LH grasps and 1 for a RH grasps. If an infant completed all 12 trials, the sum of the hand-grasp selections was divided by the total number of grasps of right handed grasps performed at the midline (i.e. \( x / 18 = n \)). If an infant performed less than 12 trials, for example, only 4 or 5 trials, then 3 trials would be used to calculate the lateralisation index (e.g. \( x / 4.5 = n \)).
Infants with scores greater than +0.333 were considered to have a right hand preference, and those falling under -0.333 were considered to have a left hand preference. Those between -0.333 and +0.333 were considered to have mixed hand preference.

**Coding success of grasps**

For the present study, codings were also made of the success of the grasp. A grasp was scored as successful if the object was grasped in a simultaneous motion or if the infant had made one quick touch before the grasp was achieved. Missing the object or if an infant carried out more than one touch scored as a failure to grasp.

**Coding behavioural state**

As the infants performed the hand preference assessment directly after having completed a full Bayley-III testing session, an observation of activity level was additionally taken for classification in the video recordings. Based on Prechtl and O’Brien’s (1982) emotional state classification, the following states were coded; state 3: quiet wakefulness, state 4: active wakefulness, state 5: crying. Further coding, adopted from Domellöf’s (2004) modification to the emotional state classification, combined the states 4 and 5 to form a singular active (A) state, and state 3 as an inactive (I) state. Coding of behavioural states (level of activity) were made between each attempted trial.

**Statistical Analyses**

IBM SPSS Statistics version 23 was used to generate analyses through chi-square test specificity of goodness of fit calculations. A one tailed t-test was used to assess overall hand preference of the infants in the study. The $\alpha$ was set to 0.05 for all analyses. Effect sizes of chi-square calculations, Phi, were calculated by using the formula, $\phi = \sqrt{\chi^2/(n*df)}$. Effect size for the one tailed t-test was denoted by $r$. Effect sizes were interpreted as 0.1 = small effect size, 0.3 = medium effect size, 0.5 = large effect size (Cohen, 1988; as cited by Kotrlik, Williams & Jabor, 2011).

An inter-rater reliability calculation was acquired by performing a Cohen’s $d$ kappa to 20 randomly selected infant lateralisation scores. The kappa test is used to determine a consistency of agreement between the accuracy of measurements of individual experimenters. An agreement of 0.81-1.00, is considered as almost perfect agreement between raters. In this case, it was revealed that there was a 0.84 (84%) agreement between the two coders (original experimenter and the present author, SL), which can be considered as a suitable agreement in the coding (McHugh, 2012).

A number of infants were not able to perform all 12 trials ($M = 10, SD = 3$). However, all infants performed at least 3 trials that was needed to compute a lateralisation index to assess handedness among the infants in the trial.
Results

Hand use preference during unimanual reaching

The lateralisation algorithm revealed that there were 5 (9.3%) infants who displayed left hand (LH) preference, 26 (48.1%) infants who displayed mixed hand (MH) preference and 23 (42.6%) infants with a right hand (RH) preference. A t-test revealed a significant effect for the lateralisation index ($M = 0.24, SD = 0.45$), $t(54) = 3.65, p = .001, r = .45$, demonstrating a general right bias at the population level with a medium to large effect size.

Unimanual grasps

A total of 19 LH grasps, 315 RH grasps and 24 bimanual grasps were reported in the present study. A manual index was calculated using the formula: $(U-B)/(U+B)$, showing that the vast majority of grasps (90.9%) was unilateral $[(505-24)/(505+24) \times 100 = 90.9]$. As there were few instances accounted for by bimanual grasps (9%) and as unimanual actions were of primary interest to the study, bimanual grasps were not included in the analyses and consequently removed from the scope of the study. Of the unimanual grasps, 37.6% was performed by the left hand and 62.4% by the right hand.

![Figure 2](image_url)

*Figure 2.* Distribution of the relative frequencies for the respective left and right hand grasps as a function of left, midline and right positions.

Reaches

As shown in Figure 2, 110 LH grasps (65.5%) and 58 RH grasps (34.5%) were reported in the left position. At the midline position, 60 LH grasps (35.9%) and 107 RH grasps (64.1%) were performed. At the right position, 20 LH grasps (11.8%) and 150 RH grasps (88.2%) were performed. Ipsilateral reach-grasps accounted for 84.5% of the total unimanual grasps.
Right hand reaches crossing over the midline to the left position accounted for 11.5% of the total contralateral grasps. Left hand reaches crossing over to the right position accounted for 4% of contralateral grasps.

It was found that left hand grasps were more likely to be used in the left position, \( X^2 (1, N = 168) = 8.25, p = .0041, \phi = .22 \). Thus, left hand grasps were significantly more likely to be used than the right in comparison to hand grasps selected by chance alone, with a small effect size. It was further found that right hand grasps were evidently more likely to be used in the midline position, \( X^2 (1, N = 167) = 6.75, p = .009, \phi = .201 \), with a small effect size. Right hand grasps were also significantly more likely to be used in the right position, \( X^2 (1, N = 170) = 58.22, p < .001, \phi = .59 \), with a large effect size.

**Reaches across the body midline**

With regard to hand preference in reaches across the midline, the chi-square test demonstrated a significantly greater amount of right hand midline crosses, \( X^2 (1, N = 338) = 102.99, p < .001, \phi = .55 \). A further test was made to assess whether the use of the left or right hand in midline crosses resulted in differences in success, but failed to reach significance, \( X^2 (1, N = 78) = 2.07, p = .15 \). Thus, the hand selection in midline crosses did not result in any increases in the success of the grasps.

*Figure 3. Percentage of successful grasps at the left, midline and right positions.*

**Success and hand choice of reach-grasps**

Figure 3 shows the percentage of successful grasps for each of the three positions. In order to assess whether the choice between the left or right hand resulted in greater success, a pearson chi-square calculation was performed for each of the positions. It was revealed that hand choice did not lead to a significantly greater success in grasps in any of the positions (left
position, $X^2 (1, N = 168) = 2.01, p = .65$; midline position, $X^2 (1, N = 167) = 2.11, p = .15$; right position, $X^2 (1, N = 170) = 1.66, p = .198$.

To further assess whether hand choice resulted in greater success, a pearson chi-square calculation was performed for the total successes and failures for the left and right reaches. No significant effect for the choice of hand and subsequent success in the grasp was found, $X^2 (1, N = 505) = 1.83, p = .176$. Thus, in the present study, the choice of hand did not affect the subsequent success of a grasp in infants at 12-months.

**Level of activity and hand choice of reach-grasps**

To assess whether the level of activity affected hand choice, chi-square calculations were performed for each position. It was found that the level of activity did not affect hand choice in the left position, $X^2 (1, N = 168) = 1.88, p = .17$, the midline position, $X^2 (1, N = 167) = 0.705, p = .401$, nor the right position, $X^2 (1, N = 170) = 0.86, p = .35$. Behavioural state does not affect hand choice in the right position. This demonstrates that the level of activity did not affect the choice of hand when reaching and grasping an object.

**Level of activity and success of reach-grasps**

To assess whether the behavioural state of the infant affected success at each grasp, a chi-square calculation was performed for each position. While no significant effect could be found for the left position, $X^2 (1, N = 176) = 0, p = .995$, or the midline position, $X^2 (1, N = 178) = 0.124, p = .725$, an evident effect was revealed for the right position, $X^2 (1, N = 175) = 9.64, p = .002, \Phi = .235$. The right position was characterised by an inactive behavioural state leading to greater success in hand grasps.

**Discussion**

The present study aimed to investigate hand preference in the unimanual prehension activity of infants aged 12 months. Overall hand preference as derived from laterality index scores revealed a significant right hand population bias. Additionally, the results show that right hand grasps accounted for almost twice as many of the unimanual grasps compared with the left hand grasps. Although ipsilateral reaches were predominately performed, infant manual midline crosses into contralateral space accounted for 15.5% of the trials. A majority of the manual midline crosses were made with the right hand. As judged by these findings, hand preference can be reliably observed in the prehension activity of infants at 12 months. Whilst the present study is to be considered preliminary due to the relatively small sample, the study supports the previous finding by Rönnqvist and Domellöf (2006), which suggests that midline crosses may be a sensitive indicator of hand-use preference. Although more representative to 12-month-old infants as in this study, the findings also provide some support for the increasingly more accepted argument that during infancy, a relatively stable hand preference exists which can be assessed (Ferre et al., 2010).
When scrutinising the overall finding of a population-level right preference, it was found that 9.1% of the infants in the present study demonstrated a left hand preference, 42.6% exhibited a right hand preference and the remaining 48.1% exhibited mixed preference. The proportion of those displaying a left handed preference is in close agreement with the notion that 10% of the adult population are left handed, additionally demonstrating that there is a higher right hand preference amongst 12-month-old infants (Cohen & Porac, 1977). The high proportion of mixed-handed infants is perhaps more surprising. The use of a lateralisation index did not reveal an overall strong right hand preference amongst the 12-month-old infants. As the sample of infants in the study comprised of healthy, full term infants, neurological causes for the high mixed preference turn out can be ruled out as a potential cause for this result.

However, the results from the present study are in agreement with the findings by Fagard et al. (2016) and Nelson et al. (2013) whom reported a high percentage of right handers compared to left handers, whilst also reporting a high number of infants displaying no preference. It may thus be that the present study has demonstrated a high mixed hand preference in infants whom are yet to display a clear preference for one hand or the other. Fagard et al. (2016) also describe a similar characteristic of high frequencies of non-lateralised infants that have also been reported in previous studies. Additionally, many previous studies have carried out the assignment of hand preference utilising different methodologies and algorithms. Thus, the mixed hand preference reported in the present study could also be possibly accounted to the way in which the lateralisation was calculated and the procedure that was used.

In addition, greater frequencies of right hand grasps were reported in both the midline and right positions compared with hand choice made by chance alone. Differences in hand-use preference between the right hand and the left hand in the right position were further supported by a large effect size indicating that there was a greater right hand-use preference at this position. A similar report could be made for hand-use preference in the left position. Hand-use differences in the left position, revealed a greater left hand-use preference in this position. Similar analyses in the midline position revealed a greater right hand-use preference in the midline-position, however both of these observations, reported small effect sizes. In consideration, it could be suggested that the lateralisation index is not an ideal measure of hand preference for 12-month-old infants, given that infants have demonstrated that they do show an overall preference for the right hand when performing midline crossings and grasps. The distribution and frequencies of the right hand and left hand-use in each of the positions in Figure 2, also closely resemble those reported in the results found in the study by Rönnqvist and Domellöf (2006).

The presence of repeated measures in the present study could have enabled a further comparison and replication of Rönnqvist and Domellöf (2006) findings. Rönnqvist and Domellöf (2006) demonstrated a great shift in the number of contalateral reaches made by infants from the age of 9 months to 12 months of age. Infants evidently became more manually lateralised with age, however the present study is unable to replicate such developmental findings. Nelson and colleagues (2013) also showed that those infants who had previously showed no preference (69%), later developed left or right hand preference (31%) as toddlers. If we were to re-test the same sample of infants later in their development, there is the possibility that a majority of these infants who were assigned mixed hand preference acquire a shift to right hand preference. Support for such a claim may be found in the fact that despite a large proportion of mixed hand preference/non-lateralised infants seen in our 12-month group, we found a higher percentage of right hand (62.4%) than left hand preference.
(37.6%) grasps. Right hand grasps accounted for almost twice as many of the unimanual grasps compared with the left hand grasps. These results are in line with Michel and colleagues (2006) who reported a majority of 7-13 month old infants exhibiting a right hand preference. In addition, Nelson and colleagues (2013) found that the percentage of right handed use ranged between 62.3-81% in 6-14 month-old infants.

An important research question in the present study concentrated on whether 12 month old infants were able to demonstrate a hand preference when performing midline crosses to reach for objects in the contralateral space. In line with previous reports, midline crossings emerge with the increased perceptual-motor ability corresponding to age-related experience in developing infants (Scharoun & Bryden, 2014), the analyses confirmed that infants at 12-months of age do perform midline crosses. Furthermore, similar to the results reported by Rönnqvist and Domellöf (2006), midline crosses reaching over to the left nearly tripled that of midline crosses reaching over to the right showing that the 12 month old infants demonstrated an evident hand preference when performing reaches across the midline. However, the choice between a right or left hand did not determine the success outcomes of the grasps carried out by midline crosses. Fagard, Spelke and von Hofsten (2009) noted that there typically is an increase in contralateral movement after 8-months of age, similarly the present study has demonstrated that contralateral movement can be found at 12-months. Experimenters had also previously assumed that those aged as young as 12-months would be too inexperienced, thus unable to illustrate sophisticated demonstrations of midline crosses, that could be assessed (Schauron & Bryden, 2014). The findings from the present study suggest otherwise, and that infants were able to demonstrate hand preference when performing reaches across the midline.

The prevailing paradigm is that midline crosses and the coinciding prevalence of spontaneous midline crossing at 12 months of age is associated with the maturation of the corpus callosum (Bishop, 1990; as cited by Rönnqvist & Domellöf, 2006). However, there is an unavoidable issue for those cases aiming to encourage reaching across the midline. Object positioning often motivates ipsilateral reaches in infants due to the reduced effort offered by taking such an option (Morange & Bloch, 1996). Studies have demonstrated that infants prefer to make reaches and grasps with the hand positioned at the same side of object (Fagard, 1998; Rönnqvist & Domellöf, 2006). Similarly, is seen in adults, Leconte and Fagard (2004) demonstrated that only in 30% of the instances were midline crosses attempted with the preferential hand when there were opportunities to move into contralateral space.

When assessing whether a left or right hand grasp affected the success of the grasps in retrieving the object, our analyses revealed that hand preference did not affect the resulting success or failure to grasp objects in any of the three positions. Nor were any differences reported between the choice of a left or right hand in the success of grasps. Further, the behavioural state did not affect success in any of the positions, except for the right position. This could be partly explained by the fact that similar studies had not explicitly coded for differences in activity. Some methodological differences had also been implemented in other studies, such as starting and stopping each trial until infants were relatively calm in terms of their level of activity.

The finding of greater success in the grasp in the right position, following an inactive behavioural state is possibly due to a more trivial explanation, denoted by the report of a small effect size, such that infants who were relatively active were not focused enough on the reach-grasp activities compulsory for the tasks. It was also revealed that the choice of hand
was not influenced by infants’ behavioural state in any of the three positions. Thus, it can be assumed that the infants’ level of activity did not affect the ability and successfulness of the reach-grasps and that hand selection is not a precursor to success in reach grasps at this age. This contradicts a common association described by Schauron and Bryden (2014) that an increased performance ability is seen when attempted with the preferred hand. A potential explanation can be found through Jäncke et al. (1998); as cited by Schauron and Bryden (2014), who describe more effort requiring to be exerted when the non-preferred hand is exercised, in order to achieve a similar level of performance as seen, when the action has been attempted by the preferred hand. This explanation better explains instances when ipsilateral reaches are attempted with the non-preferred hand however there is not enough information at present that could explain success as a result of the choice of hand used on reaches across the mid-line.

What is apparent is that infants are clearly able to show signs of assessable reaching ability with instances of hand preference behaviour, before the social or familial environment has been able to enforce more concrete forms of left hand biases (Janssen, 2004; Fagard, 2013). This is shown in the high rates of success in their grasping, as well as their demonstration of hand preference at 12 months. We could speculate the findings of our study, correspond to the notion that stable handedness exists in infancy. Although not all of the infants showed a clear hand preference for unimanual prehension of items, infants were only tested at 12 months of age and with no repeated measures for earlier or later ages. Michel and colleagues (2006) provide much motivation for the continuation of this line of research, as the investigations of infant handedness could merit important insight into the understanding of hemispheric specialisation, and the contribution of these specialisations in the different hemispheres for goal-directed reaching tasks.

There are limitations that can be found in the study that should be addressed in future studies, so discretion is advised when interpreting the findings of the study. By taking this into account, the study should be considered as a preliminary that should be replicated with a more sophisticated methodology and equipment such as kinematic recordings, which will be able to provide additional information about infant reach behaviour. Data loss had been reported in the study due to the use of video tapes and there are the possibility for Type I errors due to the use of a small visual platform to ensure the video coding, however, inter-rater reliability has demonstrated high agreement in the code scoring between both coders, in this case. Not all infants were able to perform all 12 of the trials. Only 63% of the infants were able to complete all 12 trials. Analyses showed that an average of 10 trials were attempted by all infants. This is a lot lower than Fagard et al. (2016) had suggested, that a minimum of 15 trials are necessary to evaluate handedness. This is possibly due to tiredness or boredom effects warranted from this being at the very end of the Bayley-III test and the young age of the participants, although our study demonstrate that the level of activity did not affect the outcomes of the study in any major respect. It should be noted that, seeing as the emotional state classification had been developed for use on the newborn infants, it is possibly non-optimal for use of assessing the level of activity on 12-month-old infants.

Despite limitations, it can be concluded that non-traditional assessments of hand preference such as utilising manual midline crossing on infants, could be helpful in assessing infants who have greater experience with unimanual tasks, such as those at 12 months of age. It may be of interest to direct future inquiry into the applicability of manual midline crossing, in its sensitivity as a measure, to identify non-right handedness in infants. Domellöf and colleagues (2011) describe reports of unclear hand preference and a high prevalence of non-
righthandedness among children with developmental disorders such as fetal alcohol syndrome. As the present study has provided evidence for relatively stable hand preference that can be assessed in typically developing infants, it could be speculated that children with developmental disorders will not demonstrate similar patterns of hand-use preference in manual mid-line crossing tasks, perhaps due to deficits or delays in the maturation of the corpus callosum, that is associated with the spontaneity of manual midline crossing among infants (Rönnqvist & Domellöf, 2006).
References


