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Scalp hair-whorl orientation of Japanese individuals is random; hence, the trait's distribution is not genetically determined

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Abstract

Because the features of clockwise versus anti-clockwise orientation of hair-whorl coiling developed on a person's scalp is (partially, albeit significantly) correlated with that individual's right- versus left-hand-use preference (i.e., handedness) in the US and British subjects, these traits have been recently suggested to be determined biologically and through a common genetic mechanism. Here I report results of a serendipitously made observation with the Japanese population that helps to scrutinize validity of partial correlation between these attributes and to ascertain whether the underlying gene's frequency variations exist in different gene pools. Surprisingly, the whorl orientation in the Japanese individuals was found to be random, although their handedness variation is similar to that of the US population. Therefore, the whorl orientation trait is not genetically determined in the Japanese population. This result supports the idea that separate decisions must be made during embryogenesis for developing handedness and hair-whorl features at least in Japanese individuals. A recent study found the lack of association between whorl orientation and handedness in the German population, yet previous studies suggested that their scalp hair orientation is genetically determined. Therefore, pronounced genetic variation for the hair-whorl trait exists between individuals of different geographical regions. As hand preference exhibits "complex correlation" with brain hemispheric functional specialization, implications of these findings are discussed here with the goal to define biology of brain hemispheric laterality determination.

Keywords

Human handedness trait; Scalp hair-whorl orientation; Brain laterality development; Human genetic variation

It has been a long-standing debate on the cause of human right- versus left-hand-use preference, termed handedness, with theories varying from learned behaviour, to genetics, and to a combination of both mechanisms [1–3]. The genetics aetiology has been supported by inheritance of the trait in nuclear families and adopted individuals. However, because a significant proportion of right-hander (RH) children are born when both parents are left/ambidextrous-handed (collectively termed non-right-handers, NRH), ~18% of monozygotic

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twin members despite inheriting same genetic make up are discordant for hand preference [4], and because the simple Mendelian mode of inheritance is not observed in family studies, psychologists instead favour a combination of the learned behaviour and pathological aetiologies, such as brain damage due to birth stress [5]. Genetics models propose that a single gene determines handedness; it has two alleles and random handedness develops in homozygote individuals of the minor, nonfunctional allele. Both Annett [1] and McManus [3] models propose an additive effect with varying degrees of both incompletely dominant alleles, while the “Random-recessive model” [6] proposes the functional *RGHT* (for right) allele to be fully dominant to the nonfunctional *r* (*r*, for random-handed) allele.

A recent study has advanced genetic aetiology for hand preference because another biologically determined atypical anti-clockwise (AC) hair-whorl direction developed on a person's scalp (see Fig. 1) is significantly associated with an increased probability for NRH in the US general population. In over 95% of the US unselected subjects investigated, each person develops a single hair whorl that swirls either C or AC, and the remainder most often develop two whorls, usually one C and the other AC [7]. The human skin, scalp hair whorl, brain hemispheric specialization, and handedness preference develop from the embryonic ectoderm layer of cells. It is reported that persons supporting a clear single whorl, a majority (91.6%; $N = 500$, large majority of them will be RH) exhibit a typical C rotation and a minority (8.4%) has atypical AC whorls [8]. This study involved investigation of persons with shorter hair, and the longhaired persons were not investigated because it is not possible to score their phenotype through unobtrusive observations made for convenience. In contrast, in 49 NRH persons investigated, 22 had AC and 27 had C rotation. Furthermore, in 23 AC-whorled persons investigated, 11 were NRH and 12 were RH. These results were interpreted to support a single gene with two alleles genetic model [6] whereby a single dominant *RGHT* gene with 100% penetrance causes development of both right-hand preference and C rotation of hair whorls. In individuals homozygous for the *RGHT* gene's “nonfunctional” *r* allele, both hand preference and whorl direction development is uncoupled and they are randomly and independently of each other distributed to the left- versus the right side of a person. Previous support to this random-recessive model for hand preference was provided by handedness inheritance studies in US subjects [4,6,8] and for the inheritance of only the hair-whorl trait in German subjects [9,10]. A follow-up study [11] with the German population showed that all 22 RH with C hair whorls developed typical language processing in the left-brain hemisphere, but six of 21 RH with AC whorls showed atypical language processing. The later result is similar to that observed with the NRH persons [12,13]. Moreover, a study [14] with British RH subjects observed 12.8% ($N = 125$) AC whorl rotation, and more telling, 26 AC and 22 C individuals were found among 48 NRH individuals investigated. Another recent study [15] also concluded that NRH is associated with AC swirling direction as well as to the medial position of the swirl. Therefore, an association between handedness and direction of hair-whorl traits in the British population is evidenced, thus confirming results previously reported with US subjects [8]. It seems clear that there is a common genetic mechanism that controls hand-use preference and hair-whorl orientation both in the US and British populations.

How might the hypothesized *RGHT* gene [6] control development and distribution of these traits to the body in the side-specific fashion? One possibility advanced is that the gene

might function by causing an asymmetric cell division that produces a left- and a right-side generating progenitor sister cells when these features are initially established during embryogenesis [16]. This model proposes nonrandom placement of thus differentiated sister cells with respect to both dorso-ventral and anterior-posterior axes in embryos that contain the determinant *RGHT* gene. However, there will be a random distribution of specific differentiated sister cells in *r/r* homozygous persons according to this “random-recessive model” that was advanced initially to only explain inheritance of the handedness trait. Logically, because these three traits of handedness, brain hemispheric laterality and hair-whorl orientation are randomly distributed in *r/r* individuals, possibly three separate asymmetric cell divisions, one for each trait, would be required. Concerning language lateralization trait, however, it should be noted that NRH persons still show partially biased ~70% typical: ~30% atypical brain lateralization [12,13] and those values are different from the random value of 50:50 ratio predicted by the model. It seems there exists an inherent 70:30 ratio bias in establishing brain laterality even in *r/r* individuals, but all those individuals with the functional *RGHT* gene develop determined lateralization consisting of left hemispheric language localization, right-handedness and C whorls.

The human brain hemispheres develop to be functionally asymmetric in most persons. The mechanisms that determine these asymmetries remain undefined. There is the so-called “complex association” between hand preference and brain hemispheric specialization for processing language. That is, ~97% RH and ~70% of NRH process language in the left hemisphere, the balance show atypical (bilateral or right-hemispheric) language lateralization [12,13]. It is a major question that remains unanswered as to how the two brain hemispheres are lateralized to perform different cognitive functions. Deciphering the mechanism of complex association of brain laterality with hand-use preference is likely to help define the biology of brain laterality development. It is addressed here whether the hair whorl and the handedness traits are necessarily correlated and whether their allele frequency varies in different geographical regions. Results of a pilot study with Japanese gene pool are presented.

To better appreciate the genetics of brain lateralization and its implication for psychiatric disorders presumably resulting from anomalies of development of brain laterality [17]; many questions are raised to understand biology behind the genetic aetiology. For example, how to determine whether separate decisions are made for developing the features of brain hemispheres, hand preference and hair-whorl orientation? Does natural variation exist in the allele frequency in different gene pools? Are these traits necessarily associated with each other in all populations? Moreover, one can imagine evolution of mechanisms that might confer selective advantage to persons with biased brain lateralization and hand preference, the advantage or disadvantages of the hair-whorl direction are not obvious. As it is easy to determine the hair-whorl phenotype by unobtrusively observing persons in public settings, the questions of allele frequency as well as the association between these features in gene pools of different countries can be determined. With this approach, the author made observations during a visit to Japan in 2007 that are very helpful to answer some of the questions posed above.

One is born with a specific hair-whorl rotation and the orientation does not change with age or by the direction in which hair is combed. The hair-whorl phenotype (Fig. 1) is rather easy to ascertain simply by observing subjects who support short hair length. Bald persons, those with longer hair, those with more than one whorl, and those bearing a head cap were ignored for this study. Data on subjects each one with a clear, single hair whorl were recorded. In this observational study, anonymous subjects set in public places, such as while sitting in seats in trains, or while descending on escalators were surreptitiously observed by the author. The observations were made unobtrusively, without subject's knowledge and without getting their permission for participation in the study. According to the National Institute of Health (USA) guidelines for research with humans, informed consent from subjects is not required if the subjects are anonymous, observations are made discreetly and unobtrusively, and without the subject's knowledge. This procedure was observed in the study. It is to be noted that most persons are oblivious to their "crown" whorl orientation, let alone its significance for anything else. In 100 unselected Japanese persons investigated who support shorter parietal hair, 51 had C and 49 had AC hair whorls. By following the handedness determination criterion, "Which hand do you use to hammer a nail into a piece of wood [14]?", a minority of 7.1% ($N=156$) of Japanese individuals were found to be NRH. Such a proportion of NRH is not significantly different from that of the US population. However, the observed values of 8.4% in the US [8] versus ~50% (49 among 100) AC hair-whorl rotation in Japanese individuals at large are vastly different between the two countries. Clearly, Japanese persons develop random whorl orientation. Therefore, unlike the studies quoted above with the US and British gene pools, hair direction is clearly unassociated with hand preference in Japanese people. The random whorl direction clearly suggests that genetics does not dictate distribution of this trait in Japanese individuals, just as there is no genetic basis for random C versus AC coiling of rows of pinecone scales [18]. Because an unbiased choice between two possible outcomes is expected to be random, just like the random head-versus tail-outcome of a coin toss, chance dictates the whorl orientation in the Japanese gene pool. Moreover, this result supports the idea that separate decisions must be made during development for developing handedness and hair-whorl features at least in Japanese individuals.

In contrast to random hair-whorl orientation of Japanese individuals (this study), 8.4% US individuals [8] and nearly 20% German individuals develop AC rotation [9,10,19]. Thus, a significant genetic variation exists for the whorl orientation trait between different countries. The only study for defining genetics of inheritance of the hair-direction trait by itself was performed in the German population [10] where a single gene with two-alleles model was advanced such that individuals containing one or two copies of the dominant allele, designated *R*, develop C whorls, but *all* the recessive nonfunctional allele *r/r* homozygotes develop AC whorls. It also concluded that C is a dominant trait over AC. Notably, the suggestion of all the *r/r* individuals exhibiting AC orientation is not in accord with the 50% C:50% AC orientation ratio predicted by the random-recessive model. However, subsequent re-analysis of results of this earlier study concluded that the *r/r* individuals indeed exhibit random hair orientation, and therefore, the random-recessive model for the single hair rotation trait by itself is supported in German subjects [9].

In a recent report of drafted military personnel from Germany, 18.3% RH ($N=981$) and 19.7% NRH ($N=127$) had AC direction and the rest showed C whorls [19]. The study notes that there is no association between whorl direction and handedness or brain laterality; it is concluded that there is no evidence for a common genetic mechanism of hair-whorl direction and handedness or language dominance. To explain the difference in results of this study with that of a previous one [8], authors suggest that most likely the investigation of limited number of individuals in the previous study is simply not sufficient to draw firm conclusions about the association between handedness and hair-whorl direction. It should be noted that the criteria for determining handedness vary in the two studies. Also, in light of findings with Japanese individuals discussed above, and realizing significance of several other studies that supported the random-recessive model [6,8,9,11,14–16], another most likely an evolution based explanation advanced here is that natural genetic variations concerning the hair-whorl trait must exist in different populations. Accordingly, hair-whorl direction, although determined genetically, might be established independently of handedness and brain laterality development in German subjects, but these traits are controlled by a common genetic mechanism in US subjects, whereas the unbiased hair rotation trait in Japanese people is not genetically determined.

The larger questions concerning the biology of brain laterality determination and its relevance to psychiatric disorders remain unanswered. For example, it remains to be determined how would a gene dictate ectoderm tissues laterality development [16]. Do the above-mentioned variations in different gene pools result from variation of the *RGHT*, *r* gene allele frequency or due to variation in biological targets through which the *RGHT* gene performs its function? Answering some of these questions await genetic mapping and molecular identification of the *RGHT* gene. A recent genome-wide linkage analysis with blood samples of subjects originally selected for learning disability suggested handedness gene to be linked to the maternally imprinted gene LRRTM1 [20]. However, this purported linkage should be interpreted with caution because analysis of an independent sample presented in the same study failed to replicate the LRRTM1 linkage. It is to be appreciated that the above-discussed findings of gene-pool variation in different countries should help define the mechanism of brain laterality determination. Understanding the basis of brain laterality development is crucial to define the aetiology of psychoses diseases that possibly result from impaired brain laterality development. Therefore, it will be very informative to perform similar studies in populations of other gene pools in future investigations.

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References

- [1]. Left Annett M., right, hand and brain: the right shift theory. London: Lawrence Erlbaum; 1985.
- [2]. Klar AJS. Genetics models for handedness, brain lateralization, schizophrenia, and manic-depression. *Schiz Res* 1999;39:207–18.
- [3]. McManus IC. Handedness, language dominance and aphasia: a genetic model. *Psychol Med Monogr* 1985;(suppl 8):1–40.

- [4]. Rife DC. Handedness, with special reference to twins. *Genetics* 1940;28:178–86.
- [5]. Coren S Left-hander syndrome—the causes and consequences of left-handedness. New York: Macmillan; 1992.
- [6]. Klar AJS. A single locus, *RGHT*, specifies preference for hand utilization in humans. *Cold Spring Harb Symp Quant Biol* 1996;61:59–65. [PubMed: 9246435]
- [7]. Wunderlich RC, Heerema NA. Hair crown patterns of human newborns. Studies on parietal hair whorl locations and their directions. *Clin Pediatr (Phila)* 1975;14:1045–9. [PubMed: 1183129]
- [8]. Klar AJS. Human handedness and scalp hair-whorl direction develop from a common genetic mechanism. *Genetics* 2003;165:269–76. [PubMed: 14504234]
- [9]. Klar AJS. A 1927 study supports a current genetic model for inheritance of human scalp hair-whorl orientation and hand-use preference traits. *Genetics* 2005;170:2027–30. [PubMed: 15944357]
- [10]. Schwarzburg VW. Statistische untersuchungen uber den menschlichen scheitelwirbel und seine vererbung. *Zeitsch F Morphol U Anthropol* 1927;26: 195–223.
- [11]. Weber B, Hoppe C, Faber J, Axmacher N, Fliessbach K, et al. Association between scalp hair-whorl direction and hemispheric language dominance. *Neuroimage* 2006;30:539–43. [PubMed: 16289721]
- [12]. Knecht S, Drager B, Deppe M, Bobe L, Lohmann H, et al. Handedness and hemispheric language dominance in healthy humans. *Brain* 2000;123(Pt 12):2512–8. [PubMed: 11099452]
- [13]. Rasmussen T, Milner B. The role of early left-brain injury in determining lateralization of cerebral speech functions. *Ann N Y Acad Sci* 1977;299:355–69. [PubMed: 101116]
- [14]. Beaton AA, Mellor G. Direction of hair whorl and handedness. *Laterality* 2007;12:295–301. [PubMed: 17558812]
- [15]. Schmidt H, Depner M, Kabesch M. Medial position and counterclockwise rotation of the parietal scalp hair-whorl as a possible indicator for non-right-handedness. *Sci World J* 2008;8:848–54.
- [16]. Klar AJS. An epigenetic hypothesis for human brain laterality, handedness and psychosis development. *Cold Spring Harb Symp Quant Biol* 2004;69:406–99.
- [17]. Klar AJS. A genetic mechanism implicates chromosome 11 in schizophrenia and bipolar diseases. *Genetics* 2004;167:1833–40. [PubMed: 15342521]
- [18]. Klar AJS. Fibonacci's flowers. *Nature* 2002;417:595. [PubMed: 12050641]
- [19]. Jansen A, Lohmann H, Scharfe S, Sehlmeier C, Deppe M, et al. The association between scalp hair-whorl direction, handedness and hemispheric language dominance: is there a common genetic basis of lateralization? *Neuroimage* 2007;35:853–61. [PubMed: 17275334]
- [20]. Francks C, Maegawa S, Lauren J, Abrahams BS, et al. LRRTM1 on chromosome 2p12 is a maternally suppressed gene that is associated paternally with handedness and psychizophrenia. *Mol Psychiatry* 2007;1–11.

Fig. 1.
The parietal hair-whorl phenotype. Picture of anti-clockwise hair-whorl rotation of an anonymous Japanese subject is indicated by the arrow's orientation. Reversing the orientation shown in the picture would reflect the clockwise orientation.