Hand preference for precision grasping predicts language lateralization

Claudia L.R. Gonzalez a,b,*, Melvyn A. Goodale a

a CIHR Group on Action and Perception, Department of Psychology, University of Western Ontario, London, N6A 5C2, Canada
b Department of Kinesiology, University of Lethbridge, Lethbridge, T1K 3M4, Canada

A R T I C L E   I N F O

Article history:
Received 7 November 2008
Received in revised form 21 July 2009
Accepted 28 July 2009
Available online 3 August 2009

Keywords:
Cerebral asymmetries
Dichotic listening
Language lateralization
Left-handers
Left hemisphere
Reaching and grasping

A B S T R A C T

We investigated whether or not there is a relationship between hand preference for grasping and hemispheric dominance for language—and how each of these is related to other traditional measures of handedness. To do this we asked right- and left-handed participants to put together two different sets of 3D puzzles made out of big or very small LEGO® pieces. Participants were also given two self-reported handedness questionnaires, as well as tests of grip force and finger tapping speed. A language lateralization (dichotic listening) test was also administered. We found a positive correlation between hand use for precision grasping and language lateralization (i.e. the more participants used their right hand for grasping the small LEGO® pieces, the more language was lateralized to the left hemisphere). In addition, we identified two populations of left-handers according to their grasping performance: ‘left-right-handers’, who behaved exactly like right-handers; and ‘left-left-handers’ whose performance was the mirror image of that of right-handers. Finally, we found an increase in right-hand use when right-handers and ‘left-right-handers’ had to pick up the small LEGO® pieces. We discuss our results in relation to recent notions of left-hemisphere specialization for visually guided actions and its relationship with the evolution of language.

© 2009 Elsevier Ltd. All rights reserved.

Handedness is one of the most salient traits of cerebral asymmetry. Ninety percent of the human population could be classified as right-handed in that they tend to favour this hand for a range of tasks, such as writing and using tools. In the case of more “basic” behaviours, such as reaching out and picking up an object, however, it would make sense (from an ecological and biomechanical perspective) to use the hand closer to the object rather than the preferred hand. Yet, few studies have actually compared hand preference for visually guided grasping in left- and right-handers and these have asked to pick up tools or objects one by one (Brown, Roy, Rohr, & Bryden, 2006; Calvert & Bishop, 1998; Mamolo, Roy, Bryden, & Rohr, 2004; Mamolo, Roy, Bryden, & Rohr, 2005; Mamolo, Roy, Rohr, & Bryden, 2006). Recently however, we measured spontaneous hand preference in a ‘natural’ grasping task. We asked right- and left-handed participants to put a puzzle together or to create different LEGO® models, as quickly and as accurately as possible, without any instruction about which hand to use. We found that right-handers showed a marked preference for their dominant hand when picking up objects; as a population, left-handers, however, did not show this preference for the dominant hand and instead used their right hand 50% of the time (Gonzalez, Whitwell, Morrissey, Ganel, & Goodale, 2007). Closer examination of the left-handers’ behaviour suggested that rather than using both hands equally often, some left-handers simply preferred to use their right hand whereas others preferred to use their left. But, why would some left-handers use their non-dominant right hand more often when picking up objects? It certainly did not seem to be related to the degree of left-handedness; all the left-handers in this earlier study, including those who used their right hand to pick things up, were strongly left-handed as measured by the self-reported handedness questionnaire. Indeed, even in the right-handed population there was variability in the hand that participants used to pick up the small objects. Some right-handed participants used their right hand nearly 100% of the time whereas others used it less, closer to 50% of the time.

The present investigation was designed to explore the relationship between laterality in precision grasping and other measures of laterality. First, we asked right- and left-handed participants to put together different 3D models using big LEGO® pieces or small LEGO® pieces. We anticipated that grasps made towards the big objects would be made more often with the whole hand (4–5 digits) whereas those made towards the small objects would be made with a precision (thumb and index) or a tripod grasp (thumb, index and middle finger). In this way, we hoped to see if the degree of skill needed to grasp an object plays a role in determining which hand one chooses in order to pick it up.

Secondly, we wondered if traditional measures of handedness (self-reported questionnaires and hand-performance tasks) would predict hand preferences for visually guided grasping. Some studies have shown, for example, that performance variables such as grip
force and/or finger tapping speed correlate well with self-reported handedness questionnaires (Brown et al., 2006; Corey, Hurley, & Foundas, 2001; Peters & Durding, 1979). Thus, we wanted to see if these measures would also correlate with hand preference for grasping. To do this, we asked participants to complete the Waterloo and the Edinburgh handedness questionnaires as measures of self-reported handedness, and we recorded grip force and finger tapping speed as hand performance measures.

Finally, participants were given a dichotic listening test to investigate the possibility of a relationship between hemispheric dominance for language and visuomotor control. It has been estimated that over 95% of right-handed people and 70–80% of left-handers show language lateralization to the left hemisphere (Annett & Alexander, 1996; Kimura, 1983; McKeever, Seitz, Krutsch, & Van Eys, 1995; Rasmussen & Milner, 1977). The remaining 20–30% of left-handers appear to have language bilaterally represented or atypically represented in the right hemisphere. With this in mind we reasoned that perhaps those left-handers (that like right-handers) prefer using their right hand for grasping would have normal language representation to the left hemisphere. Conversely, those left-handers that show a clear preference for using their left hand would perhaps show atypical hemispheric (bilateral or right hemisphere) language representation. In other words, we were set to investigate if there is a relationship between hemispheric lateralization for grasping and for language.

1. Methods

1.1. Participants

Self-reported right- and left-handed volunteers were recruited from the University of Lethbridge. Eighteen right-handers (10 females) and eighteen left-handers (12 females), ranging in age between 19 and 35 took part in this experiment. The studies were approved by the local ethics committee and all participants gave written informed consent before participating in this study. All participants were naïve to the purpose and hypothesis of the study.

1.2. Materials and procedures

Participants were comfortably seated in front of a table (107 cm × 77 cm) and were asked to perform six tasks in the following order: (1) two grasping tasks, (2) the waterloo handedness questionnaire (WHQ), (3) a grip strength (GS) measure, (4) a finger tapping (FT) speed measure, (5) the Edinburgh handedness questionnaire (EHQ), and (6) a Dichotic listening test (DLT) to determine hemispheric lateralization for language.

1.2.1. Grasping tasks: big-piece models

A total of forty-eight LEGO® pieces (ranging in size from 6.5 cm × 3.2 cm × 2.0 cm to 3.0 cm × 3.0 cm × 2.0 cm) were used to construct four different sample models (see Fig. 2 for an example). The samples were prepared by the investigator ahead of time, and one sample at a time was presented to the participant for reproduction. The same four models were used with all participants. All LEGO® pieces were randomly distributed across the tabletop. A strip of white tape divided the tabletop in half. The same number of pieces was placed on the left hand and right side of the table. Care was taken to ensure that each participant was seated facing the middle of this display, with an equal number of pieces to his or her left and right. Each sample model was handed to the participant for close inspection but once they reported to be ready, the investigator placed the model at the far end of the tape that divided the tabletop in half. Participants were instructed to reproduce the models as fast and as accurately as possible, without any instruction about which hand to use. No pieces were replaced after each model was completed. The time taken to complete each model was recorded by the investigator using a stop watch. Small-piece models: In a separate grasping condition, sixty-three small LEGO® pieces (ranging in size from 6.0 cm × 0.7 cm to 0.5 cm × 0.3 cm) were used to construct four different models (see Fig. 2 for an example). All procedures were identical to those used for the big-piece models. The order of presentation for the big- or small-piece models was counterbalanced among participants (i.e., some participants were asked to complete the big-piece models first, and others the small-piece models).

1.2.2. Waterloo handedness questionnaire (WHQ)

Participants were given a questionnaire identical to the one used by Brown and colleagues (Brown et al., 2006). The WHQ asks participants to rate which hand they prefer to use on 20 different tasks (spin a top, hold a paintbrush, pick up a book, use a spoon to eat soup, flip pancakes, pick up a piece of paper, draw a picture, insert and turn a key in a lock, insert a plug into an electrical outlet, throw a ball, hold a needle while sewing, turn on a light switch, use the eraser at the end of a pencil, saw a piece of wood with a hand saw, open a drawer, turn a doorknob, hammer a nail, use a pair of tweezers, writing, and turn the dial of a combination lock) on a scale with the following possible answers: +2 (right always), +1 (right usually), 0 (equal), −1 (left usually) and −2 (left always). Each response was scored as either +2 or −2 and a total score was obtained by adding all values. Scores range from +40 for exclusive right-hand use to −40 for exclusive left-hand use.

1.2.3. Grip strength (GS)

GS was measured with a hand-held dynamometer. For this test, participants remained seated and were asked to place their forearm on the surface of the table. The dynamometer was then placed in the participants’ hand and they were then asked to ‘squeeze’ it as hard as they could without lifting their arm. Participants were given two trials with each hand in an alternating manner and their score was the mean of the two trials for each hand. Performance was recorded in kg.

1.2.4. Finger tapping (FT)

With their index finger, participants were asked to tap as fast as they could a button mounted on a small plastic box (10 cm × 8 cm). The button was connected to an automatic counter. Three 10-s bouts were recorded for each hand for each participant in an alternating mode. The participants’ score was the mean of the three trials for each hand.

1.2.5. Edinburgh handedness questionnaire (EHQ)

Participants were presented with a modified version of the EHQ (Oldfield, 1971). The EHQ asks participants to rate which hand they prefer to use on 13 different tasks (signing a document, writing, drawing, throwing, using scissors, using a toothbrush, using a knife (without a fork), using a spoon, using a broom (upper hand), striking a match, opening a box (the lid), kicking with the foot, and swinging a bat) and whether or not they ever use their other hand (non-preferred hand) for the same activity. Scores were calculated by giving a score of 2 points to every answer (right or left) in which participants reported that they would never attempt to use the non-preferred hand. One point is given to those answers indicating that the non-preferred hand is also used (right or left). Scores are calculated with the following formula: \( R = 2L \times R \) where \( L \) represents the total number of left-hand tasks the participant reported that they would never attempt to do and \( R \) represents the total number of right-hand tasks the participant reported that they would never attempt to do.

1.2.6. Dichotic listening test (DLT)

Hemispheric language dominance was assessed with the Dichotic-Listening-Words test obtained from the Department of Psychology at the University of Victoria in British Columbia (Hayden & Spellacy, 1969). A digital stereo radio cassette recorder (Samsung RCD-995) and a pair of headphones (SONY digital reference dynamic stereo headphones MDR-70D) were used to administer the DLT. In this test, a total of 66 one-syllable pairs of words are arranged into 22 lists of 3 word pairs. Each word in each pair is selectively channeled to each ear, with the words presented simultaneously to the two ears. Participants were told that they would hear different words coming to the two ears at the same time (e.g., ‘cat’ in one ear, and ‘cow’ on the other ear). They were told that they would hear a list of three pairs of words and then the voice would pause. During the pause, the participants were asked to report as many words as they could from the list that they just heard. Two practice trials were given to each participant. The 20 remaining sets were given with a pause after the 10th set at which time participants were asked to reverse the headphones (to account for any discrepancies between the left and right headphone). Scores were calculated by adding up all of the items reported for each ear. The maximum score for each ear was 60 points.

1.3. Analyses

Performance on the grasping tasks and on the DLT were videotaped with a Canon ZR 30 MC digital video camcorder with a shutter speed of 1 ms. For the grasping tasks the camera was positioned directly in front of the participant approximately 50 cm above the tabletop so that it gave a full view of both hands. A Sony video cassette recorder DSR-11 was used, when needed, for frame-by-frame analysis. For the grasping tasks the total number of different grasps (whole hand, four finger, tripod, or precision grip) with the right and left hands (RH-grasps, LH-grasps) was recorded for each participant. Separate totals were calculated for grasps directed to the left and right sides of the table.

For the grasping tasks and the dichotic listening task the scores were transformed into a percent right-hand (ear) advantage (i.e., RH performance/RH performance + LH performance) > 100) for each participant. The scores from grip strength and finger tapping were transformed into a laterality quotient (e.g., RH performance – LH performance/RH performance + LH performance). As a result, a positive score suggested right-hand superiority and a negative score left-hand superiority.

2. Results

For the two grasping tasks, the grip strength test, and finger tapping speed no significant sex differences or interactions were
found in the analyses; therefore we pooled the male and female data within each handedness group.

2.1. Grasping tasks: big-piece models

Participants used a full-hand or four-digit grasp when picking up the big LEGO pieces (see Fig. 1). Overall, right-handers used their right hand 65.2% of the time and left-handers used their left hand 54.3% of the time to pick up the objects (Fig. 2). No significant differences between the two groups ($p > 0.05$) were found. The time that participants took to complete the five models was similar for right-handers (average: 138.8 s) and left-handers (average: 135.3 s). No significant differences were found between the groups ($p > 0.05$).

2.2. Small-piece models

In contrast to the full-hand grasps observed when people picked up the big LEGO© pieces (see Fig. 1), overall, right-handers used their right hand 75.0% of the time whereas left-handers used their left hand 54.8% of the time (Fig. 2). We conducted a repeated-measures ANOVA with handedness (Left, Right) and grasping task (Big Lego, Small Lego) as main factors. A significant interaction between handedness and grasping task was found ($F(1,34) = 4.9; p < 0.05$). Analysis of the simple effects of the handedness by grasping task interaction revealed that right-handers used their dominant right hand more when picking up the small pieces than when picking up the big pieces ($t(17) = 3.5; p < 0.01$), the same was not the case for left-handers for whom the scores were virtually identical for big and small pieces ($t(17) = 0.13; p = 0.89$). The time that participants took to complete the five models was similar for right-handers (average: 264.5 s) and left-handers (average: 248.2 s). No significant differences were found between the groups ($p > 0.05$).

Grasping behaviour according to right-handers, “left-right-handers” and “left-left-handers”.

Fig. 3A shows the individual differences in hand use by right-handers for the big-piece and the small-piece grasping tasks. Fig. 3B shows the individual differences in hand use by left-handers. As can be seen, two separate populations of left-handers seem to emerge with respect to the hand that they preferred to use to pick up objects: “left-right-handers” who overall used their left hand less than 50% of the time; and “left-left-handers” who used their left hand more than 50% of the time. To demonstrate that these populations, although arbitrarily determined, reflected real differences in performance, we carried out an ANOVA with three groups (right-handers, left-right-handers and left-left-handers) over the scores of right hand use for both grasping tasks. Not surprisingly, as Fig. 4...
shows, the performance of left-left-handers with the big LEGO© pieces was different from the performance of right-handers and left-right-handers ($F(2,33) = 9.79; p < 0.001$) which in turn was not different between each other ($p = 0.65$).

We found the same pattern of results when we analyzed the data from the small LEGO© grasping task (Fig. 4). Again not surprisingly, performance by left-left-handers was different from that of right-handers and left-right-handers ($F(2,33) = 25.7; p < 0.0001$), and performance of right-handers and left-right-handers was virtually identical ($p = 0.99$).

2.3. WHQ

The average score in the questionnaire for right-handers was $+29.5$ points ($\pm 1.1SE$) out of the maximum possible of $+40/−40$ points. The average score for left-handers was $−17.27$ ($\pm 2.5SE$). As expected, this difference was significant ($t(34) = 16.9; p < 0.0001$). To find out if overall right-handers were more thoroughly right-handed than left-handers were left-handed, the scores from the questionnaire were converted to an absolute values (by multiplying the negative values by $−1$). A $t$-test on these values showed a significant difference between the two groups ($t(34) = 4.4; p < 0.0001$).

2.4. Grip strength

The scores of one participant deviated from the mean by more than three standard deviations thus was excluded from the analysis. Table 1 shows the scores on this task according to handedness and hand. When we analyzed the scores from the laterality quotient we found that grip strength differed between right- and left-handers ($t(33) = 2.45; p < 0.02$). This difference is because right-
handers displayed a positive score (3.17 ± 0.74) whilst left-handers showed a (slight) negative score (−0.89 ± 1.5). When we compared the scores in kgW of both hands, we found that the right hand of right-handers was significantly stronger than their left hand (t(17) = 4.04; p < 0.001; by paired t-test) but the left hand of left-handers was not significantly stronger than their right hand (t(16) = 0.48; p = 0.63). This means that only right-handers show an asymmetry between the two hands (favoring the right hand) with respect to grip strength.

2.5. Finger tapping

Overall we found that hand superiority in finger tapping speed differed between right- and left-handers (t(34) = 3.7; p < 0.001). Like in the measure of grip strength the score for right-handers was positive (4.74 ± 1.1) and negative in left-handers (−0.97 ± 1.0). Right-handers tapped the key significantly faster with their right hand (t(17) = 4.5; p < 0.0005), but left-handers did not show the same advantage with their left hand (t(17) = 0.9; p = 0.3). Again, only right-handers show an asymmetry between the two hands (favoring their right hand) with respect to finger tapping speed. 

Table 1 shows the overall performance of participants in this task.

2.6. EHQ

The average score for right-handers was +75.6 (±2.8 SE) and −44.0 (±6.5 SE) for left-handers. This difference was significant (t(34) = 16.7; p < 0.0001). A t-test on the absolute values showed a significant difference between the two groups t(34) = 4.5; p < 0.0001.

For both handedness questionnaires further analyses were carried out to find out if there were differences between the two left-handed groups (divided accordingly to their grasping performance) with respect to the right-handed group. This was not the case. Both left-handed groups were not different from each other but did differ significantly from the right-handers. 

2.7. Dichotic listening test

There were no significant differences (p > 0.1) between the number of words recalled by right-handers (57.0 ± 2.4) and left-handers (59.3 ± 1.7) or by males (55.5 ± 2.9) and females (59.9 ± 1.4). There was, however, a significant interaction between handedness and sex when we analyzed the right-ear advantage scores (F(1,32) = 5.34; p < 0.05) with no main effect of handedness (p > 0.3) nor sex (p > 0.6). The significant interaction was due to the fact that right-handed females scored higher (69.24 ± 4.8) than their male counterparts (60.63 ± 2.9) and left-handed females scored lower (54.8 ± 2.9) than their male counterparts (66.97 ± 7.4). In other words, left-handed females showed the lowest right-ear advantage whereas right-handed females showed the highest right-ear advantage.

2.8. Correlation and regression analyses

We carried out a correlation analysis with the scores from all the tasks to find out if standard measures of handedness (self-report questionnaires and hand-performance tasks), visuomotor control of grasping, and language were correlated. Table 2 shows all significant correlations. Some results were expected but others were not. For example, we expected that the grasping tasks would be correlated with the handedness questionnaires (as they were). We also expected to see a correlation between the grasping tasks and the performance tasks (grip strength and finger tapping speed)—so it was somewhat surprising to find that this was not the case. We will come back to this point in the discussion of our paper. We also expected to find (and we did) a correlation between the handedness questionnaires and the performance tasks given that similar results have been reported previously (Brown et al., 2006). Our most notable finding, however, was the significant correlation between both grasping tasks and the dichotic listening test. This finding suggest that the more participants used their right hand to pick up the different LEGO® pieces the more language was lateralized to their left hemisphere (thus a greater number of words recalled from the right ear). Importantly, no correlation was found when only right-handers (p = 0.08) or only left-handers (p = 0.1) were included in the analyses. In other words the relationship between hemispheric lateralization for language and grasping emerges only when samples of the two populations are considered (a population-level effect). In addition to the correlations, we carried out a stepwise multiple regression analysis to determine what factors could best predict language lateralization. We found that precision grasping

Table 1

Scores (mean ± SE) on the grip strength and finger tapping tasks according to handedness and hand.

<table>
<thead>
<tr>
<th>Handedness</th>
<th>Hand</th>
<th>Grip strength (kgW) mean ± SE</th>
<th>Finger tapping (# of taps in 10 s) mean ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right-handers</td>
<td>Left</td>
<td>38.6 ± 1.6</td>
<td>52.89 ± 1.6</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>41.03 ± 1.5</td>
<td>58.33 ± 2.0</td>
</tr>
<tr>
<td>Left-handers</td>
<td>Left</td>
<td>37.17 ± 2.1</td>
<td>55.08 ± 1.6</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>36.65 ± 2.3</td>
<td>54.04 ± 1.4</td>
</tr>
</tbody>
</table>

Table 2

Correlation matrix of all variables.

<table>
<thead>
<tr>
<th>Grasping %RH_Adv_Big</th>
<th>Grasping %RH_Adv_Small</th>
<th>WHQ</th>
<th>EHQ</th>
<th>GS</th>
<th>FT</th>
<th>DLT %RH_Adv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grasping %RH_Adv_Big</td>
<td>Pear Corr 1 **</td>
<td>.894**</td>
<td>.463**</td>
<td>.459**</td>
<td>.057</td>
<td>.119</td>
</tr>
<tr>
<td>Grasping %RH_Adv_Small</td>
<td>1 **</td>
<td>.576**</td>
<td>.565**</td>
<td>.163</td>
<td>.186</td>
<td>.440**</td>
</tr>
<tr>
<td>WHQ</td>
<td>1 **</td>
<td>.958**</td>
<td>.439**</td>
<td>.507**</td>
<td>.302</td>
<td></td>
</tr>
<tr>
<td>EHQ</td>
<td>1 **</td>
<td>.459</td>
<td>.559</td>
<td>.272</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GS</td>
<td>1 **</td>
<td>.479</td>
<td>.292</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FT DLT %RH_Adv</td>
<td>1 **</td>
<td>.226</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.01 level (2-tailed).

** Correlation is significant at the 0.05 level (2-tailed).
(as measured by scores in grasping the small pieces) was the only significant independent variable that determined language laterality \( (p = 0.01; \text{adjusted } R^2 = 0.15) \). Furthermore, we also found that the dichotic listening test together with the Edinburgh handedness questionnaire were the major predictors of hand preference for precision grasping \( (p < 0.001; \text{adjusted } R^2 = 0.34) \). So there seems to be an intimate relationship between language lateralization and hand preference for precision grasping—and a weaker relationship between handedness (as measure by the Edinburgh handedness questionnaire) and hand preference for precision grasping.

3. Discussion

The results of our study show two main findings: (1) an increase in right-hand use for grasping when precision is needed, and (2) a relationship between hand preference for these precision grasps and hemispheric dominance for language.

In a previous study (Gonzalez et al., 2007) we showed that, compared to right-handers, left-handers use their non-dominant hand much more often to pick up objects. In other words, when picking up objects, right-handers showed a strong preference for their dominant right hand, whereas left-handers used their right hand as often as their dominant left hand. In that study, we measured hand preference for grasping as participants gathered pieces for assembling two different puzzles: one that involved large flat puzzle pieces, and the other the construction of 3D models using smaller LEGO© pieces. We noticed a slight increase in right-hand use when participants picked up the LEGO© pieces as compared to the puzzle pieces. One of the purposes of the present experiment was to explore the possibility that right-hand use for precision grasping would increase as a function of the degree of precision required to grasp the objects. In the current study, participants were presented with large or very small LEGO© pieces; we expected that the participants would use a whole hand grasp to pick up the large pieces and a precision grasp to pick up the small pieces. Not surprisingly, we found this to be the case (see Fig. 1). Participants used either the whole hand or four digits to grasp the big pieces whereas they used a precision or a tripod grasp to pick up the small ones. The fact that we found an increase in right hand use for grasping the small objects—even in a left-handed subpopulation (left-right-handers), strongly suggests that the degree of skill or precision required to pick up an object plays an important role in determining which hand is selected to carry out the action.

As we observed in our previous study (Gonzalez et al., 2007), the left-handers were not the mirror image of right-handers. Overall, left-handed participants tended to use their non-dominant right hand to pick up the LEGO© pieces. In fact, some left-handers looked just like right-handers. When we divided the left-handers into two groups on the basis of their hand preference for grasping (using a 50% cut off), the two ends of the continuum appeared to be quite different. Indeed, they could be characterized as representative of two distinct populations of left-handers (at least when it comes to precision grasping): a ‘left-right-handed’ population that used their right hand close to 75% of the time and a ‘left-left-handed’ population that used their right hand less than 25% of the time. Although the distinction of these two populations was purely arbitrary, it is interesting to note that the left-right-handers grasping preference was identical to that of right-handers (see Fig. 4). Some of these individuals were even more right-handed than a good many of the right-handers. For example, participants L1 to L5 had higher right hand use scores than participants R12 to R18 (see Fig. 3). Interestingly, other (traditional) measures of handedness failed to reveal or even to follow this pattern. For example, one of our left-handers (participant L1), who used predominantly her right hand (with scores of 92.3% in right hand use for grasping small LEGO© pieces) to pick up the objects, had some of the most left-handed scores in the two self-report handedness questionnaires (−28 in the Waterloo and −61 in the Edinburgh). In the same way, our most left-handed left-handers had asymmetries in the performance tasks (grip force and finger tapping) that would have classified him as a right-hander. In short, it seems that the pattern of hand use for spontaneous grasping in left-handers does not follow traditional measures of handedness. This is important because it suggests that the lateralization of visuomotor control in left-handers is not strongly coupled with the lateralization of praxis (the generation of complex movements often associated with the use of a tool). We obtained a measure of praxis from scoring the items on the Edinburgh and Waterloo handedness questionnaires that referred to actions using a tool (i.e. signing a document, writing, drawing, using scissors, using a toothbrush, using a knife (without a fork), using a spoon, using a broom (upper hand), striking a match, using a paintbrush, using a spatula, using a drawing device, using a key, using a needle, using a hammer and using tweezers). As it can be seen in Fig. 3, the hand used for precision grasping was not always the hand that participants reporting using to accomplish the tasks of the handedness questionnaires particularly in left-handers. In short, within the left-handed group, hand use for precision grasping was dissociated from hand use in praxis.

We also found no correlation between our grasping tasks and either the finger tapping or the grip force tasks, even though scores on these two simple motor tasks were both significantly correlated with the handedness questionnaires, as others have previously reported (Brown et al., 2006; Peters & Durding, 1979; Peters, 1976; Todor & Kyprie, 1980; Todor, Kyprie, & Price, 1982). The fact that others have found positive correlations between grasping and performance tasks could be due to the difference in the nature of our grasping task and that of others. In our grasping tasks rather than measuring the performance of one hand at a time (Brown et al., 2006; Brown, Roy, Rohr, Snider, & Bryden, 2004) our participants used their hands freely as they reached and grasped the different LEGO pieces. It is possible that the unrestricted use of both hands in this task does not reflect the performance of each hand measured separately (as it is the case in the grip force and finger-taping tasks).

More importantly however, the absence of a correlation between hand preference for grasping and these motor performance tasks suggests that there is something about visuomotor control and handedness that does not map onto other measures of laterality in motor control.

Finally, it should be noted that we found no evidence for a sex difference in any measure related to handedness, including grasping, motor performance tasks, and handedness questionnaires. But the absence of a sex difference in traditional measures of handedness (questionnaires and motor performance) is probably due entirely to our recruitment protocol (and the small sample size).

Perhaps our most significant finding was the demonstration of an intimate relationship between language lateralization and hand preference for grasping. Our correlation and regression analyses clearly show that the more the right hand is used for precision grasping the more language appears to be lateralized to the left hemisphere (at least as measured by a right-ear advantage in the dichotic listening test). Furthermore, the same relationship between these two variables was evident for the prediction in the opposite direction (i.e. the degree of right-ear advantage in the DLT also predicts hand preference for grasping). Thus, even with our small sample of 36 participants, we were able to demonstrate a relationship between language lateralization and hand preference for precision grasping. Although only fifteen percent of the variance in language lateralization was accounted for by hand preference for grasping, it is possible that with more participants and the aid of imaging techniques this number could increase. Importantly, no other measure of handedness was correlated with language lateralization in our sample. Taken together, this suggests that the visual
control of precision grasping and language are controlled by the same hemisphere, a relationship that has not been demonstrated before.

It is important to note that our assumption of hemispheric lateralization for language is based entirely on the results of the dichotic listening test. This test, however, has been widely used for determining hemispheric dominance for language (Hugdahl, 2003). Furthermore, studies investigating the relationship between ear advantage in the DLT and language localization using functional magnetic resonance imaging (fMRI) however, have yielded a concordance ranging from 80 to 95 percent in healthy participants and in epileptic patients (Fernandes, Smith, Logan, Crawley, & McAndrews, 2006; Hund-Georgiadis, Lex, Friederici, & von Cramon, 2002). Similar results have been obtained from studies comparing the DLT and the intracarotid amobarbital test (Wada test; Fernandez & Smith, 2000; Hugdahl, Carlsson, Uvebrant, & Lundervold, 1997; Strauss, Gaddes, & Wada, 1987; Zatorre, 1989)). In further studies, we hope to have more extensive (and direct) measures of hemisphere specialization for language using imaging techniques.

Historically, it has been argued that left-hemisphere specialization for language evolved from an earlier specialization of this hemisphere for the control skilled movements of the hand and limb (Liepmann, 1908). Although there indeed may be a relationship between the lateralization of language and praxis, the fact that we observed a relationship between language lateralization and handedness for visuomotor control suggests a different evolutionary scenario. In fact, there is evidence that our closest primate relative, the chimpanzee (Pan troglodytes), shows a pattern of hand preference for precision grasping that resembles our own (Hopkins, Cantalupo et al., 2005; Hopkins, Cantalupo, Wesley, Hostetter, & Pitcher, 2002; Hopkins, Wesley, Russell, & Schapiro, 2006). When chimpanzees pick up small morsels of food using their index finger and thumb, they tend to use their right hand. Similarly, when extracting peanut butter from a tube with their index finger, they also favour their right hand. Thus, handedness for precise visually guided movements and a corresponding specialization of visuomotor mechanisms in the left hemisphere may pre-date the emergence of handedness for praxis and left hemisphere specialization for praxis and language. Evidence for this speculation comes from studies in chimpanzees. First, Hopkins and colleagues have shown for example, a population-level right-handedness in chimpanzees when reaching for and grasping small pieces of food using a precision grip (thump and index finger; Hopkins, Russell, Hook, Braccini, & Schapiro, 2005b). Second, the same group has shown population-level right-handedness for referential manual gestures in chimpanzees (Hopkins, Cantalupo et al., 2005). Furthermore, they have also shown evidence that asymmetries in the homologues in chimpanzees to Broca’s and Wernicke’s areas are associated with handedness for tool use in these animals (Hopkins, Russell, & Cantalupo, 2007). This evidence led the authors to suggest (and we agree) that the neural substrates of tool use may have served as a pre-adaptation for the evolution of language in humans. Because visually guided prehension in primates almost certainly emerged before tool use and speech, is tempting to speculate that left-hemisphere specialization for visuomotor control was a pre-adaptation that the right-handed control of praxis could build upon. In other words, it is sensible to think that the neural substrates for visuomotor control already set in place in the left hemisphere (over several million years) would have served as a platform for the emergence of more specialized skilled movements and eventually language.

In conclusion, our finding of a relationship between hand preference for skilled grasping and language lateralization provides another scenario for the evolutionary basis of hemispheric asymmetries and sets the stage for further investigations of the relationship between visuomotor control, praxis and language.

References


