NeuroImage

www.elsevier.com/locate/ynimg
NeuroImage 35 (2007) 853 – 861

The association between scalp hair-whorl direction, handedness and hemispheric language dominance: Is there a common genetic basis of lateralization?

Andreas Jansen,[a,b,*,1] Hubertus Lohmann,[a,1] Stefanie Scharfe,[a] Christina Sehlmeyer,[a] Michael Deppe,[a] and Stefan Knecht[a,b]

[a]*Department of Neurology, University of Münster, Germany*
[b]*IZKF Münster, University of Münster, Germany*

Received 31 August 2006; revised 11 December 2006; accepted 13 December 2006
Available online 29 December 2006

The hemispheres of the human brain are functionally asymmetric. The left hemisphere tends to be dominant for language and superior in the control of manual dexterity. The mechanisms underlying these asymmetries are not known. Genetic as well as environmental factors are discussed.

Recently, atypical anticlockwise hair-whorl direction has been related to an increased probability for non-right-handedness and atypical hemispheric language dominance. These findings are fascinating and important since hair-whorl direction is a *structural marker* of lateralization and could provide a readily observable anatomical clue to *functional brain lateralization*.

Based on data on handedness and hair-whorl direction, Amar Klar proposed a genetic model ("random-recessive model") in that a single gene with two alleles controls both handedness and hair-whorl orientation (Klar, A.J.S., 2003. Human handedness and scalp hair-whorl direction develop from a common genetic mechanism. Genetics 165, 269–276). The present study was designed to further investigate the relationship between scalp hair-whorl direction with handedness and hemispheric language dominance. 1212 subjects were investigated for scalp hair-whorl direction and handedness. Additionally, we determined hemispheric language dominance (as assessed by a word generation task) in a subgroup of 212 subjects using functional transcranial Doppler sonography (fTCD). As for the single attributes – hair-whorl direction, handedness, and language dominance – we reproduced previously published results. However, we found no association between hair-whorl direction and either language dominance or handedness. These results strongly argue against a common genetic basis of handedness or language lateralization with scalp hair-whorl direction. Inspection of hair patterns will not help us to determine language dominance.

Keywords: Hemispheric specialization; Language lateralization; Handedness; Scalp hair-whorl direction; fTCD

Introduction

Asymmetry is a common phenomenon in higher organisms. It can be found, for instance, in the development of cortical functional asymmetries. In humans, hemispheric asymmetry is most pronounced for language, for which the left hemisphere is generally dominant (Rasmussen and Milner, 1977; Knecht et al., 2000b). Handedness is correlated with language dominance, in that left-handed persons are more likely than right-handed individuals to be atypically (bilateral or right-hemispheric) lateralized for language (Pujol et al., 1999; Knecht et al., 2000b; Szaflarski et al., 2002). The underlying mechanisms of these asymmetries are not understood. Genetic as well as environmental factors are discussed (McManus, 1985; Shaywitz et al., 1995; Annett and Alexander, 1996; Klar, 1999; Corballis, 2003). Theories concerning the cause of lateralization vary from learned behaviour, to strictly genetics, to a combination of both mechanisms (Hatfield, 2006).

Another marker for asymmetry that recently became important in lateralization research is scalp hair-whorl direction. The rate of anticlockwise hair-whorls has been shown to be less than 10% in the general population (Wunderlich and Heerema, 1975; Klar, 2003; Ziering and Krenitsky, 2003). Atypical anticlockwise hair-whorl direction has been associated with increased probability for non-right-handedness (Klar, 2003) as well as atypical hemispheric language dominance (Weber et al., 2005). These findings are especially important since hair-whorl direction is a *structural*

* Corresponding author. Department of Neurology, University of Münster, Albert-Schweitzer-Straße 33, D-48129 Münster, Germany. Fax: +49 251 834 8181.
E-mail address: anjan@uni-muenster.de (A. Jansen).
[1] Both authors contributed equally to the present study.
Available online on ScienceDirect (www.sciencedirect.com).

1053-8119/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.neuroimage.2006.12.025

marker of lateralization and is not influenced by culture. Therefore its association with language lateralization or handedness could help in understanding the underlying cause of *functional lateralization* (Hatfield, 2006).

Klar proposed a genetic model ("random-recessive model") in that a single gene with two alleles controls both handedness and hair-whorl orientation (Klar, 2003). The dominant allele predisposes right-handedness and a clockwise hair spiral. Even having a single copy would yield a right-handed bias. However, having only the recessive version, rather than causing non-right-handedness, would not convey a particular lateralization and result in a 50:50 mix of right-handers and non-right-handers. In addition, the "random allele" would lead to a separate 50:50 chance of having counter-clockwise hair-whorls. Further implications of this model for the development of language lateralization and brain laterality per se were discussed (Klar, 1996, 2003, 2004, 2005; Weber et al., 2005). One prediction of the random-recessive model is that the traits of handedness, language dominance and scalp hair-whorl rotation are uncoupled in individuals with one form of atypical lateralization. People being either non-right-hander, having atypical language dominance or having a counter-clockwise hair-whorl are proposed to have a 50:50 chance for developing a typical or atypical form of lateralization with regard to the other attributes.

As interesting and fascinating as the connection between the *structural lateralization marker* hair-whorl direction and the *functional lateralization markers* handedness and language dominance is, data from almost all functional imaging studies on the relationship between handedness and hemispheric language dominance are at odds with the random-recessive model. They predict that the rate of left-hemispheric dominance among non-right-handers is considerably higher than 50% (Pujol et al., 1999; Knecht et al., 2000b; Szaflarski et al., 2002). For example, although Knecht et al. found in a functional transcranial Doppler (fTCD) sonography study an association between the lateralization of both handedness and language dominance, even in strong lefthanders (Oldfield score <-99) the incidence of right-hemispheric dominance was only 27% (Knecht et al., 2000b). In the present study, we therefore set out to further investigate the association between scalp hair-whorl direction, handedness and hemispheric language dominance.

In a first step we investigated hair-whorl direction and handedness in a large sample of subjects ($n>>1000$). Our prediction was that right-handed subjects predominantly had a typical hair-whorl, while non-right-handed subjects had a significant higher probability of having an atypical anticlockwise scalp hair-whorl direction. According to the random-recessive model, we expected them to have a 50% chance to have either a typical or an atypical hair-whorl.

In a second step, we measured hemispheric language dominance by fTCD in a subgroup of subjects with atypical hair-whorl direction or atypical handedness (i.e. non-right-handedness). FTCD is a non-invasive technique that allows reliable assessment of brain lateralization of various higher cognitive functions; for a review see Deppe et al. (2004). Again, the prediction was that atypical hair-whorl direction and atypical handedness are associated with a significant higher chance of having atypical hemispheric language dominance.

Methods

Subjects

1217 healthy volunteers participated in the study. All subjects gave their written informed consent prior to participation, according to the declaration of Helsinki. Most participants were drafted military personnel. Participants were not provided financial reimbursement.

Five subjects were excluded from further analysis since their questionnaires were not filled completely (e.g., data about age or sex were missing). 1086 (89.6%) of the remaining subjects were male (mean age 21.5±4.0 years, range 17–63 years) and 126 (10.4%) were female (mean age 21.5±4.0 years, range 17–48 years). The significant higher ratio of men compared to women is explained by the employment structure of the German Federal Armed Forces.

For all subjects we determined the number of hair-whorls, scalp hair-whorl direction and handedness. Since it was impractical to assess hemispheric language dominance in all subjects, we chose to determine language dominance specifically in subjects with atypical counter-clockwise hair-whorl direction as well as in non-right-handed subjects with typical hair-whorl direction.

Determination and classification of hair-whorl direction

Most Caucasian persons display at least one hair-whorl on the back of the head (Wunderlich and Heerema, 1975). Only crown hair-whorl patterns were examined; frontal patterns were ignored. The heads of the subjects were viewed from behind while they were sitting on a chair so that the examiner was looking directly at the hair crown.

Classification of hair-whorls

We only considered subjects with a single hair-whorl with clear rotation. Individuals who were bald, lacked a hair-whorl or had multiple hair-whorls were excluded from further analysis, since Klar's random recessive-recessive model was only formulated for such subjects (Klar, 2003; Weber et al., 2005). Whorls were classified as being clockwise ("typical") or counter-clockwise ("atypical") according to the swirling direction of the hair. When there was more than one crown hair-whorl, we classified them as doubles or triples; for a detailed classification scheme of hair scalp hair-whorls see Ziering and Krenitsky (2003).

Determination and classification of handedness

Handedness was assessed by the Edinburgh handedness inventory (Oldfield, 1971), which ranges from −100 for strong left-handedness to +100 for strong right-handedness. In this questionnaire, subjects are asked which hand they prefer to write, to draw, to throw a ball, to use a pair of scissors, a toothbrush, a knife, a spoon or a broom (upper hand), to strike a match or to open a box.

Classification of handedness

Individuals were considered to be *right-handed* if they had an Oldfield score of at least +30 and *non-right-handed* if they had a Oldfield score of less than +30 (Knecht et al., 2000a). Thus, both left-handers and ambidextrous individuals are pooled as non-right-handed.[2]

[2] "Atypical handedness" is defined inconsistently in the literature. For a better comparison between the results of this study and earlier studies, we also applied other definitions of "non-right-handedness". Overall, the results did not change (see Discussion).