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1 May 1968

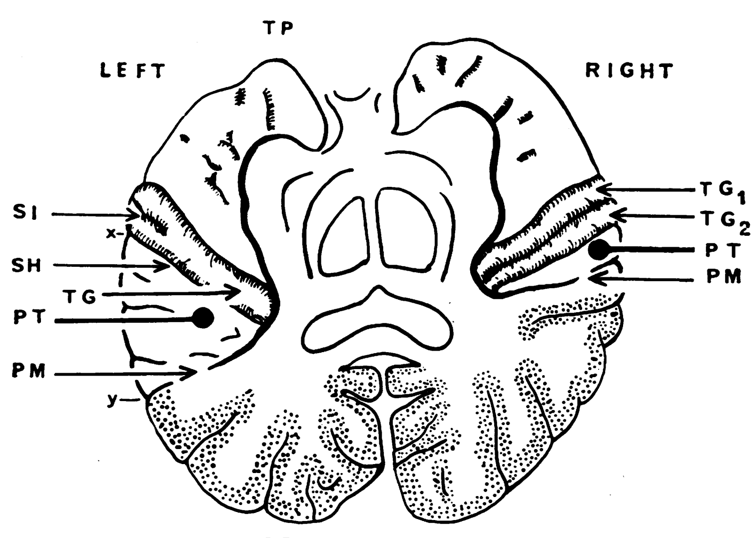
Human Brain: Left-Right Asymmetries in Temporal Speech Region

Abstract. *We have found marked anatomical asymmetries between the upper surfaces of the human right and left temporal lobes. The planum temporale (the area behind Heschl's gyrus) is larger on the left in 65 percent of brains; on the right it is larger in only 11 percent. The left planum is on the average one-third longer than the right planum. This area makes up part of the temporal speech cortex, whose importance is well established on the basis of both anatomical findings in aphasic patients and cortical stimulation at operation.*

It is generally accepted that the preponderance of the human left hemisphere in speech functions is not associated with significant structural differences between the two halves of the brain (*1*). We reinvestigated this problem on an extensive sample and found highly significant differences between the left and right hemispheres in an area known to be of significance in language functions.

Our material consisted of 100 adult human brains, obtained at postmortem, and free of significant pathology (*2*). The hemispheres were divided, and then the upper surface of the temporal lobe (supratemporal plane) was exposed on each side by a cut made in the plane of the Sylvian fissure. Figure 1, a drawing of a typical specimen, illustrates the anatomical landmarks. Figure 2 is a photograph of a specimen which demonstrates the typical left-right asymmetries. The posterior border of the planum temporale slopes backward more sharply on the left, while the anterior border of the planum (formed by the sulcus of Heschl) slopes forward more sharply on the left; both effects combine to produce a larger planum temporale on the left. A sharper backward slope was found on the left in 57 percent and on the right in 18 percent ($P < .001$), with equality on the two sides in 25 percent of the brains examined. A sharper anterior slope was found on the left in 40 percent and on the right in 24 percent ($P < .05$), with equality in 36 percent. The planum temporale was larger on the left in 65 percent and on the right in 11 percent ($P < .001$), with equality in 24 percent of our specimens.

The length of the outer border of the planum temporale (*x–y*, Fig. 1) was 3.6 ± 1.0 cm on the left and 2.7 ± 1.2 cm on the right ($P < .001$); the planum was 0.9 cm or one-third longer on the left than on the right. These measurements are compatible with observations (*1, 3*) that the left Sylvian fissure in man is on the average longer than the right. Our data show that this difference is accounted for by the increased length of the left planum tem-



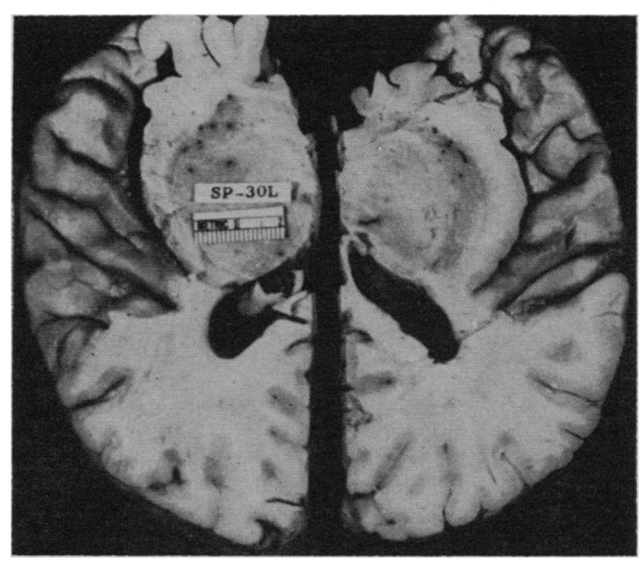


Fig. 1 (left). Upper surfaces of human temporal lobes exposed by a cut on each side in the plane of the Sylvian fissure; anatomical landmarks and typical left-right differences are shown. The posterior margin (*PM*) of the planum temporale (*PT*) slopes backward more sharply on the left than on the right, so that end *y* of the left Sylvian fissure lies posterior to the corresponding point on the right. The anterior margin of the planum formed by the sulcus of Heschl (*SH*) slopes forward more sharply on the left. In this brain there is a single transverse gyrus of Heschl (*TG*) on the left, but two on the right (TG_1, TG_2). *TP*, Temporal pole; *OP*, occipital pole; *SI*, sulcus intermedius of Beck. Fig. 2 (right). Upper surfaces of temporal lobes exhibit typical right-left differences. Sharper backward slope of posterior margin and sharper forward slope of anterior margin of planum temporale on the left, larger planum on the left, and longer outer border of left planum are evident.

porale. Handedness data were, for reasons beyond our control, not available to us. Since, however, about 93 percent of the adult population are right-handed, while 96 percent are left-brained for speech, our 100 cases must have consisted overwhelmingly of subjects that were left-brain dominant for speech. It would of course be most useful to study the patterns found in the brains of right-hemisphere-dominant subjects.

These studies support earlier assertions (*4–6*), in studies lacking quantitative data or based on small samples, that the supratemporal plane showed marked right-left asymmetries in man. Pfeifer (*5*) and von Economo and Horn (*6*) found by contrast no asymmetries in the same region in anthropoid apes.

While Heschl's gyrus contains the primary auditory cortex (*TC*) the planum temporale contains auditory association cortex (areas *TB* and *TA*) (*6*) which extends on to the lateral surface of the posterior portion of the first temporal gyrus. These regions of auditory association cortex on the left constitute the classical Wernicke's area, a region known from anatomical findings in aphasic patients (*7*) and from stimulation studies during neurosurgical procedures (*8*) to be of major importance in language functions. Our data show that this area is significantly larger on the left side, and the differences observed are easily of sufficient magnitude to be compatible with the known functional asymmetries (*9*).

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Eye Tracking of Observer-Generated Target Movements

Abstract. *When an observer moves his arm he shows more precise visual tracking of a target mounted on his fingertip—the eye lags behind the target less and makes fewer corrective saccades—than when he relaxes his arm and the experimenter moves it in a similar manner. Apparently the control system for eye movements can use outflow (efferent) signals in order to anticipate motion of the self-moved target.*

When an observer attempts to keep his line of sight fixed on a moving target, his eyes perform tracking movements. The eye can remain on target with little or no lag when the target moves periodically at a low frequency (*1, 2*). If motion of the target is made aperiodic, its "predictability" decreases and tracking performance deteriorates, as indicated by increasing lag between orientation of the eye and direction of target. These results have been found with targets that move independently of control by the observer. The tracking of targets that are moved by the observer himself has not hitherto been examined, although one might expect that any additional information about target motion would aid tracking. We now report results indicating that the observer can more accurately track a target that he moves himself than a target that is moved without his control.

In order to compare the accuracy of tracking self-produced target motion with that of independent motion, the observer tracked a spot on his own finger under two conditions: (i) when he himself moved his arm in an irregular manner (hereafter called the active condition), and (ii) when his relaxed arm was moved in a similar manner by an external force (passive condition). The movements of both eye and target were recorded during the two conditions of target motion. In both cases, the displacements and rates of movement of the arm were comparable, but only in the case of observer-produced movement was there additional information available and potentially useful to the oculomotor control system for tracking, namely the efferent or outflow signals to the musculature present with all voluntary movements (*3*).

The target was a 2-mm square of black tape fastened on the fingernail of the third finger of the right hand of the observer. His right arm rested on a flat lever, pivoted near the elbow, restricting movement of the target to an arc in a frontal plane 30.5 cm from the cornea of the right eye. Movement of the target was limited to 10 degrees (in visual angle) to the right and left of the observer's midsagittal plane. Registration of arm (and therefore target) position was provided by a potentiometer geared to the pivot of the lever. Horizontal eye movements were recorded using a photoelectric technique yielding measurements accurate, in this instance, to one-half degree of horizontal displacement of the eye (*2*). The observer's head was held in position by having him bite a bar holding a wax dental impression. Although he viewed his right hand binocularly, the horizontal movements of only the right eye were recorded.

Four male and two female students and employees at Massachusetts Institute of Technology were used as observers in the study. Their ages ranged from 19 to 33 years. The visual acuity of all observers was sufficient to perform the task without corrective lenses. In the active condition, the observer was instructed to look at the black square of tape on his fingertip and to follow it as best he could while rapidly moving his hand back and forth at an irregular rate of approximately three to four reversals of direction per second within the 20-degree range of travel of the lever. In the passive condition, the observer relaxed his arm on the lever, allowing the experimenter to move the arm through a pattern of displacements similar to the one the observer used in the active condition. The observer was again instructed to look at the target at all times. Arm (target) position and eye position were recorded simultaneously on two channels of a Sanborn recorder, operating at a paper speed of 100 mm/sec. Only the data from observers whose movements in the active condition were very similar to their movements in the passive condition (determined by counting the number of direction reversals and checking average amplitude during the first 15 seconds of recording) were kept for analysis.

Figure 1 shows a typical record of hand and eye movements under active and passive conditions. For each condition the target (hand) record is on top, and maximum peak-to-trough