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Does handedness or digit ratio (2D:4D) predict lateralised cognitive ability?

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ABSTRACT

We measured the second to fourth (2D:4D) digit ratio in participants who carried out a phonological task (memory for word order) and a spatial task (mental rotation). We also assessed hand preference and determined the relative skill of their left and right hands. Regression analyses showed that the *difference* between the 2D:4D ratio on the left and right hands (Dr-l), was a significant predictor of performance on the memory for word order task. Handedness was a significant predictor of unique variance only if Dr-l was excluded from the regression analyses. Performance on the mental rotation task was not predicted either by handedness, 2D:4D or Dr-l. The findings are discussed in terms of a possible differential effect of sex hormones on the two cerebral hemispheres.

1. Introduction

Almost all humans show a preference for using one hand over the other. The distribution of hand preference is J-shaped reflecting predominant use of the right hand while the distribution of the difference in skill between left and right hands is approximately normal and shifted to the right of zero, the point of equal skill (Annett, 2002). The importance of handedness lies in its relationship with lateralisation of brain function, especially language (Beaton, 2003, chap. 4). There are fewer left-handed women than men (Papadatou-Pastou, Martin, Munafò, & Jones, 2008) consistent with a role for sex hormones in the determination of handedness and, by implication, hemispheric asymmetry of function.

Geschwind and Galaburda (1987) argued that, due to its influence on early cell loss, pre-natal levels of testosterone (T) are related to cerebral lateralisation and handedness. This has become known as the GBG (Geschwind–Behan–Galaburda) theory. Although it has been severely criticised, and the evidence in its favour is decidedly mixed (Bryden, McManus, & Bulman-Fleming, 1994), it continues to motivate empirical research and permeate much theoretical discussion (see Lust et al., 2011).

Sex hormones, and levels of foetal T in particular, have been hypothesised to influence the ratio of the length of the second to the fourth finger on each hand (Manning, Scutt, Wilson, & Lewis-Jones, 1998). This ratio (2D:4D) is sexually dimorphic (Manning, 2002), being about unity in females and less than unity in males. Manning, Bundred, Newton, and Flanagan (2003) showed that the 2D:4D ratio is related to the structure of the androgen receptor (AR) gene which determines sensitivity to T. Specifically, the number of CAG sequence repeats (CAGn) in exon 1 of the AR gene was positively and significantly correlated with right hand 2D:4D and even more so with the *difference* between the 2D:4D ratios of the right and left hand (Dr-l). Results in the same direction (significant only on a one-tail test) were recently reported for Dr-l by Hurd, Vaillancourt, and Dinsdale (2010).

Administration of T to pregnant rats leads to changes in the relative length of the digits on the forepaws of the offspring (Talarovičová, Kršková, & Blažeková, 2009). In mice, the 2D:4D ratio is determined not by T alone but by the relative balance of prenatal T and prenatal oestrogen signalling during a narrow window of foetal development (Zheng & Cohn, 2011). The ratio is not affected by administration of hormones or receptor agonists outside this period of gestation or post-natally, thereby establishing the critical developmental basis of 2D:4D ratio. It is highly probable that these findings map onto patterns of human 2D:4D (Manning, 2011).

If 2D:4D is indeed a biological marker for levels of, and/or sensitivity to, relative levels of pre-natal T (for reviews and further arguments see Manning, 2002, 2011; Hönnekopp & Watson, 2010) then a number of predictions follow from the GBG theory. One is that left-handers have smaller 2D:4D ratios than right-handers. The findings have not been consistent but a relationship has been reported not between 2D:4D of the left or right hand but between the *difference* in size of the ratios of the two hands

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(Dr-l) and some measure of manual preference or relative hand skill (for review see Beaton, Rudling, Kissling, Taurines, & Thome, 2011).

There are suggestions that, like handedness (see Faurie et al., 2008), 2D:4D ratio relates to performance on certain cognitive tasks (e.g. Beech & Beauvois, 2006; Brosnan, 2008). Given that handedness and 2D:4D ratio are related (Beaton et al., 2011) while the number of CAG repeats in exon 1 of the AR gene relates to both digit ratio (Manning et al., 2003) and handedness (Medland et al., 2005) it is surprising that digit ratio and handedness have not been considered together in studies of cognitive ability.

According to the GBG theory, high levels of pre-natal T are associated with deviations from the standard pattern of left hemisphere dominance for language and right-handedness. Anomalous or non-standard laterality was said to be associated with dyslexia, in particular. The core deficit in dyslexia is widely agreed to be an impairment or weakness in the phonological domain (see Beaton, 2004 for review). A corollary is that the standard pattern of left hemisphere lateralisation and right handedness is associated with normal levels of phonological ability.

Left hemisphere dominance for language is unlikely to be all-or-none, but rather a graded characteristic (Zangwill, 1960) related to handedness (see Knecht et al., 2000) and variation in 2D:4D ratio (see Bourne & Gray, 2009) both these being related to levels of cognitive ability. Annett (2011) has found associations between types of dyslexia and handedness, as between speech lateralisation and phonological skill (Annett, 1991). She has also reported an association between relative skill of the two hands and scores on tests of phonology (Annett, 1992, 1999).

We predicted therefore that a tendency towards left-handedness and/or a low 2D:4D ratio (high foetal T) and/or low Dr-l (see Section 4) would be associated with relatively low phonological ability.

Geschwind and Galaburda (1987) argued that high levels of pre-natal T are associated with relatively enhanced functioning of the right hemisphere, and thus with visuo-spatial skills. We therefore also included in our study a test of mental rotation as this has in some studies been related to handedness (see Peters, Reimers, & Manning, 2006) or to digit ratio (Peters, Manning, & Reimers, 2007; Puts, McDaniel, Jordan, & Breedlove, 2008). We expected to find an inverse relation between digit ratio and visuo-spatial ability.

2. Method

2.1. Participants

Participants were the 38 participants from Beaton et al. (2011) to whom were added a further 30 participants. The combined sample therefore consisted of 36 males and 32 females (mean age 29.04 years, s.d. = 14.06). The sample was not random with regard to handedness; we deliberately included more left-handers than would be found in a representative sample of the population in order to provide a reasonable distribution of handedness scores. Participants were, however, not informed that handedness was a variable of interest until after the conclusion of the study.

2.2. Procedure

The data were collected from individuals one at a time. All participants completed Annett's (1970) Hand Preference Questionnaire (AHPQ) as modified by Briggs and Nebes (1975). According to their scoring scheme a hand preference score is obtained by summing across all 12 items. The range of scores is from −24 (always the left hand for all items) to 24 (always the right hand for all items). In its original form Annett's inventory is not scored in this way. Instead, a number of handedness sub-groups or categories are derived from the pattern of answers to the 12 questionnaire items (Annett, 1970). There are good theoretical reasons (Annett, 2002; Beaton, 2003, chap. 4) to prefer the method of classifying handedness adopted by Annett rather than simply summing scores over all items of a questionnaire, the most widely used method in the literature, so in the present study both Annett's method and the Briggs–Nebes method of scoring were used.

In order to assess different aspects of handedness, relative hand skill as well as preference, participants also completed Annett's peg-moving task (for details of apparatus and instructions see Annett, 2002). Using the left and right hands alternately (starting hand being counterbalanced across participants) each participant completed three trials with each hand. The time taken by each hand for each trial was recorded to the nearest 1/10th of a second and the mean value for each hand entered into subsequent analyses.

The length of each participant's index and ring fingers on their left and right hand was measured to the nearest 0.01 mm using Vernier callipers. Measurements were taken from the ventral proximal crease of the digit to the tip of the finger; where more than a single crease was present measurement was made from the most proximal crease. The 2D:4D ratio is the ratio of the length of the index finger to that of the ring finger thus measured.

Participants were given a test of phonological ability, memory for word order, which has yielded differences in scores as a function of handedness in children and undergraduates (Annett, 1992, 1999). Participants heard sets of five to seven words spoken at the same time as they were shown the same words but in a different order. The task was to indicate the order in which the words had been spoken by writing the appropriate number above each word. There were 20 experimental trials presented after two practice trials. The score was the number of fully correct trials.

In addition to the phonological memory test, each participant carried out the re-drawn version (Peters et al., 1995) of the original Vandenberg and Kuse (1978) test of mental rotation ability. In this version of the test, on each trial a target figure has to be matched to two of four alternative choices; one mark is awarded only if both choices are correct on a given trial. There were 24 experimental trials presented after three practice trials.

The research reported here was carried out in accordance with the code of ethics embodied in the Declaration of Helsinki.

3. Results

Handedness was first assessed according to the AHPQ then adjacent classes combined as recommended by Annett (2002) for small sample sizes. There were 35 strong or consistent right-handers (17 female), 13 inconsistent right-handers (4 female), 11 inconsistent left-handers (7 female) and 9 consistent left-handers (4 female). A Briggs–Nebes score was also calculated for each participant.

The distribution of the difference (L − R) between mean peg-moving times of left (L) and right hands (R) was approximately normal with no outliers but, as expected for a non-random sample which included a relatively large proportion of left-handers, was less shifted to the right than for an unselected sample. For the purposes of analysis, relative hand skill for each participant was expressed as a laterality index (Li) according to the formula $Li = (L - R/(0.5[L + R])$.

3.1. Digit ratio

The second and fourth fingers of each hand of 10 of the original 38 participants were measured on two occasions, approximately