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Asymmetries of the Auditory Areas of the Cerebrum

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Abstract

A total of 29 human cadaver brains were examined for asymmetries of the left and right Sylvian fissure, Heschl's gyri, and planum temporale. The mean lengths of these structures were all significantly greater on the left side than on the right. There was considerable morphologic variability in these structures as evidenced by the number of Heschl's gyri that ranged from one to three per hemisphere in different brains, although there was no significant asymmetry in the number of Heschl's gyri in individual brains.
Asymmetry of the Sylvian fissure was correlated with the greater length of the planum temporale on the left side. Although it is well known that the planum temporale is larger in the left hemisphere than in the right, little has been reported on Heschl's gyri in this regard. It is possible that asymmetries in higher auditory and language function may be attributable to anatomic asymmetries of not only the planum temporale but also Heschl's gyri.

Key Words: Heschl's gyri, planum temporale, Sylvian fissure, asymmetry

In 1968 Geschwind and Levitsky published their now well-known article on asymmetry of the gross anatomy of the human brain. These authors reported that in 100 brains the planum temporale (PT) was larger on the left in 65 specimens while only 11 brains had a larger right planum. Geschwind and Levitsky (1968) also stated that the left PT was, on average, almost one-third larger than the right PT. This study indicated that there is an asymmetry of parakonio-cortex since the PT is composed mainly of this type of (auditory) cortex (Rubens, 1977). Also, it is now well known that if the PT area is damaged, Wernicke's aphasia is likely to result, suggesting the likelihood of a pathologic-anatomic relationship. Geschwind and Levitsky's study (1968) also supported the cerebral dominance theories, which in turn influenced interpretation of many psychological measures of hemispheric asymmetry, including dichotic listening.

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The study by Geschwind and Levitsky has been replicated with essentially similar results by Yeni-Komshian and Benson (1976) and Wada et al (1975). However, Wada et al (1975) reported that in 8 percent of their series the PT was not present. Although the Geschwind and Levitsky (1968) article is the best known, it was not the first to report asymmetry of the PT. In 1930 von Economo and Horn found the left PT to be larger than the right in a small series of human brains.

In studying auditory structures of the human brain, the Sylvian fissure (SF) (sometimes termed the lateral fissure) is a key landmark. The SF morphology and symmetry is closely related to that of the PT, which is located at the posterior segment of the SF. Rubens (1977) cites Cunningham and Eberstaller (Cunningham, 1892; Eberstaller, 1890) as being the first to observe asymmetries of the SF. A century ago these anatomists reported that the left SF was longer than the right. Subsequent articles reported great variability in measurement in comparing the left and right SFs, with common finding being that the left was longer than the right (von Economo and Horn, 1930; Shellshear, 1937; Connolly, 1950). Rubens et al (1976) also found the left SF longer than the right in their series of 36 brains. They reported great divergence in comparing the course of the left and right SF. This divergence seemed most notable at the posterior portion of the SF, where the left side tended to extend more posteriorly. Rubens et al (1976) attributed this differential finding in the posterior segment to the larger size of the PT in the left hemisphere.

Although there are reports on asymmetry of the PT and SF in the human brain, little such data are available on its major auditory structure, Heschl's (transverse) gyrus (HG). One of the important facets of HG is that it has multiple intra- and interhemispheric connections. There is evidence of four (direct and indirect) pathways from the medial geniculate and pulvinar of the thalamus that input to the HG by way of the internal capsule (Streitfeld, 1980). The HG has anterior connections to the insula and frontal operculum, and posterior input to the PT and areas of the supramarginal and angular gyrus, as well as occipital lobe (Galaburda and Sanides, 1980; Carpenter and Sutin, 1983; Musiek, 1986a). In addition, there are connections with the inferior parietal lobe (Galaburda and Sanides, 1980; Carpenter and Sutin, 1983). Interhemispheric connections of HG are primarily via the posterior half of the corpus callosum with the majority of these being homolateral projections (Musiek, 1986b). Campain and Minkler (1976) reported that the total area of HG was slightly larger on the right, but no statistics were applied to this finding. Galaburda and Sanides (1980) studied the cytoarchitectonic organization of the auditory areas of the human cerebrum. These investigators demonstrated that there is considerable variability in left and right hemispheres of the auditory cortex. Total cytoarchitectonic volumes of the left and right auditory cortex regions were similar. Campain and Minkler (1976) reported more gyri on the right than left, and the number of HG ranged from one to three per hemisphere.

Given the paucity of data on the gross anatomic features of HG and composite studies focussing on the HG, SF, and PT, measurement of these structures in the human brain was undertaken.

METHOD

Human cerebrums were taken from 19 female and 14 male cadavers with a mean age of 79 years. Causes of death (as could be determined indirectly) were distributed among several general categories: cardiac and/or vascular disorder (15), cancer (7), respiratory arrest (6), pneumonia (2), brainstem hemorrhage (1), natural causes (1). In one additional specimen, death may have been caused by a form of dementia. Handedness was not determined. Four brains were discarded because of structural defects that would have affected accurate measurements. Replicated measurements were made using calipers, flexible rulers, and cloth tape measures. The SF measurement extended from the temporal crest (the juncture of the anterior ascending and posterior horizontal rami) to the posterior termination of the SF defined by the anterior margin of the supramarginal gyrus (Fig. 1). The PT was measured along the cortical surface from its anterior border, which is formed by Heschl's sulcus, to the end of the SF (Fig. 2). These two measurements were made with the cerebrum intact to permit better meas-

Figure 1 Measurement of the right Sylvian fissure along the outer and superior surface of the superior temporal gyrus (*arrow*). This measurement included the area from the temporal crest (*anterior*) to the anterior margin of the supramarginal gyrus.

Figure 2 Measurement of the left planum temporale (*arrow*).

urement of the contours along the SF and determination of the beginning and end points. Heschl's gyri were measured with the superior temporal plane and end points. Heschl's gyri were measured with the superior temporal plane exposed. Both the width of HG (from the anterior sulcus to the posterior sulcus of HG along the cortical surface) and length of HG (from the cortical surface at the midpoint of the width, along the midline of HG medioposteriorly to the cortex of the posterior insula) were measured (Fig. 3).

RESULTS

The statistical comparison of homologous structures on each side of the brain was accomplished using paired *t*-tests. The mean left SF length was significantly greater than the right ($p < 0.001$)(Fig. 4). This same trend of asymmetry was found for the PT ($p < 0.001$) and HG length ($p < 0.001$) (Figs. 5 and 6). However, the width of the HG was not significantly greater for the left side ($p < 0.057$) (Fig. 7). A test of statistical correlation was done to determine if the length of the PT was correlated with the length of the SF. For the left side the Pearson product correlation was 0.683 ($p < 0.0001$) while for the right side it was 0.636 ($p = 0.0002$), indicating a strong correlation.

The incidence of asymmetry between hemispheres in the four areas of the brains examined (PT, SF, HG width, HG length) was also determined. As seen in Figure 8 there was a left-sided predominance.

The final analysis compared the number of HG for the left and right hemispheres. The number of gyri (on either side) ranged from 1 to 3 but little asymmetry was noted (Table 1). In fact, 16 of the 29 brains examined had the same number of gyri on each side.

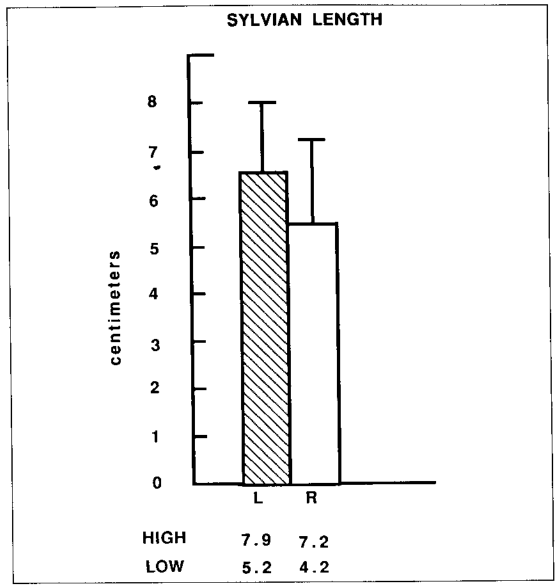

Figure 4 The mean length (in centimeters) of the left and right Sylvian fissures. The high and low numbers indicate the longest and shortest measurements obtained in our sample. (Vertical lines indicate 1SD.)

Figure 3 The length (*long arrow*) and width (*short arrow*) of this right Heschl's gyrus.

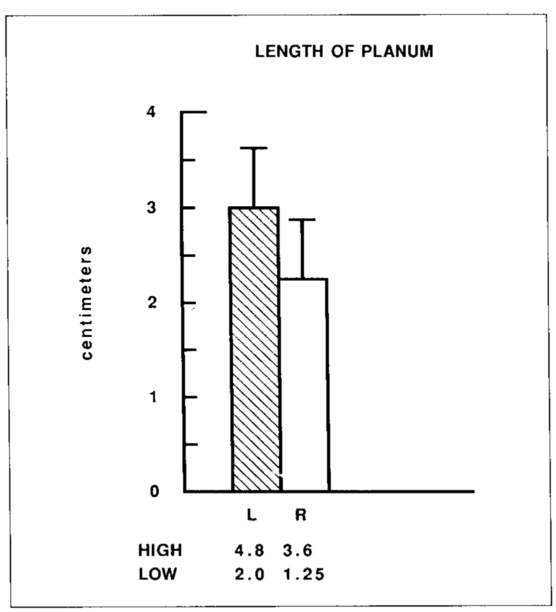

Figure 5 The mean length (in centimeters) of the left and right planum temporale. The high and low numbers indicate the longest and shortest measurements obtained in our sample.

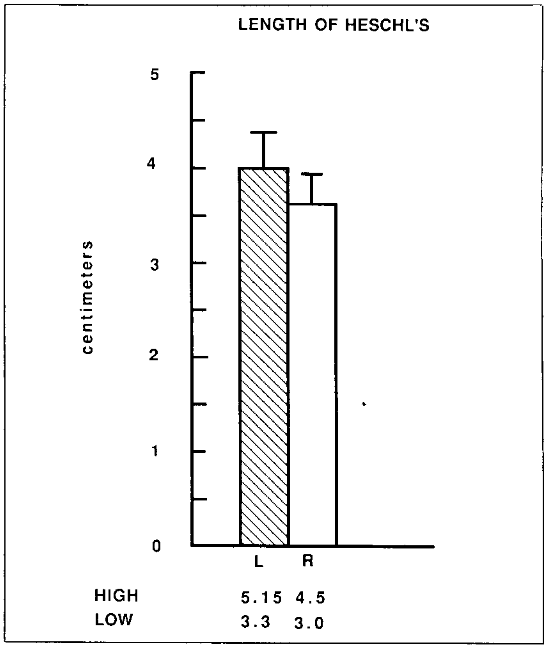

Figure 6 The mean length (in centimeters) of the left and right Heschl's gyri. The high and low numbers indicate the longest and shortest measurements obtained in our sample.

DISCUSSION

This composite study examined left-right asymmetries of the SF, PT, and HG in the human brain. As found with previous studies, the SF and PT were significantly longer on the left side in all specimens (von Economo et al, 1930; Connolly, 1950; Rubens, 1977). Our findings indicate that there is a relationship between the length of the SF and the length of the PT. Since our measurements of the SF included the PT it is difficult to say which one is influencing the other. However, if the mean PT length is subtracted from the mean SF length for each side, the remaining SF length is essentially the same for right and left hemispheres (3.18 cm, left; 3.21 cm, right). This would suggest that the SF asymmetry is attributable to the PT asymmetry. Earlier studies suggested that SF asymmetry was related to increased length beyond the central sulcus (Connolly, 1950; Shellshear, 1937), an area that includes the PT. Our findings are also consistent with those of Rubens et al (1976), suggesting that the slope of the left PT is in a more posterior direction than that of the right. This course of the PT makes it longer on the left side.

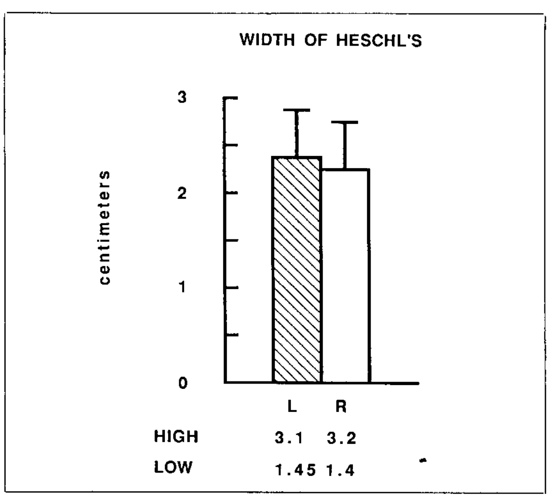

Figure 7 The mean width (in centimeters) of the left and right Heschl's gyri. The high and low numbers indicate the widest and narrowest measurements obtained in our sample.

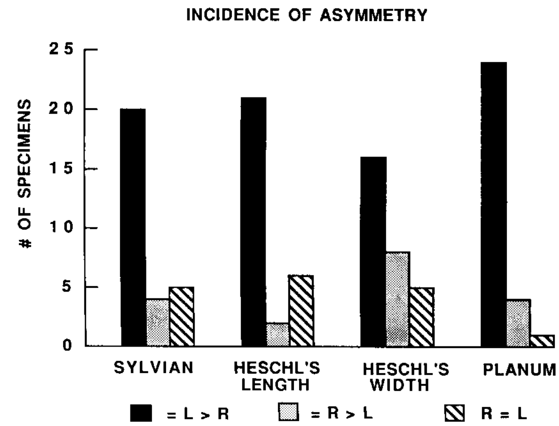

Figure 8 The incidence of asymmetries of the auditory areas of the brain specimens in this study.

The mean length of HG was also greater in the left hemisphere than in the right. The course of the HG runs in a lateromedial and anteroposterior direction. Since the HG proceeds along two planes, the length of the posterior SF as well as the lateromedial depth of the SF may be correlated with HG length.

Table 1 Number of Heschl's Gyri (n = 29)

Left Hemisphere	*Right Hemisphere*	*Number of Subjects*
1	1	5
1	2	6
2	1	7
2	2	10
3	3	1

Our present findings indicate that the SF and HG, as well as the PT, are all longer in the left hemisphere. Possible functional implications to this finding in the SF and HG include many of the same ones previously discussed in reference to the PT. For example, there is evidence that late auditory evoked potential amplitudes are greater over the left hemisphere than the right for verbal stimuli (Morrell and Salamy, 1971). It has also been reported that right ear (left hemisphere) acoustic stimulation results in a larger middle latency potential (Pa) than does left ear (right hemisphere) stimulation (Hood and Berlin, 1984). Since it is believed that the late and middle evoked potential responses may, at least in part, be generated by the primary auditory cortex (Vaughan and Ritter, 1969; Kaga et al, 1980), it seems possible that the asymmetry observed in these potentials may be related to asymmetries of HG and the PT.

The right ear advantage in dichotic listening for speech is well known (Kimura, 1961). It is inviting to speculate that these functional asymmetries are related to the probability that more "auditory substrate" exists with a larger HG and PT in the left hemisphere. Although this is certainly not the most prominent theory for the right ear advantage, the asymmetry in cortical and auditory pathways has been considered as a possible explanation (Sidtis, 1982).

The existence of morphologic differences between the hemispheres should be considered in any theory of cerebral dominance used to explain right/left differences in functional test results. "Dominance" differences cannot be attributed to brainstem pathways alone, given what we already know about the hemispheric differences (Harnad et al, 1977). The structural differences noted in the present study imply that the larger areas do have more neural substrate, more neurons, and more interconnection within hemispheres and between hemispheres. However, these anatomic differences are probably influential only in functional activities that involve types of binaural but not monaural listening. They may help explain differences between right and left ear performance some individuals exhibit on tests of dichotic listening.

It also could be speculated that the larger auditory anatomic structures on the left side of the brain provide a basis for a greater language development than the smaller anatomic areas on the right side of the brain. Thus, more people are left hemisphere dominant for language, and left hemisphere brain damage is much more likely to lead to aphasia.

The known variability in auditory evoked potential studies may be related to the great interspecimen variability noted in our measurements. Not only was there notable variability in the size of the reported structures, but morphologic differences in these structures from one brain to the next were striking. These findings could have implications in electrode placement for recording evoked potentials. For example, according to our findings a T-4 electrode placement at the same location on the scalp may not have the same underlying neural substrate in each individual. Also, a T-4 (right hemisphere) placement may not overlie the same area of a structure as a T-3 (left hemisphere) in the same individual. The underlying morphologic asymmetries may contribute to apparent electrophysiologic asymmetries between individuals and between hemispheres.

This concept gains support from a recent study by Steinmetz et al (1989). Using magnetic resonance (MR) scans, these investigators examined the accuracy of electrode placement (using the international 10-20 system) in reference to cortical structures. In this study variances between electrode site and its supposed corresponding anatomic site were as much as 4 cm in some subjects. The variances shown in the present study, as well as in the report by Steinmetz et al, could be factors contributing to the overall variability noted for the middle and late evoked and event-related potentials.

While agreeing with the classic findings of Geschwind and Levitsky (1968), in regard to PT asymmetry, we advocate further consideration of HG and PT in investigations of an anatomic basis for language or auditory functional asymmetries.

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