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LEFT HEMISPHERE SPECIALIZATION FOR LANGUAGE IN THE NEWBORN

NEUROANATOMICAL EVIDENCE OF ASYMMETRY

BY

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FUNCTIONAL asymmetry of the two cerebral hemispheres in man has been accepted for over a century. In contrast, until recently no anatomical asymmetries were found associated with the functional differences, although the assumption remained that perhaps some subtle structural asymmetry might exist related to the functional differentiation (Mountcastle, 1962). Recently Geschwind and Levitsky (1968) reported a gross left-right morphological asymmetry, observable by naked eye inspection, in the posterior region of the superior surface of the temporal lobe (planum temporale) which is part of the classical area of Wernicke known to be of significance for language function. In 65 per cent of their sample of adult brains, linear measurement of this region was greater on the left side. They suggested that the anatomical difference is of sufficient magnitude to be compatible with the functional asymmetry of the two hemispheres in mediating language.

It is not known at what time in ontogenetic development this anatomical asymmetry is first present. Such information would be relevant for the issue of the origin of the adult pattern of hemispheric functional asymmetry. It has been clearly shown that speech functions are lateralized in the left hemisphere in most adults regardless of hand preference (Branch, Milner and Rasmussen, 1964; Zangwill, 1967). The question remains whether this nonrandom pattern of hemispheric functional asymmetry results from biological pre-programming or environmental factors such as language learning or preferential hand usage.

Information as to the onset of the anatomical asymmetry would also be important for any theory about the role of innate biological factors underlying language acquisition. Recent behavioural studies in which infants as young as 4 weeks of age were observed to discriminate acoustic differences, specifically those across phonemic boundaries which are relevant for linguistic classifications and which are universal across cultures (Eimas, Siqueland, Jusczyk and Vigorito, 1971; Trehub and Rabinovitch, 1972), suggest that aspects of speech perception may be biologically pre-programmed at an unexpectedly early age.

The purpose of the present study was to examine the human temporal lobe for evidence of anatomical asymmetry in the neonatal period, when no learning related to language or unimanual hand preference has occurred. The specific hypothesis investigated was whether the area of the superior surface of the temporal lobe known to mediate language in the adult is larger in the left than in the right hemisphere in the human neonate.

METHOD

Adult and neonatal brains free from neurological pathology (causes of death identified at post-mortem for the neonates were categorized as cardiovascular, respiratory and gastro-intestinal diseases) were obtained at post-mortem and immersion-fixed in 5 to 10 per cent formalin. In order to expose the planum temporale in its entirety, the specimen was first stripped of its meninges. A horizontal section, superior and parallel to the lateral (Sylvian) sulcus, was then made across the frontal and parietal lobes so that the greater part of the "operculum" of the insula was removed, leaving behind the irregular gyri that abut on the lateral sulcus from above. These gyri were removed by separation and blunt dissection from the superior surface of the temporal lobe. Careful attention was paid to the removal of all overhanging gyri in order to define correctly the posterior limit of this surface. The dissection was carried out on each side in turn. The specimen was then photographed, posed carefully so that the superior temporal surfaces exposed by dissection lay horizontal.

Preliminary morphological inspection of some adult specimens in the present study indicated that the shape of the planum may vary considerably. For this reason it seemed possible that area measurement might be a more valid indicator of left-right asymmetries than the linear measurement used in the previous work of Geschwind and Levitsky (1968). Furthermore, the preliminary work indicated that the criteria for defining the landmarks of the planum are not always clear-cut. The previous work assumed, on the basis of the classical literature, that two transverse temporal gyri (that is, two Heschl gyri) may exist in the right but not in the left hemisphere, and the planum was accordingly defined as the superior temporal surface posterior to the first transverse gyrus on the left, but the surface posterior to the first or second (if present) transverse gyrus on the right. For comparability with the work of Geschwind and Levitsky (1968) the same assumptions were held in the present report for linear measurement, as well as for an additional set of area measurements of the planum temporale.

Unexpectedly, in the present study two Heschl gyri (defined as two transverse gyri each bounded posteriorly by a complete transverse fissure) were often encountered on the left side as well as on the right, contrary to tacit assumptions based on the classical literature. There is no reason to believe, however, that the primary auditory cortex (Heschl gyri) in the two hemispheres is anatomically asymmetrical. There is recent evidence that there is no consistent quantitative difference between the right and left cochlear nuclei (Konigsmark and Murphy, 1972). In view of these findings, it was thought that the criteria of the previous measurements create a bias in favour of a larger left planum. Thus a second set of area measurements was obtained in which the planum temporale was defined comparably for both hemispheres as the area posterior to the first transverse gyrus, or, when present, to the second transverse gyrus, regardless of the hemisphere involved (termed nonbiased measurements).

Area measurement was obtained by means of a planimeter and was defined as that value which occurred on at least two of three measurement trials for each area. No area differed more than 0·2 cm^2 between measurements. The linear measurement was defined as the distance between the most anterior and posterior points of the planum adjacent to the lateral edge.

Thirty specimens were measured: 16 were adult specimens and 14 were infants (which included 11 neonates) whose postnatal ages were 1, 1, 1, 2, 2, 6, 11, 13, 19 and 21 days and 1, 2, 3 and 3 months with a median age of 12 days.

Results

Table I presents the mean measurements for the planum temporale for the adult and neonatal specimen groups. Both the linear and the two area measurements indicated significantly larger planums in the left than in the right hemisphere for both

TABLE I.—MEASUREMENTS (CM) OF THE PLANUM TEMPORALE IN ADULTS AND NEONATES

Group	*n*		*Left* $\bar{X}$	*Left* *S.D.*	*Right* $\bar{X}$	*Right* *S.D.*	*t*	*% specimens larger on left*
Adults	16	linear	3·7	1·3	1·5	1·0	5.36†	81
		area	7·2	1·7	3·0	1·7	7·04†	94
		area (nonbiased)	4·8	3·2	3·0	1·7	1·88*	69
Neonates	14	linear	1·9	0·8	0·9	0·6	3·49†	86
		area	2·1	0·9	1·1	0·6	3·98†	86
		area (nonbiased)	1·9	0·7	1·1	0·6	3·89†	79

* $P<\cdot 05$ (one-tailed test). † $P<\cdot 005$ (one-tailed test).

the adult and neonatal groups. Fig. 1a (Plate LII) presents a typical neonatal specimen.

The correlations between linear and the first set of area measurements within each group for the left and right hemispheres respectively were highly significant: $r=0{\cdot}79$, and 0·93 (adult); and $r=0{\cdot}86$ and 0·82 (neonate). Analysis of the nonbiased area scores for each group indicated that the area of the left planum was reduced but was still significantly larger by approximately two-thirds than the comparable area on the right side.

Left-right differences of the planum were also examined for males and females separately in the neonatal group. For the females ($n=5$, age range: 2–21 da, $\bar{X}=8{\cdot}8$ da) the left planum was significantly larger than the right (mean nonbiased area measurements were 1·8 and 0·9 cm^2 respectively, $t=2{\cdot}75$; $P\doteq 0{\cdot}025$, one-tailed test). For the males ($n=9$, age range: 1–90 da, $\bar{X}=33{\cdot}8$ da) the left planum was again significantly larger than the right (mean non-biased area measurements were 1·9 and 1·2 cm^2, $t=2{\cdot}68$; $P<\cdot 025$, one-tailed test). However, the mean postnatal age for the males was greater than for the females. Therefore a subgroup of male specimens was selected to be comparable to the female group in age range ($n=5$, age range: 1–19 da, $\bar{X}=6{\cdot}6$ da). For this group of males the difference between the left and right planums was not significant (mean measurements were 1·5 and 0·8 cm^2 respectively, $t=1{\cdot}55$; $P\doteq\cdot 10$, one-tailed test).

It was also found that two Heschl gyri occurred with equal frequency (50 per cent) in the left and right hemispheres in the adult group, with the two gyri occurring equally often (25 per cent) in both hemispheres of the same brain, either hemisphere alone, or neither hemisphere. Fig. 1b presents an adult specimen with two Heschl gyri on each side. In the neonatal group, two Heschl gyri were found in the left and right hemispheres in two and five specimens respectively.

Discussion

Both the linear and area measurements of the planum temporale of the adult specimens indicated a marked anatomical asymmetry. The left planum was found to be significantly larger than the right. This asymmetry as gauged by linear measurement alone has been previously documented by Geschwind and Levitsky (1968). The correlation between linear and area measurements for each hemisphere was large, thus confirming the validity of the previous work using linear measurement to assess the size of the planum.

The absolute linear measurements as well as the measures of variation for the present sample of 16 adult specimens are remarkably similar to those for the 100 adult specimens studied by Geschwind and Levitsky. The findings of a consistent left-right anatomical asymmetry with the marked similarity in absolute size of left and right plana by independent workers in different settings indicate that despite the enormous variation in fissuration pattern in the human brain, the planum temporale is at least one cortical surface whose outer boundaries can be objectively defined and for which there is a consistent left-right asymmetry across individuals. That such consistent findings are observed in such a small sample (n=16) attests to the reliability of the anatomical asymmetry. Moreover, since the asymmetry occurs in an area of relevance to language function and in the direction compatible with known functional asymmetry for language, the anatomical data have considerable behavioural implications.

The anatomical asymmetry between left and right plana was also found in the neonatal specimens on all measurements taken. The size of the left-right difference in the neonates was proportionately at least as large as that in the adult sample. A possible sex difference in left-right asymmetry of the planum in neonates was also observed. The anatomical difference was not as marked for males as for females within the first few days of life. These results are consistent with other reports indicating a similar sex difference in language development (McCarthy, 1954) and in hemispheric lateralization of language (Kimura, 1967).

Origin of Adult Pattern of Lateralization of Language Functions

The anatomical data indicate that the human infant is born with or develops very soon after birth a larger area in the left hemisphere in a region known to be of significance for language function. It is suggested that this anatomical asymmetry precedes any learning effects, since the postnatal age of the infants precluded little if any environmental experiences, such as language acquisition or preferred hand usage. It is further suggested that the observed neonatal anatomical asymmetry provides a structural basis for the adult pattern of lateralization of language functions and it is such biological structures, rather than experiential factors, which are the determining factors in predisposing the left hemisphere to become the major hemisphere in mediating language functions.

The present data do not support an environmental explanation of the predominance of left hemisphere speech lateralization in adults, such as that of Gazzaniga (1970) which attributes importance to experiences resulting from unimanual hand preference. He suggests that the left hemisphere is usually the more important in mediating language function as a result of early right-hand preference in environmental exploration and of correspondingly greater information processing by the left hemisphere early in life when interhemispheric connexions are thought to be nonfunctional. The fact that most left-handed as well as right-handed individuals have speech functions represented in only the left hemisphere (Branch, Milner and Rasmussen, 1964) also makes it unlikely that hand preference *per se* can account for the lateralization pattern of speech function.

It is possible that it is hand preference which is guided to some degree by the anatomical bias. Previous interpretation (Geschwind and Levitsky, 1968) of anatomical asymmetry in relation to manual preference was based on an estimate of 93 per cent incidence of right-handedness in the general population, but a recent study (Annett, 1967) reports that the incidence of individuals with consistent right-hand preference (that is, all unimanual tasks performed consistently with the right hand) is about 70 per cent, although the incidence including all dextrals (consistent and mixed or ambidextrous) is about 96 per cent. The frequency of a larger left planum (based on nonbiased area measurements) in both the adult and neonatal groups in the present report approximates the estimate of the incidence of consistent dextrals. This suggestion of an association between hand preference and anatomical asymmetry must remain tentative, however, in view of the small sample size and the uncertainty as to the particular measurement of the planum which best reflects the relationship between structure and function.

It is estimated that the incidence of unilateral left-sided speech lateralization in the general population is about 85 per cent, calculated as follows: approximately 95 per cent of consistent right-handed individuals, considered to be 70 per cent of the general population, have speech represented in the left hemisphere, and approximately 65 per cent of left-handed and ambidextrous individuals with no clinical evidence of early left-sided brain damage, considered to be 30 per cent of the population, have speech represented in only the left hemisphere (Branch, Milner and Rasmussen, 1964). This estimate of 85 per cent incidence of unilateral left-sided speech lateralization in the general population is not entirely matched by either the estimate of 70 per cent incidence of consistent dextrals or of 70 per cent incidence of a larger left planum temporale, which suggests the possible role of yet another variable related to the lateralization of language function.

Biological Basis for Language Development

The anatomical asymmetry found in neonates favouring a left temporal lobe area of known significance for the reception of language in adults supports the hypothesis that the human newborn has a pre-programmed biological capacity to process speech sounds. The superior surface of the left temporal lobe of the neonate may be at least part of the neuro-anatomical substrate for the recently documented ability (e.g. Eimas *et al.*) of neonates to discriminate speech sounds along adult phonemic categories at an age when little, if any, learning has been possible.

Anatomical asymmetry in language areas is clearly present at an age when bilateral representation and hemispheric transferability of speech are still present (Basser, 1962; Rasmussen, 1964), but the upper limits of language acquisition by the right hemisphere after early left hemisphere damage have yet to be defined (Lansdell, 1969). They may prove to be limited through the absence of a pre-programmed anatomical structure in the right hemisphere which is specific to the left.

SUMMARY

Anatomical measurements of the language-mediating area of the superior surface of the temporal lobe (planum temporale) were obtained for the left and right hemispheres for a group of 14 neonatal and 16 adult human brain specimens. It was found that the left-sided area was statistically significantly larger in the neonate, as in the adults. It is suggested that this anatomical asymmetry is present before any environmental effects such as language learning and unimanual preference and may be an important factor in determining the typical pattern of left hemisphere speech lateralization found in most adults. Furthermore, it is suggested that this neonatal asymmetry indicates that the infant is born with a pre-programmed biological capacity to process speech sounds.

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REFERENCES

ANNETT, M. (1967) The binomial distribution of right, mixed and left handedness. *Q. Jl exp. Psychol.*, **19**, 327–333.

BASSER, L. S. (1962) Hemiplegia of early onset and the faculty of speech with special reference to the effects of hemispherectomy. *Brain*, **85**, 427–460.

BRANCH, C., MILNER, B., and RASMUSSEN, T. (1964) Intracarotid sodium amytal for the lateralization of cerebral speech dominance. *J. Neurosurg.*, **21**, 399–405.

EIMAS, P. D., SIQUELAND, E. R., JUSCZYK, P., and VIGORITO, J. (1971) Speech perception in infants. *Science, N.Y.*, **171**, 303–306.

GAZZANIGA, M. S. (1970) "The Bisected Brain." New York: Appleton.

GESCHWIND, N., and LEVITSKY, W. (1968) Human brain: left-right asymmetries in temporal speech region. *Science, N.Y.*, **161**, 186–187.

KIMURA, D. (1967) Functional asymmetry of the brain in dichotic listening. *Cortex*, **3**, 163–178.

KONIGSMARK, B. W., and MURPHY, E. A. (1972) Volume of the ventral cochlear nucleus in man: its relationship to neuronal population and age. *J. Neuropath. exp. Neurol.*, **31**, 304–316.

LANSDELL, H. (1969) Verbal and nonverbal factors in right-hemisphere speech: relation to early neurological history. *J. comp. physiol. Psychol.*, **69**, 734–738.

MCCARTHY, D. (1954) Language development in children. *In:* "Manual of Child Psychology." Edited by L. Carmichael. New York: John Wiley. Pp. 492–630.

MOUNTCASTLE, V. B., Editor (1962) "Interhemispheric Relations and Cerebral Dominance." Baltimore: Johns Hopkins Press.

RASMUSSEN, T. (1964) Discussion on the current status of cerebral dominance. *Res. Publs Ass. Res. nerv. ment. Dis.*, **42**, 113–115.

TREHUB, S. E., and RABINOVITCH, M. S. (1972) Auditory-linguistic sensitivity in early infancy. *Devl Psychol.*, **6**, 74–77.

ZANGWILL, O. L. (1967) Speech and the minor hemisphere. *Acta neurol. psychiat. belg.*, **67**, 1013–1020.

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PLATE LII

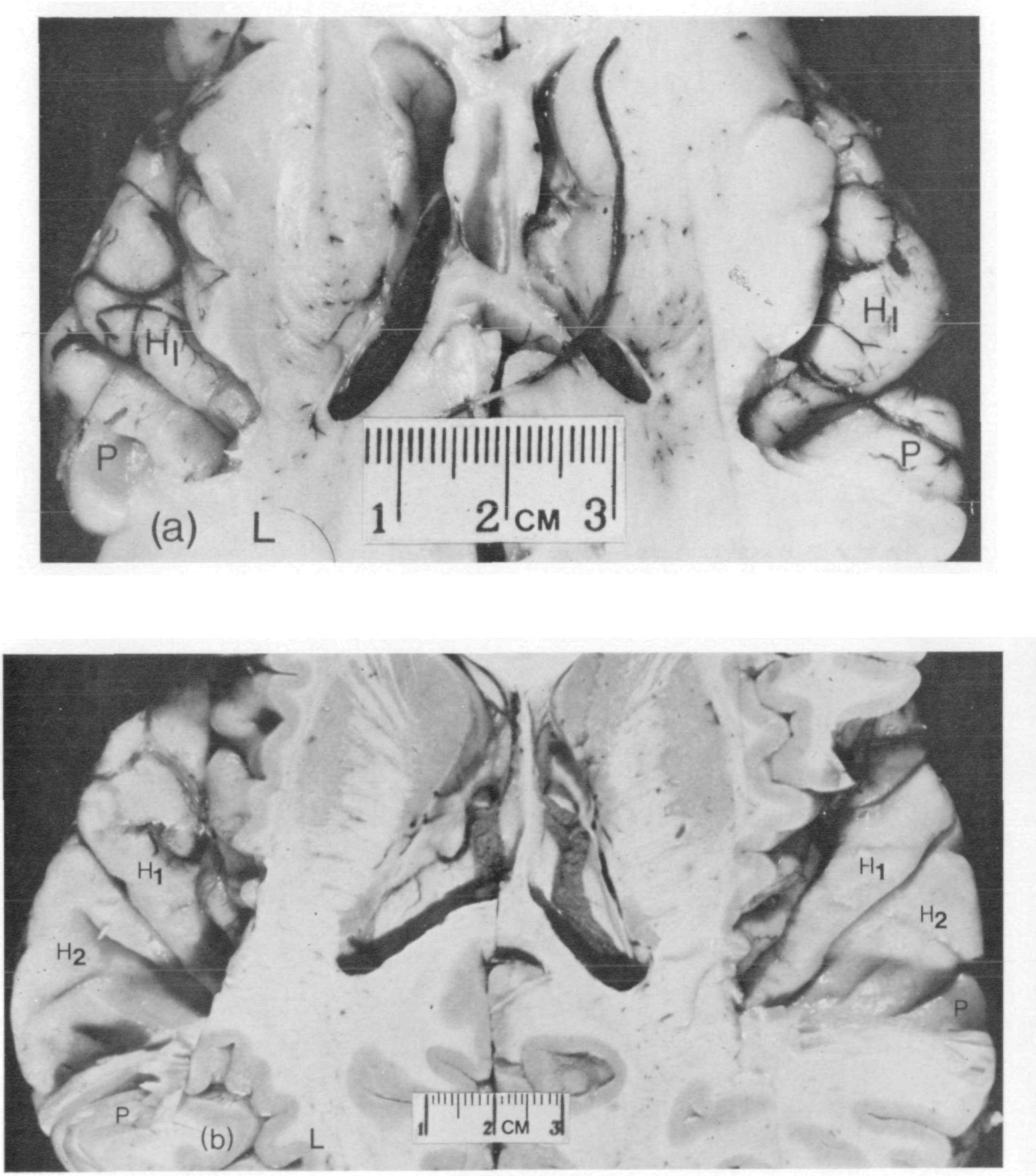

FIG. 1.—Exposed surface of superior temporal lobe: (a), a 2-day-old infant, (b) an adult. P, planum; H_1, first Heschl gyrus; H_2, second Heschl gyrus; L, left hemisphere.

To illustrate article by Sandra F. Witelson and Wazir Pallie.