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Research report

Latent variable analysis indicates that seasonal anisotropy accounts for the higher prevalence of left-handedness in men

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ABSTRACT

According to the Geschwind-Galaburda theory of cerebral lateralization, high intrauterine testosterone levels delay left brain hemisphere maturation and thus promote left-handedness. Human circulating testosterone levels are higher in the male fetus and also vary with length of photoperiod. Therefore, a higher prevalence of left-handedness, coupled with seasonal anisotropy (i.e., a non-uniform distribution of handedness across birth months or seasons), may be expected among men. Prior studies yielded inconsistent evidence for seasonal anisotropy and suffered from confounding and a number of shortcomings affecting statistical power. This study examined hand preference and associations of handedness with sex, age, and season of birth in independent discovery ($n = 7658$) and replication ($n = 5062$) samples from Central Europe with latent class analysis (LCA). We found clear evidence of a surplus of left-handed men born during the period November–January, which is consistent with predictions from the Geschwind-Galaburda theory. Moreover, seasonal anisotropy fully accounted for the higher prevalence of left-handedness among men, relative to women. Implications of these findings with regard to seasonal anisotropy research and handedness assessment and classification are discussed.

1. Introduction

Limb preference and handedness are phenomena of many biological species. In humans, a dominant preference of the right limb for manual tasks is culturally universal (with a prevalence rate of right-handedness of about 90%; Coren, 1993; Peters, Reimers, & Manning, 2006) and has been linked to brain lateralization. Whilst the genetic bases of handedness are still under debate (McManus, Davison, & Armour, 2013; Medland et al., 2009), there have been numerous accounts investigating its associations with human capacities and traits.

However, research into handedness has also produced some fickle and elusive results. Whilst a higher prevalence of left-handedness among men appears to be a robust finding

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(Papadatou-Pastou, Martin, Munafò, & Jones, 2008), the evidence for some assumed biological underpinnings of left-handedness appear inconclusive. The cerebral lateralization theory of Geschwind-Galaburda (Geschwind & Galaburda, 1985a, 1985b, 1985c, 1987) posits that high intrauterine levels of testosterone promote the development of left-handedness because of differential effects of testosterone on brain hemisphere maturation; specifically, left brain hemisphere maturation is delayed. Male brains are exposed to substantially higher testosterone levels than female brains during prenatal development; hence, a sex effect for handedness may be expected. Furthermore, the secretion of sex hormones is higher during seasons with a long photoperiod, i.e., extended day length (Macchi & Bruce, 2004). As a consequence, the theory also suggests a birth seasonality effect, i.e., seasonal anisotropy, with regard to handedness.

There is direct (Lombardo et al., 2012) and indirect (Beaton, Rudling, Kissling, Taurines, & Thorne, 2011) evidence for associations of intrauterine testosterone levels with brain development and left-handedness in men. In contrast, evidence for seasonal anisotropy is highly inconsistent: studies have reported anisotropy for widely different periods of the year, alternately affecting either men, or women, or both sexes likewise, or have found no effect at all (Stoyanov, Nikolova, & Pashalieva, 2011). One meta-analysis (Jones & Martin, 2008), based on 48581 participants from 11 primary studies, has concluded that in the Northern hemisphere more left-handed men are born during the period March–July. This meta-analysis has been criticized with regard to the handedness classification in the primary studies (Beaton, 2008). Indeed, its conclusion runs counter to expectation, because in the Northern hemisphere the photoperiod is the longest during May–July. However, the critical period of testosterone-induced human sexual differentiation does not occur perinatally, but much earlier prenatally, during gestational weeks 8–24; afterwards, plasma testosterone levels are generally low (Baron-Cohen, Lutchmaya, & Knickmeyer, 2004). The peak of embryonic neuronal migration also occurs during gestational week 12–20 (Tau & Peterson, 2010). Testosterone-induced effects on brain lateralization thus likely take place early during embryonic development. For the Northern hemisphere one would therefore expect more left-handed men to be born during November–January, not during March–July, as suggested by the meta-analysis. Some studies indeed have reported a higher prevalence of left-handedness or non-right-handedness among men born in winter and/or autumn (Badian, 1983; Preti, Lai, Serra, & Zurrida, 2008; Stoyanov et al., 2011). However, in light of the accumulating inconsistent findings in general, more evidence is clearly needed. Moreover, studies on this theme need to take into account specific validity threats and statistical power considerations, as elaborated below.

Whilst the effects of sex hormones and sex chromosomes on brain differentiation are likely more complex than previously thought (Lentini, Kasahara, Arver, & Savic, 2012; Lust et al., 2011), available research in this area suffers from at least three different sources of bias and confounding which all threaten reliability and decrease statistical power. First, sample size is a pervasive problem in all handedness-related research. The skewed 10:90 handedness ratio lowers the power of statistical tests by about 50%, as compared to an optimally powered 50:50 ratio. Alternatively, oversampling left-handers may result in dissimilarity of sampled populations and thus introduce additional bias.

Second, handedness classification is often problematic. Hand preference in writing is molded by social and cultural pressure (Preti et al., 2011), which might lead to an underestimation of the true associations of handedness with other variables, when handedness classification is solely based on the hand used for writing (Papadatou-Pastou et al., 2008). More reliable multi-item inventories, like the Edinburgh Handedness Inventory (EHI; Oldfield, 1971) or the Lateral Preference Inventory (LPI; Coren, 1993), still use arbitrarily adopted criteria and either a dichotomy (right/left, right/non-right) or a trichotomy (right/mixed/left) for handedness classification. This may prohibit direct comparisons between studies and thus renders meta-analytical results questionable (Beaton, 2008). Moreover, such varying classification criteria may even lead to different conclusions derived from the same data (Denny, 2008; Kelley, 2012). What is more, scoring and classification typically assigns equal weight to all items within an inventory. However, psychometrically this may be inappropriate (Dragovic, 2004). Existing taxometric (Dragovic, Milenkovic, & Hammond, 2008) and latent class analyses (Büsch, Hagemann, & Bender, 2009; Dragovic & Hammond, 2007; see Methods) suggest that handedness in actual fact is discrete and thus support classification approaches. However, studies on handedness associations with other variables seldom make use of latent variable analyses that would allow for a differential weighting of indicators and the direct modeling of handedness.

Third, photoperiod in the Northern hemisphere is longest during May–July, shortest during November–January, and intermediate during February–April and August–October. Some studies have based their analyses either on the four meteorological seasons (winter: December–February; spring: March–May; summer: June–August; autumn: September–November; e.g., Stoyanov et al., 2011) or on the astronomical seasons (winter: December 21/22–March 19/20; spring: March 20/21–June 20; summer: June 21–September 21/22; autumn: September 22/23–December 20/21; e.g., Tonetti, Adan, Caci, Fabbri, & Natale, 2012). Other studies have contrasted half-year periods (meteorological autumn and winter versus spring and summer; Martin & Jones, 2008) or have used a monthly resolution for analysis (e.g., Milenković, Rock, Dragović, & Janca, 2008). However, the meteorologically or astronomically defined seasons match with the seasons, as defined by photoperiod variation, by at most about two-thirds, and monthly analyses neglect the non-independence of consecutive months. Q2

In the present study an attempt was made to overcome all of the above shortcomings. Given the inconsistency of past research, we investigated handedness and its seasonal anisotropy in a discovery sample as well as in an independent replication sample, in order to assess the replicability of our own initial findings. Independent discovery and replication samples within the same study are now considered best practice in genome-wide association studies, in order to guard against false-positive findings and to demonstrate the robustness of an effect, if the replication is successful

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