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Short Communication

On the relationship between degree of hand-preference and degree of language lateralization

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ABSTRACT

Language lateralization and hand-preference show inter-individual variation in the degree of lateralization to the left- or right, but their relation is not fully understood. Disentangling this relation could aid elucidating the mechanisms underlying these traits. The relation between degree of language lateralization and degree of hand-preference was investigated in extended pedigrees with multi-generational left-handedness (n = 310). Language lateralization was measured with functional Transcranial Doppler, hand-preference with the Edinburgh Handedness Inventory. Degree of hand-preference did not mirror degree of language lateralization. Instead, the prevalence of right-hemispheric and bilateral language lateralization rises with increasing strength of left-handedness. Degree of hand-preference does not predict degree of language lateralization, thus refuting genetic models in which one mechanism defines both hand-preference and language lateralization. Instead, our findings suggest a model in which increasing strength of left-handedness is associated with increased variation in directionality of cerebral dominance.

1. Introduction

Language lateralization and hand-preference can be described in terms of direction (right or left) as well as degree (strongly lateralized or more bilaterally represented (Isaacs, Barr, Nelson, & Devinsky, 2006)). It has been hypothesized that degree of hand-preference mirrors degree of language lateralization, e.g. that mixed-handers have the highest prevalence of bilateral lateralization and that strong left/right-handers have the highest prevalence of strong language lateralization (Annett, 1999; Crow, Crow, Done, & Leask, 1998; McManus, 1985). However, due to the low prevalence of mixed-handedness and atypical (bilateral and right-hemispheric) lateralization in unselected samples, limited data is available to test this hypothesis (Knecht et al., 2000; Pujol, Deus, Losilla, & Capdevila, 1999; Szaflarski et al., 2002). Improved understanding of the relationship between these two traits could help to investigate the development of cerebral organization, but also inspires our understanding of the genetic underpinnings of both traits.

In this study, we investigated the relation between degree of language lateralization and degree of hand-preference and tested whether hand-preference can be used as a predictor for atypical language lateralization. We enriched the data for atypically lateralized subjects, by including large families with multiple left-handers. Hand-preference was measured with the Edinburgh Handedness Inventory, language lateralization with functional Transcranial Doppler (fTCD) in a fairly large sample.

2. Results

2.1. Direction of language lateralization and hand-preference

In the whole sample, there were 232 (74.8%) subjects with left-hemispheric lateralization and 78 (25.32%) with atypical lateralization (right-hemispheric or bilateral lateralization). In the subgroup of right-handers, there were 144 (84.2%) left-lateralized subjects and 27 (15.8%) atypical subjects. In the left-handed subgroup, there were 88 (63.3%) left-lateralized and 51 (36.7%) atypical subjects. In the male subgroup (n = 122), there were 64 right-handers, of which

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52 (81.32%) were left-lateralized and 12 (18.8%) atypical. Of the 58 male left-handers, there were 37 (63.8%) left-lateralized and 21 (36.2%) atypical subjects. The female subsample (n = 188) showed comparable figures, with 92 (86.0%) right-handers showing left-lateralization and 15 (14.0%) showing atypical lateralization. In the female left-handers there were 51 (63.0%) left-lateralized and 30 (37.0%) atypical subjects. There was no difference in prevalence of atypical lateralization between the male and female right-handers (Chi-square = 0.67, P = 0.41) or male and female left-handers (Chi-square = 0.01, P = 0.92).

2.2. Degree of language lateralization vs. degree of hand-preference

Curve estimation of continuous hand-preference (EHI lateralization indices, LI-EHI) and language lateralization (fTCD lateralization indices, LI-FTCD) data using non-linear regression as implemented in SPSS 22 showed the best fit for a cubic regression analysis with LI-EHI as the independent and LI-fTCD as the dependent variable, in comparison with linear and quadratic regression analysis ($y = 2.63 + 0.14 * x + +/-0.56 * x^2 + 0.95 * x^3$, $R^2 = 0.081$, $F = 9.033$, $df1 = 3$, $df2 = 306$, $p < 0.001$, Constant = 2.626, $b1 = 0.140$, $b2 = -0.561$, $b3 = 0.949$).

In the categorical analysis of degree of language lateralization, frequencies of bilateral, moderate right-hemispheric and strong right-hemispheric lateralization increased when moving from strong right-handedness to strong left-handedness, but not in all groups: mixed handers had a lower prevalence of moderate right-lateralization (4.3%) than moderate right and left handers (6.0% and 6.9% respectively). Moderate left-handers had a lower prevalence of bilateral lateralization (17.2%) than mixed and strong left-handers (26.1% and 29.8% respectively). See Fig. 1 and Table 2 for an overview of the frequency distribution. Frequencies peaked in the strong-left-handedness subgroup for all three measures. The overall frequency distribution of atypical lateralization (bilateral, moderate right- and strong right-hemispheric lateralization collapsed) also peaked in the strong left-handedness subgroup (47.4%) see Fig. 2 for a depiction of language lateralization indices plotted against hand-preference indices.

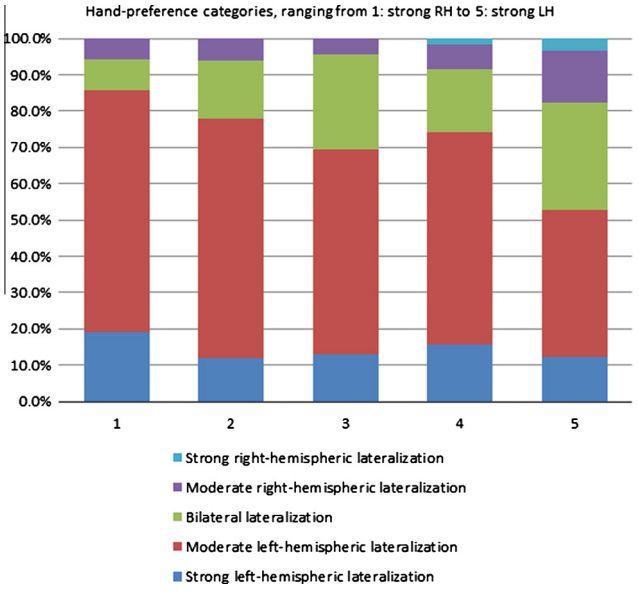

Fig. 1. Degree of language lateralization vs. degree of hand-preference. The proportion of each of 5-language lateralization categories (strong left-hemispheric, moderate left-hemispheric, bilateral, moderate right-hemispheric and strong right-hemispheric) is plotted against 5 categories of hand-preference (strong right-handedness, moderate right-handedness, mixed-handedness, moderate left-handedness, strong left-handedness).

Table 1
Cut-off values for different categories of hand-preference and language lateralization.

Hand-preference categories	LI-EHI	Language lateralization categories	LI-FTCD
Strong right-handedness	$\geqslant 0.75$	Strong left hemispheric lateralization	$4.8 \leqslant$ LI < 8
Moderate right-handedness	$0.25 <$ LI $\leqslant 0.75$	Moderate left hemispheric lateralization	$1.6 \leqslant$ LI-fTCD < 4.8
Mixed handedness	$-0.25 <$ LI < 0.25	Bilateral lateralization	$-1.6 <$ LI-fTCD < 1.6
Moderate left-handedness	$-0.75 <$ LI $\leqslant -0.25$	Moderate right hemispheric lateralization	$-4.8 <$ LI-fTCD $\leqslant -1.6$
Strong left-handedness	$\leqslant -0.75$	Strong right hemispheric lateralization	$-8 <$ LI-fTCD $\leqslant 4.8$

2.3. Degree of hand-preference as a predictor for atypical lateralization

The mixed model analysis showed an association of all five categories of hand-preference with language lateralization ($p < 0.001$ for all cutoffs). Sensitivity was 0.78 and specificity 0.44 when using moderate left-handedness as a predictor for atypical lateralization. This changed to a sensitivity of 0.35 and a specificity of 0.78 when using strong right-handedness as a cut-off. Prediction was poor with an AUC for all models under 0.63.

3. Discussion

In this study, we investigated the relationship between degree of language lateralization and degree of hand-preference in a large sample of multigenerational pedigrees with multiple left-handers, in order to test whether degree of hand-preference can predict degree of language lateralization. 'Degree' indicates the extent to which the function is lateralized. Language lateralization could be successfully measured with functional Transcranial Doppler (fTCD) in 310 subjects, who were categorized as having strong, moderate or mixed hand-preference, as well as having strong, moderate or bilateral language lateralization (see Tables 1 and 2). We found that degree of hand-preference does not mirror degree of language lateralization. Instead, strong left-handedness showed the highest prevalence of bilaterality as well as the highest prevalence of moderate and strong right-hemispheric lateralization. Apparently, stronger left-hand preference results in a higher chance for atypical language lateralization. Thus, degree of hand-preference cannot serve to predict degree of language lateralization. The relation between degree of hand-preference and degree of language lateralization fits a cubic regression model.

In line with these results, the mixed model analysis showed that degree of hand-preference on a five point ordinal scale cannot predict atypical lateralization (i.e. bilateral and right-hemispheric lateralization, collapsed into one group). Our finding that degree of hand-preference does not mirror degree of language lateralization is in line with previous studies (Knecht et al., 2000; Pujol et al., 1999; Szaflarski et al., 2002) that did not show a direct coupling between degree of hand-preference and degree of language lateralization. Instead, the data from our study corroborates previous studies (Knecht et al., 2000; Pujol et al., 1999; Szaflarski et al., 2002) showing that the prevalence of both right- and bilateral lateralization becomes higher with increasing left-hand