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One hand or the other? Effector selection biases in right and left handers

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ABSTRACT

Much debate in the handedness literature has centred on the relative merits of questionnaire-based measures assessing hand preference versus simple movement tasks such as peg moving or finger tapping, assessing hand performance. A third paradigm has grown in popularity, which assesses *choices* by participants when either hand could be used to execute movements. These newer measures may be useful in predicting possible "reversed" asymmetries in proportions of non-right handed ("adextral") people. In the current studies we examine hand choice in large samples of dextral (right handed) and adextral participants. Unlike in some previous experiments on choice, we found that left handers were as biased towards their dominant hand as were right handers, for grasping during a puzzle-making task (study 1). In a second study, participants had to point to either of two suddenly appearing targets with one hand or the other. In study 2, left handers were not significantly less one handed than their right-handed counterparts as in study 1. In a final study, we used random effects meta analysis to summarise the possible differences in hand choice between left handers and right handers across all hand choice studies published to date. The meta analysis suggests that right handers use their dominant hand 12.5% more than left handers favour their dominant hand (with 95% confidence that the real difference lies between 7% and 18%). These last results suggest that our two experiments reported here may represent statistical Type 2 errors. This mean difference may be related to greater left hemispheric language and praxic laterality in right handers. Nevertheless, more data are needed regarding the precise proportions of left and right handers who favour their preferred hands for different tasks.

1. Introduction

Right hand preferences for skilled activities such as handwriting and throwing are typically associated with left hemispheric specialisation for speech and language (Knecht et al., 2000; McManus, 2002; Rasmussen and Milner, 1977; Van der Haegen et al., 2012). This relationship implies that the articulatory requirements of speaking may be a crucial component of the left hemispheric system and may confer some advantages to the limbs controlled by the same hemisphere (Carey et al., 2009; Goodale, 1988; Kimura, 1993; Rushworth et al., 2001; Rushworth et al., 2003; Rushworth et al., 2001). Evidence for this idea has been obtained from the study of patients with manual apraxia, a disorder which involves poor production of movements to command (and/or copying movements) in spite of relatively intact strength and position sense (Goldenberg, 2013). Apraxic patients predominantly have lesions in the left hemisphere, yet (when they are testable) both the hands often display approximately equal levels of difficulty with movement imitation (Kimura, 1993; Kimura and Archibald, 1974). In fact, aphasic patients are often apraxic, and even when the deficits occur in isolation, problems with non-speech oral movements can be found. Selection of appropriate movements and planning how these movements will be joined together in a sequence have been of particular relevance (Kimura, 1982).

In spite of early assumptions of right hemispheric dominance for speech and language in left-handed people (Harris, 1991), it is now well established that approximately 70% of any large sample of left handers will actually be more reliant on the left hemisphere for speech and language (e.g. Knecht et al., 2000; see Carey and Johnstone, 2014, for review). Therefore, if the praxic system overlaps with speech lateralisation (at least in terms of being in the same hemisphere), then a substantial proportion of any sample of left handers will have the praxic system in the hemisphere which controls their *non-dominant hand*. In such cases, the non-dominant

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hand might be subtly advantaged, and/or the dominant hand subtly disadvantaged, compared to the dominant and non-dominant hand of the right hander.

In tasks such as visually-guided aiming, in right handers, the right hand is superior to the left in terms of speed and accuracy (Carnahan, 1998; Fisk and Goodale, 1985) although reaction times of the left hand can be lower than those of the right (Boulinguez et al., 2000; Carson et al., 1995). In contrast, left handers tend to be slower to initiate a movement and reach a lower peak velocity than their right-handed counterparts (Goodale, 1990). More crucially, as a group they were relatively symmetrical compared to the right handers. In other words, left handers are less lateralised than right handers, as one hand was not greatly superior to the other. According to Goodale (1990), the "odd hand out" is the right hand of the right hander, which in the vast majority of any such sample will have "privileged access" to the sensorimotor control systems of the speech-dominant left hemisphere. However, in other experiments, some data suggest that left handers as a group behave like right handers (literally. e.g. right hand duration and accuracy advantages, left hand reaction time advantages) in terms of right and left hand kinematics, supporting a link between hand movement asymmetries and probable speech lateralisation (Boulinguez et al., 2001). Clearly, sampling error can be an issue with left handers, unsurprisingly.

Kinematic studies such as these require expensive equipment and extensive off-line data analysis, which partially explains why, unfortunately, the sample sizes tend to be somewhat limited. Studies of hand *choice*, on the other hand, rather than hand kinematics, might be advantageous for larger-sample testing. Once the within-participant reliability of any measure has been established (which could allow for relatively short testing sessions if the effects are robust), they can be administered to large samples with only the requirement of accurate recording of choice by an experimenter. In fact, there is already some suggestion in the literature that such tasks result in weakened or even *reversed* asymmetries in left handers.

The best example to date is from Gonzalez et al. (2006), who used a hand choice task which required participants to make jigsaw puzzles on a table. The midline of the table was marked so that participants' reaches could be coded as ipsilateral (on the same side of the table as the grasping limb) or contralateral (on the opposite side of the table to the grasping limb). It was found that right handers used their dominant hand for 78% of their reaches, whereas left handers used their "dominant" left hand only 48% of the time. In other words, as a group left handers had a slight tendency to choose to use their non-dominant hand.

In the first follow up experiment, Gonzalez et al. (2007) asked participants to make Lego™ constructions as well as jigsaw puzzles. They found that the left handers used their dominant hand only 44% of the time to pick up the Lego™ pieces, and on 49% of occasions to reach and grasp the puzzle pieces. Conversely, right handers used their right hand 82% and 76% of the time for grasping Lego™ and puzzle pieces respectively. The implication here is that left handers use their non-dominant hand more often, and are not mirror images of right handers, which is contrary to findings in other experiments where right and left handers have displayed similar patterns of dominant hand choice (Bishop et al., 1996; Bryden et al., 2000; Calvert and Bishop, 1998).

Harris and Carlson (1993) performed a grasping choice experiment with a large number of dextral and adextral adults and children. Participants were required to pick up single objects with either hand either centrally or in left or right space, and then pass them to the experimenter. For central targets, the 40 dextrals and 40 adextrals were equivalent in their bias towards preferred hand use (77% in dextrals; 83% in adextrals). Hemispace, as in the Gonzalez and colleagues' tasks, biased participants towards ipsilateral hand use, but this effect only decreased dominant hand use by about 7–8% in contralateral space, equivalently in both groups.

Hand choice tasks were designed, in part, to demonstrate how willing participants are to use their non-preferred hand when it becomes more difficult for the preferred hand, typically by placing targets into peripheral space using some sort of horizontal array. For example, Bryden et al. (1994) designed elongated variants of a dot filling and a pegboard task, which required participants to use only one hand at a time starting from extreme left and extreme right-sided positions. The authors found that left handers were significantly more left handed than right handers, and right handers were significantly more right handed than left handers. Unfortunately by analysing these data by left and right, rather than preferred and non-preferred hands, little could be concluded about strength of preference in these first hand choice tasks. (In other words, in an analysis of variance, when a factor "hand" is created by levels "left" versus "right", main effects and their associated interactions are difficult to interpret. Instead, if the question relates to right handers being more *one handed* then left handers, hand should instead have as levels "preferred" versus "non-preferred"). Steenhuis (1999) repeated these modified peg and dot filling tasks with larger samples. As in the earlier experiment, the supplied statistics are not particularly well suited to our research question here (at least in terms of the *proportions* of people who prefer their preferred hand in each handedness group). Nevertheless, the 52 dextrals and 48 adextrals did not differ significantly in terms of their *mean* magnitude of their preferred hand biases.

Calvert and Bishop (1998) extended earlier work by Bishop et al. (1996) on their own hand choice task, which seems to differentiate between strong and less strong right handers (as defined by questionnaire). They contrasted dextral and adextral groups on pointing to named locations, picking up cards and placing marbles, again utilising a horizontal array where less comfortable reaches across the body are required in contralateral space. They also argue that showing that dextrals and adextrals differ on this task is rather uninteresting, and that more stringent tests would be able to differentiate between subgroups of right handers, as theirs does (also see Bishop et al., 1996).

Between-participant variability can be a serious source of noise in studies of left-handed participants. For example, precise details of participant recruitment and selection are often sorely lacking. Smaller sample sizes can contribute to between study differences. In the experiments of Gonzalez et al. (2006, 2007) the left-handed group was composed of either 10 or 11 participants. In the Calvert and Bishop (1998) study 33 left handers were recruited but they were split into strong and mixed left-handed groups. Bryden et al. (2000) utilised 25 left handers in their experiment. It is not clear from the methods sections of the early studies by Gonzalez and colleagues whether or not these samples (of left handers in particular) overlapped. Nevertheless, Gonzalez and Goodale (2009) report data from a later sample of 18 left- and 18 right handers obtained from the University of Lethbridge and found similar results for grasping biases in picking up Lego™ pieces[1]. They also claim that these asymmetries predict hemispheric lateralisation of speech and language as assessed using a dichotic listening test.

In the hand choice studies using elongated stimulus arrays, participants were constrained to use only one hand at a time. It may be that these kinds of constraints influence hand choice, relative to other tasks where both limbs may move to distinct targets as in the Gonzalez puzzle and Lego tasks.

As a first step in reconciling these discrepancies in hand choice of left handers, we decided to use the Gonzalez et al. (2006) puzzle task with a larger sample of left- and right-handed individuals. We

[1] Later studies from the Lethbridge laboratory, published recently, also do not mention any overlap of samples from Gonzalez and Goodale (2009) Stone et al. (2013) and de Bruin et al. (2014).