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Laterality Effects In Twins

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Abstract. The laterality effects in 10 symmetrical EEG derivations in twins (20 MZ and 20 DZ pairs with a mean age of 20.5 years) were examined. The quantitative and qualitative analyses gave the following results: (1) cotwins in the MZ and DZ pairs differed particularly in the intensity of asymmetry for EEG parameters — one was more asymmetrical than the other; (2) among the MZ twins there were no "mirror" pairs (opposite asymmetry of the EEG), even where opposite-handedness existed. For example, a right-handed twin had an asymmetrical EEG, while the other, a left-hander, had a symmetrical one; (3) the most asymmetrical EEG was in the temporal derivations showing a more active left hemisphere; and, (4) there was no evidence of genetic influence in the intensity of EEG asymmetry.

Key words: Asymmetry, Twins, Laterality, Mirror-imaging, Electroencephalogram (EEG)

INTRODUCTION

Abundant clinical and experimental evidence shows that there are many morphological and functional manifestations of asymmetry in the human brain hemispheres. It is interesting to note, that morphological and functional asymmery is not only observed in adults but also in newborns [11,22,23]. The existence of brain laterality at birth would suggest, therefore, that it is an inborn or even hereditary feature.

Attempts to explain asymmetric manifestations in the human brain have been made in the context of mendelian laws. For the most part, these dealt with the more marked visible asymmetries, such as handedness [2,4,17,28]. For the same purpose, other researchers, and we in this present study, chose another method – twin studies. Twins are known to differ from the rest of the population in many aspects. For instance, left-handedness is more common in twins (usually within-pair discordant, ie. one left-handed, the other right) than in singletons [3,13,19,23,25,30]. Although hand asymmetry is perhaps the oldest recognised discordancy among twins, many other morphological and functional asymmetries have since emerged, eg. direction of hair whorl, eye and leg asymmetries, dermatoglyphic asymmetries etc. [14,24,27-29]. Lateral discordancy is found in both MZ and DZ twin pairs and this would suggest that asymmetry inversion is a characteristic pertaining to twinning in general [14].

The most well-known explanation of the phenomenon of discordancy in MZ twins is to be found in Newman's work [24,25]. He maintains that asymmetry inversion, or "mirror-imaging", in MZ twins takes place during embryonic development and, more specifically, in the stage when the embryo divides into two organisms. In other words, that MZ twins without, or with only slight traces of, mirror-imaging are those resulting from a relatively early embryonic division, ie. before the more right/left differences between the two halves of the embryo have been determined. On the contrary, those (MZ pairs) demonstrating extensive mirror-imaging, result from a later twinning division when the right/left differences are more strongly established. C.E. Boklage [7] offers the consideration that monozygotic twinning is an anomaly of embryonic symmetry development. This hypothesis is supported by the fact that mirror-imaging is more common in conjoined twins, appearing, as expected, in the later stages of embryogenesis and, in some cases, with extreme inversion eg. location of internal organs, etc. It does not, however, explain the occurrence of lateral discordance in DZ twins nor does it answer many other questions relating to lateral discordance in MZ twins such as the appearance of mirror-imaging in some traits and not in others; the different expressions of mirror-imaging in a given conjoined pair. Many such queries remain to be answered.

Another conceivable explanation for laterally discordant twins could be due to their particular susceptibility to environmental influences, which may be different for each cotwin. This is likely to magnify the proportion of discordant MZ and DZ pairs. Many are of the opinion that laterally discordant twins result from unequal intrauterine (environmental) conditions and/or birth stress [6,7,9,23,28].

Apart from the foregoing considerations, there are, however, some "genuine" cases of mirror-imaging in MZ twin pairs, due to their specific embryogenesis in deriving from one zygote. Mirror-imaging in the narrowest sense, ie. (embryonic) discordant mirror-MZ pairs, would appear to account for the greater number of left-handers among MZs compared to DZs [23]. Nevertheless, the overall number of "genuine" mirror-image MZ pairs is not likely to be great. Twin statistics show that the number of MZ twins resulting from embryo division after amniogenesis (8th/9th day embryonic development when bilateral traits are expected to have appeared), accounts for no more than 3-4% of the total number of MZ pairs [7,8,13]. Nevertheless, the mirror-image theory persists, as an explanation of discordance in various functions and traits in MZ twins [5,18,26,32]. Often the terms "mirror-image" and "discordance" are interchanged. In our opinion the term "mirror-image" should be applied exclusively in relation to MZ pairs possessing "genuine" mirror-image functions and/or traits. In all other cases, including DZ within-in pair discordancy, the term "lateral discordance" would be more appropriate.

A large amount of literature exists on handedness and other morphological asymmetries in twins but very little is known about the laterality effects of psychological and psychophysiological characteristics in twins. Some evidence emerged on mirror-image manifestations in the EEGs of MZ twins [26] and some on ear asymmetry based on the dichotic listening procedure [32]. To date, research into the special features of brain asymmetry function in twins has not been sufficiently addressed.

In the present study, we attempt to investigate, in detail, the asymmetrical features in the EEGs of MZ and DZ twin pairs. One previous investigation on this topic was performed [26], but it was reserved to a small group of MZ twins only, without any comparative study on DZ twins. Here we also evaluate hereditary and environmental influences on the interindividual variability in the intensity of EEG hemisphere asymmetry.

MATERIALS AND METHODS

The study group was made up of 20 MZ and 20 DZ same-sexed pairs, all aged between 18 and 26 years (average 20.5 years). Zygosity was determined by morphological, dermatoglyphical, odontoglyphical and, in some cases, immunogenetic data.

Two EEG recording sessions were run on each subject: an adaptive session and an experimental session. Cotwins were examined on the same day. During the sessions, each subject was seated, with eyes closed, in a comfortable reclining chair in a darkened, soundproof room. The EEGs were recorded on 10 electrodes (F_3, F_4, C_3, C_4, P_3, P_4, 0_1, 0_2, T_3, T_4, in a 10-20 system) referred to linked mastoids.

The EEGs of the experimental sessions were analysed. EEG interhemisphere asymmetry, in each symmetrical pair of derivations, was evaluated with reference to four EEG parameters: mean α–amplitude, α-index, variance of the discrete values of amplitudes (σ^2 DVA), and the relationship between the strengths of the periodic process, compared to the random process ($K_{p/r}$). The first two parameters were computed by hand: the mean values of α-amplitude, as average of pick-to pick amplitudes on all α-waves in ten -1sec EEG segments, with α-rhythm pronounced; and, the α-indexes, according to the traditional 1 meter EEG recording, with 30 mm/sec paper speed. To get the remaining two parameters, autocorrelation functions were calculated, for 6sec EEG segments recorded synchronously in all areas, 3 to 5 minutes after recording began. The standard EEG form was translated into a numerical one with the aid of a curve-code transformer, called "Silhouette", registering an 0.0133sec time-shift. Each EEG segment, therefore, was obtained in sequence form with each sequence consisting of 450 ordinates. These ordinates (obtained after "Silhouette" transformation) were used to calculate the variance in the discrete values of amplitude (σ^2 DVA) on a Nairy-2 computer. In addition, autocorrelation analysis of the ordinates was also carried out. The maximum time-shift was 0.93sec with each consecutive time-shift value differing from the preceding one by 0.133sec. Analysis of the autocorrelograms included the calculation of coefficients to express the relationship between the strengths of the periodic process and those of the random process [12], or parameter $K_{p/r}$.

The intensity of interhemisphere asymmetry, for all four parameters mentioned above, was calculated by the formula:

$$AI = D/d - 1$$

where AI is the asymmetry intensity; D, the greater value of the given parameter; and d, the lesser value of the same parameter, all in a given pair of EEG derivations regardless of left- or right-hemisphere involvement. AI is valued from 0 upwards, ie. the greater AI, the more pronounced interhemisphere asymmetry, and so when AI = 1, D:d = 2:1. Thus, AI allows the extent of asymmetry to be evaluated, independent of right- or left-hemisphere dominance.

Handedness was estimated by the modified Annett Questionnaire [1,31] and on subject's self-report.

RESULTS

We first considered AI in the MZ and DZ twin groups. The AI mean values in Fig. 1 show that asymmetry for all four parameters is more pronounced in the temporal leads nad noticeably different from results in the other leads.

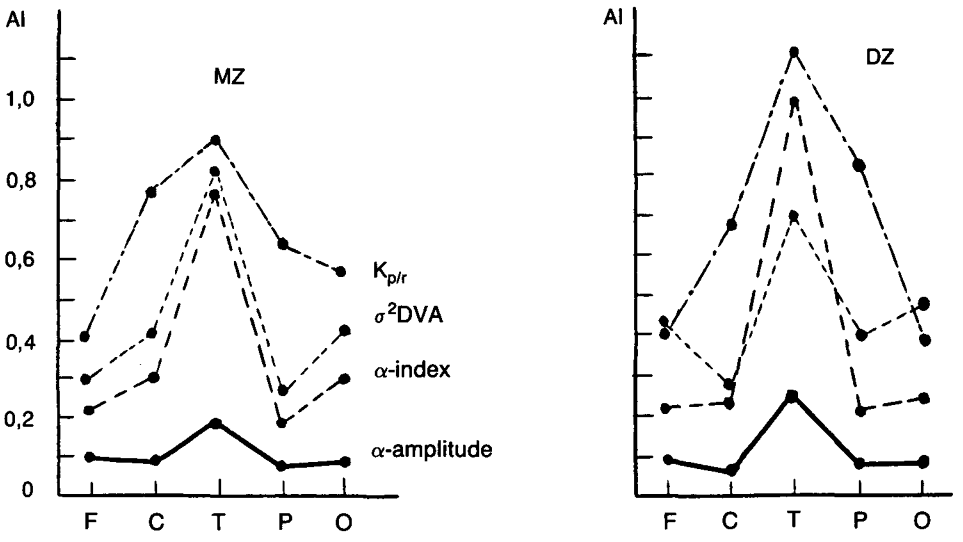

Fig. 1. Mean values of asymmetry intensity (AI) for 4 EEG parameters.
F = frontal, C = central, T = temporal, P = parietal, O = occipital brain regions.

Intraclass correlations are given in Table, with almost all coefficients having low values. In the MZ group, there are only two significant coefficient values concerning asymmetry for α-index, and these relate to the frontal and central regions of the brain. The remaining MZ coefficients are, more or less, equal to those of the DZ group.

To gain greater insight into the low values of similarity in the twins, and to better understand the phenomenon of EEG asymmetry in twins as a whole, we further observed those subjects with noticeable EEG asymmetry, on each pair of leads and for the four parameters being analysed. We used the criterion $\bar{x} + 2/3\sigma$, with $\bar{x}$ the mean value of AI for a given parameter in each pair of leads for each subject and σ the standard deviation. If AI was greater than $\bar{x} + 2/3\sigma$, asymmetry was seen as distinct. Twin part-

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Table - Intraclass correlations for EEG asymmetry intensity (AI)

EEG parameters	Groups (20 pairs ea.)	Brain Regions				
		Temporal	Frontal	Parietal	Occipital	Central
Amplitude	MZ	−0.157	−0.046	−0.357	−0.152	−0.138
	DZ	−0.008	−0.031	−0.050	−0.024	−0.216
α-index	MZ	−0.035	0.853	0.168	0.093	0.498
	DZ	−0.107	0.050	0.114	0.108	−0.094
$\sigma\text{-}^2$DVA	MZ	−0.076	0.194	0.052	0.102	0.073
	DZ	−0.107	−0.069	0.192	−0.026	0.280
$K_{p/r}$	MZ	−0.144	−0.167	0.180	−0.128	0.330
	DZ	−0.236	−0.083	0.038	0.267	0.444

ners, with asymmetrical EEGs in relation to the particular parameter applied, were classified as asymmetrical concordant (ACC); a pair with symmetrical EEGs were classified as symmetrical concordant (SCC); and, lastly, if one twin had an asymmetrical EEG and the cotwin a symmetrical one, these were classified as laterally discordant (LDC). Up to this stage, the direction of asymmetry (ie. right or left dominance) was not taken into account.

The diagrams in Fig. 2 show the proportions of ACC, SCC, and LDC pairs among the MZ and DZ twin groups. In constructing these diagrams, all cases of asymmetry, regardless of parameter reference, were taken into account. The two most obvious

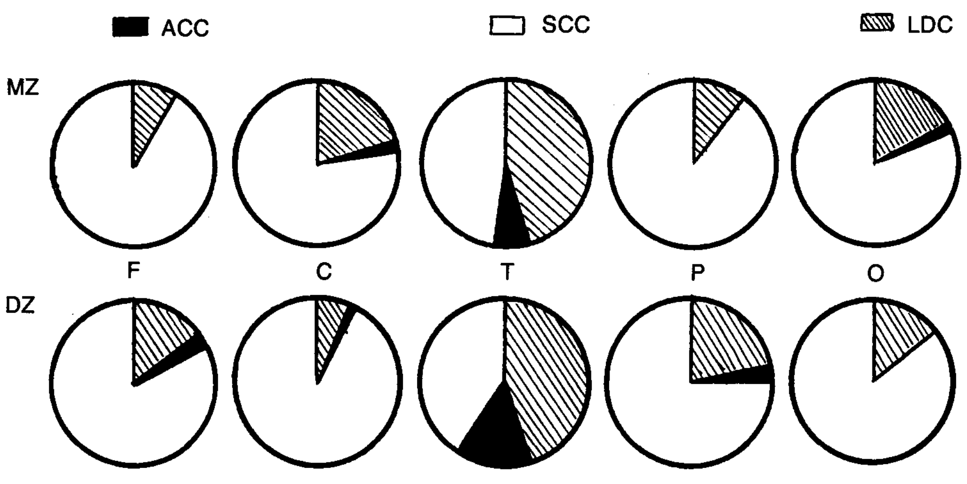

Fig. 2. Twin pairs with noticeable EEG asymmetry in one or both partners. Proportions of asymmetrical concordant (ACC), symmetrical concordant (SCC) and laterally discordant (LDC) MZ and DZ twin pairs.

results were: first, the majority of subjects with clearly defined EEG asymmetry were found in the temporal leads; second, asymmetrical concordant pairs (ACC) were almost non-existent in either (MZ,DZ) group. We conclude, therefore, that where one twin has a distinctly asymmetrical EEG, the cotwin usually does not.

Fig. 3 illustrates the analysis of EEG laterality in twins with regard to hemisphere dominance for each EEG parameter and the zone of registration. The columms represent the proportion (%) of subjects with left- or right-hemisphere dominance for each EEG parameter. It can be seen that right-hemisphere dominance in the temporal leads is the most frequent, especially for α-amplitude and α-index parameters. This means that the EEG of the left temporal lobe is more active. There are only a few cases of asymmetry in frontal leads, with the direction of the asymmetry for α-amplitude and α-index opposite to that seen in the temporal leads. Here left-hemisphere dominance is noted. No similar tendencies are evident for the remaining leads and parameters.

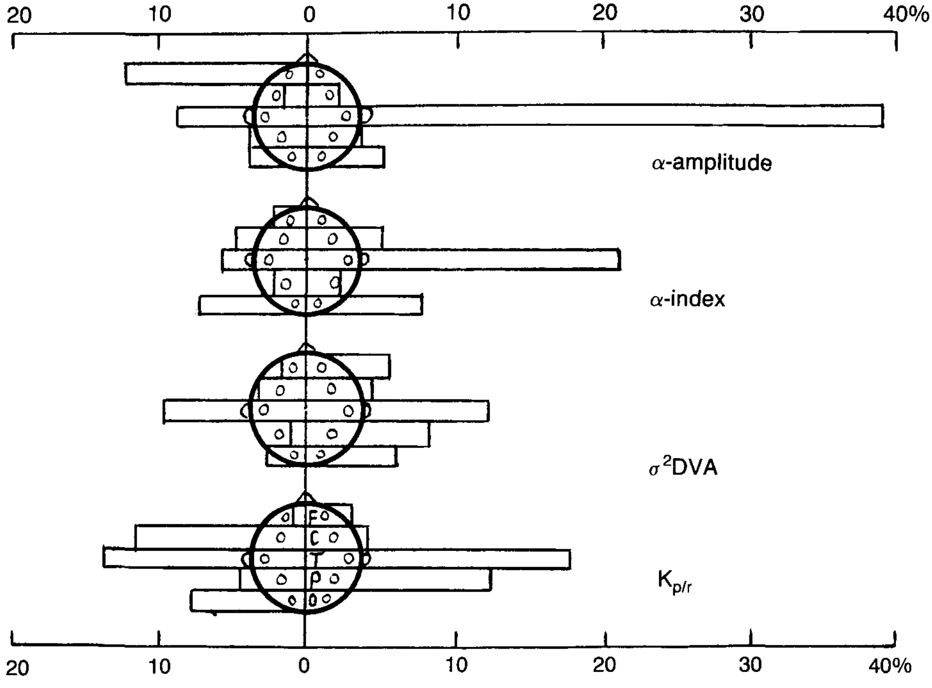

Fig. 3. Subjects (% of total) with expressed right-hemisphere and left-hemisphere dominance for EEG parameters.

In the added analysis of the subjects with noticeable EEG asymmetry, we identified several cases with simultaneous temporal EEG asymmetry for three, or all four, parameters. These subjects, 12 in all, were identified among 6 MZ and 6 DZ same-sexed pairs. Four subjects in the MZ pairs and 5 in the DZ pairs had right-hemisphere dominance in the temporal leads for all four parameters. All pairs were LDC – one twin

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with a distinct asymmetrical EEG, the other with a more symmetrical one. It is interesting to note, that in 4 pairs of the 6 MZ pairs, the twin with noticeable EEG asymmetry and right-hemisphere dominance was also right-handed, whereas the cotwin with a symmetrical EEG was either left-handed or ambidextrous.

DISCUSSION

Our data are comparable to those obtained by Raney [26] on a sample of 17 pairs of MZ twins. In 65% of these 17 MZ pairs, the author revealed the contralateral asymmetry for α-amplitude, amount of α-activity, and for several behavioural features. These twins were considered to be mirror-image with more pronounced interhemisphere difference in one cotwin. The greater expression of EEG parameters in the nondominant hemisphere and the independent asymmetry of different brain regions were also noted.

In general terms, our data are consistent with Raney's, but we would decline to say that our twins were "mirror-imaging". Where one twin had an asymmetrical EEG; the other had a symmetrical one, but mirror-imaging implies opposite asymmetry. Based on the data presented here, different intensity of asymmetry may be considered a particular characteristic of the EEGs of MZ twins.

On the hypothesis that lateral dominance is an innate feature [2,16,17], and that hand discordancy in MZ twins is a postnatal indicator of their late embryonic twinning division [5,7,24,25], one would expect to find mirror-MZ twins with opposite hemisphere asymmetry. It should be noted, however, that postnatal development of these MZ twins may take place in a social environment where different influences are exerted to secure right-hand (left-hemisphere) dominance. As a result, in response to such influences, the innate asymmetry of the right-handed twin will be strengthened, while the left-handed cotwin will probably become ambidextrous (symmetrical). Furthermore, if we suggest that the human brain electrophysiological features change in response to environmental influences (as happens in experiments of targeted environmental influences on the neurophysiological development of young animals), we would expect to find asymmetrical EEG patterns in a right-handed MZ twin, but in the left-handed partner, who will experience the environmental influences as a contradiction of his/her natural asymmetry, it is most likely that he/she will develop symmetrical EEG patterns. We observed this phenomenon of opposite hemisphere dominance in some of our MZ twin pairs: one twin being right-handed and having an asymmetrical EEG; the other left-handed (ambidextrous) with a symmetrical EEG. It could be that these are "genuine" mirror-image MZ pairs. This phenomenon was not found in the DZ pairs. Although some DZ twins had opposite hand dominance, similar lateral differences for EEG parameters were absent. This leads us to believe that the greater proportion of left-handedness among MZ twins is partly due to "mirror-imaging" (in its narrowest sense), even though some authors refute the mirror-imaging hypothesis [10].

The foregoing treats interhemisphere asymmetry as a special feature in the EEGs of twins, but it also establishes that MZ and DZ cotwins are dissimilar in their asymmetry intensity (AI) which means that the individual variability for this parameter is due to environmental factors. In previous studies [20,21], we established that for several EEG parameters the left hemisphere, rather than the right hemisphere, (espeically in the temporal regions), is more susceptible to environmental influences. It may be possible, therefore, that the intrapair dissimilarity of AI observed in the present study is due to the difference between right and left hemisphere EEG susceptibility to environmental influences.

Twin study is often used to investigate the genetic and environmental contributions to individual differences in lateralized traits eg. physical dexterity, verbal and spatial abilities etc., but as twins differ from the population in their asymmetrical traits, this too must be considered in order to obtain a more realistic evaluation. We believe it is necessary to make quantitative estimations of hereditary and environmental influences on the individual characteristics of the right and left hemispheres and not just on the parameters for asymmetry intensity alone. A qualitative analysis of the asymmetrical traits in twins is also necessary.

Another point to be noted is that the areas of the brain differ from one another in their asymmetrical characteristics and because of the genetic and environmental factors which contribute to individual differences. Psychologists and physiologists alike find the temporal lead readings in EEGs of particular interest. Previous studies have shown that the EEG of the left temporal region is more susceptible to environmental influences than any other area of the brain [20,21]. Environmental factors would, therefore, seem to play a significant role in EEG tracings of the left temporal region. Another interesting point is that most morphological asymmetry was found in this region [15]. The foregoing highlights the importance of this specific area of the brain in the formation of hemisphere asymmetry function and its ensuing effects on verbal performance and hand dominance.

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