

45 • LANGUAGE AND THE BRAIN

The human brain consists of several anatomically distinct regions. The largest part is the *cerebrum*, which is divided into two great lobes of similar size – the left and right *cerebral hemispheres*. The hemispheres are connected to the spinal cord by the *brain stem*, which consists of the *mid-brain*, the *pons*, and the *medulla oblongata*. At the back of the pons is the *cerebellum*, which is responsible for the maintenance of body posture and the smooth coordination of all movements.

Most research has focused on the structure and function of the cerebrum, especially on its surface layer of grey matter (nerve cells), the cerebral *cortex*, which is the area primarily involved in the control of voluntary movement and intellectual functions, and in the decoding of information from the senses. Beneath the cortex is a body of white matter (fibre tracts), which transmits signals between the different parts of each hemisphere, and between the cortex and the brain stem. A notable feature is that the surface of the cortex is not smooth, but has folded in on itself, to produce a series of *convolutions*, or *gyri*, which are separated by *fissures*, or *sulci*.

The figure below shows the main anatomical features. Seen from above (a), the main feature is the *median longitudinal fissure* separating the hemispheres. It does not extend the whole way through the cerebrum: lower down, the hemispheres are joined by a thick bundle of nerve fibres, the *corpus callosum*. This is the means whereby information can be transmitted from one hemisphere to the other. Seen from the side (b), the main features are the *central sulcus* (the *fissure of Rolando*) and the *lateral sulcus* (the *Sylvian fissure*), which are used as criteria for dividing the brain into its four main lobes: *frontal*, *temporal*, *parietal*, and *occipital*.

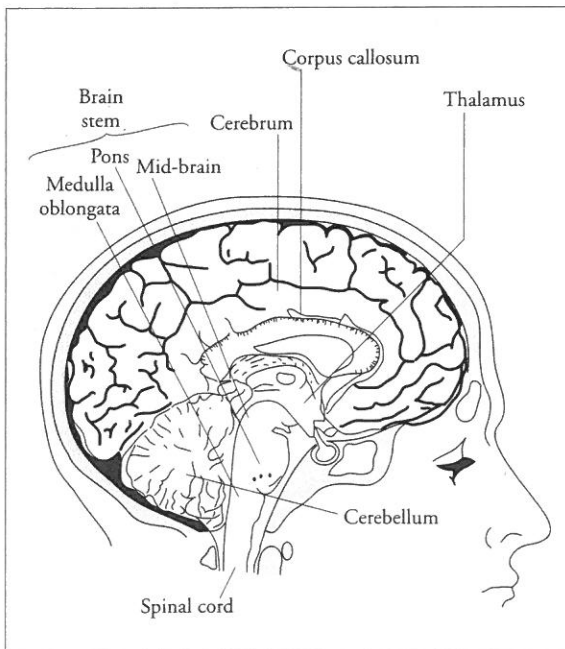
One other important anatomical fact needs to be borne in mind when discussing brain functions: each hemisphere controls movement in and receives sensory input from the *opposite* side of the body. Many nerve fibres from the two hemispheres cross each other as they descend through the brain stem, so that the left hemisphere controls the movement of the right side of the body, and vice versa. That is why brain damage to one hemisphere is usually correlated with bodily effects (such as paralysis) on the opposite side. In the case of the ears, signals from each ear go to *both* hemispheres, but most information is transmitted to the opposite side – a fact that has led to an important technique for investigating brain function (p. 261). In the case of the eyes, the situation is yet more complex: the left half of the visual field of *each eye* transmits informa-

tion to the right hemisphere, and vice versa. Such sophisticated 'wiring', it has been suggested, enables us to make many more qualitative judgments about sounds and images (e.g. about their distance and location) than might otherwise be possible.

DOMINANCE

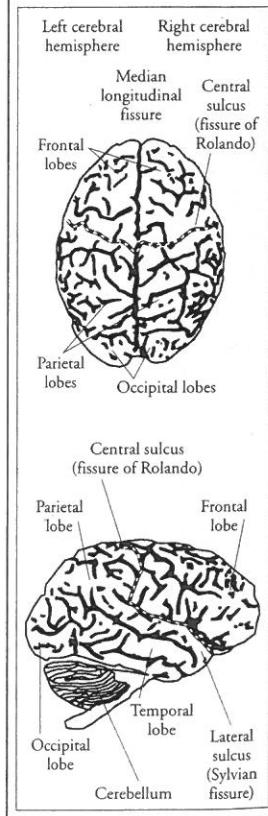
The functional relationship between the brain's two hemispheres has for over a century been a major focus of research in neuropsychology and clinical neurology. For some time, it was thought that one hemisphere (the left, in most people) was superior to the other in the control of most activities. Today, it is recognized that each has its own role, being more involved in the performance of some activities and less involved in others. A hemisphere is thus said to be the 'dominant' or 'leading' one for certain mental functions. The development of these functions within one or the other hemisphere is known as 'lateralization'.

Language and handedness have long been the two major factors in any discussion of cerebral dominance. The left hemisphere is dominant for language in most right-handed people (estimates are usually over 95%). This is most noticeable in cases of *aphasia* (p. 272), where damage to the left side of the brain may cause both language handicap and a right-sided paralysis. However, the



Below left: A section through the brain, showing the main anatomical areas.

Below: The brain seen from (top) above and (bottom) the side, showing the cerebral hemispheres and the four main lobes



FINDING OUT ABOUT DOMINANCE

Brain abnormalities

- The traditional approach, used since the first systematic work on aphasia (p. 272) in the mid-19th century, is to identify the location of a specific area of brain damage (a 'lesion'), and see whether behaviour has been affected in any predictable way.
- It is sometimes necessary to remove the whole cortical area of a diseased hemisphere ('hemispherectomy'). The effects on behaviour can then be observed.
- It is possible to observe what happens to behaviour while one hemisphere is temporarily anaesthetized. The usual technique, often used before brain surgery, is to inject sodium-amytal into one of the carotid arteries (the 'Wada' technique); this

paralyses a hemisphere for 2–3 minutes, during which time some of the patient's language or other abilities can be tested.

- A great deal of information has been obtained from the results of surgery which may be carried out in cases of severe epilepsy. The hemispheres are separated at the corpus callosum ('commissurotomy'). This enables the role of each side of the brain to be studied independently – the 'split brain' experiments.

These studies have shown that there are no major changes in intellect, personality, or everyday behaviour following the operation, but deficits are found in the ability of the two hemispheres to integrate their activities. The effect on language use is par-

ticularly dramatic. For example, when an object is presented to the right visual half-field, (right-handed) patients can talk about it: the visual information is relayed to the left hemisphere, where speech processing takes place. However, if the same object is presented to the left visual half-field, patients will be unable to talk about it, even though they have seen it: the visual information has gone to the right hemisphere, where no speech processing takes place.

Monitoring

- An established approach ('electroencephalography' (EEG)) uses electrodes placed on the surface of the scalp to monitor continuous cortical electricity activity – in particular, the amount of 'alpha' rhythm in the brain waves, which is reduced when an area of the brain is in active use.

- A related technique (the 'averaged evoked response') uses electrodes to monitor the activity in an area of the brain in response to repeated presentations of a stimulus.
- Techniques are also now available to monitor neuronal activity by observing changes in metabolic rate

within a hemisphere. In particular, increases in cortical blood flow can be measured through radioactive tracers. There are also ways of showing different kinds of chemical action and temperature changes (p. 262).

- An area of the normal brain can be electrically stimulated, to see what effect this has on behaviour. This approach has mainly been used to establish areas of motor and sensory control (p. 262).

Experiments

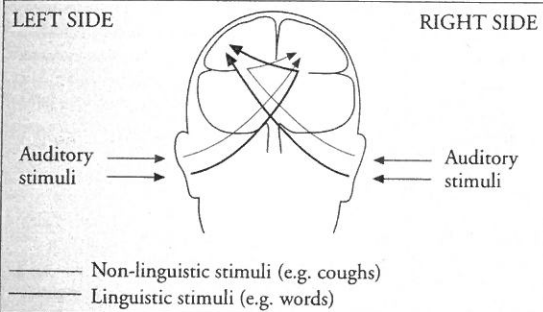
The role of each hemisphere in processing a stimulus can be inferred from the different time it takes a person to react when stimuli are presented to each side of the body. In a 'dichotic listening' task, for example, different stimuli are simultaneously presented to each ear, and the subject has to report what is heard. When the signals to one ear prove to be more accurately or rapidly reported, it is concluded that the opposite hemisphere is more involved in their processing. In this way, for instance, a general right-ear advantage has been shown for linguistic signals, and a left-ear advantage for non-verbal signals, such as music

and environmental sounds.

Problems

These approaches present many problems of principle and method. Although the imaging techniques now used in clinical neurology are a great step forward, they still convey very limited information about brain function. It is not always possible to be precise about the location of a lesion, which in any case is not usually a neatly defined area. Moreover, there is always a problem in generalizing from the performance of a diseased brain to that of a normal brain.

Studies using healthy brains also pose difficulties. There are problems with reaction-time experiments, where it is necessary to match competing stimuli in a very accurate way, and to control variations in subjects' responses (due to such factors as shifting attention). Also, the detailed data provided by monitoring devices (such as EEG) can as yet be given only a very general interpretation. However, technical progress, and associated computational analysis, suggest a promising future in this area.



The routes between ears and hemispheres, as shown by dichotic listening tasks.

relationship is not a symmetrical one: it does not automatically follow that the right hemisphere is dominant for language in left-handed people. Left-handers are by no means a homogeneous group, and in over 60% of cases the left hemisphere is either dominant for language or very much involved ('mixed' dominance). A pattern of mixed dominance throughout the body (for example, a person may be right-handed, left-footed, and right-eyed), further complicates the investigation.

The specialized intellectual functions of each hemisphere, and their neurophysiological bases, are only partly understood. There are important anatomical asymmetries between the hemispheres (for example, there are differences in the length and orientation of the Sylvian fissure, and there is often a larger left temporal plane (part of the temporal lobe)); but it is unclear how these relate to functional specializations. However, on the basis of various kinds of experimental and clinical evidence, several generalizations have been made. With right-handed people, the left hemisphere is found to be dominant in such activities as analytical tasks, categorization, calculation, logical organization, information sequencing, complex motor functions, and language.

The right is said to be dominant for the perception and matching of global patterns, part-whole relationships, spatial orientation, creative sensibility, musical patterns, and emotional expression or recognition.

These identifications must be made cautiously, avoiding an oversimplified contrast – such as is found when people talk about the left hemisphere as the 'analytic' or 'intellectual' part of the brain, and the right as the 'creative' or 'emotional' part. It is now known, for example, that the right hemisphere can handle certain nonverbal tasks that require intellectual capacity (such as spatial judgment), and that there is a limited capability for auditory analysis and comprehension. Moreover, it must not be forgotten that there are several activities that usually involve *both* hemispheres (such as face recognition, and the factors involved in attention and fatigue) – a fact that is currently attracting a great deal of research as scholars focus on the brain's integrating (rather than the lateralized) abilities. As with the studies of localization (p. 262), therefore, statements about the relationship between anatomical form and intellectual function, given our present state of knowledge, must remain extremely tentative.

LOCALIZATION

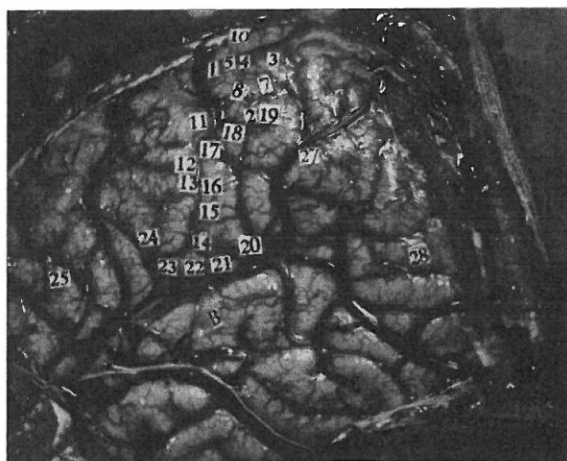
The idea that a single area of the brain can be related to a single behavioural ability, such as vision or speech, is known as the theory of cerebral 'localization'. Support for the theory came from the work of such neurologists as Paul Pierre Broca (1824–80) and Carl Wernicke (1848–1905), who had found that damage to specific areas of the brain correlated with the loss of certain kinds of linguistic ability in their patients (aphasia, p. 272). Damage to 'Broca's area' resulted in a reduced ability to speak, though comprehension remained relatively unimpaired. Damage to 'Wernicke's area' resulted in a reduced ability to comprehend speech, though the ability to speak was relatively unaffected.

From the outset, the theory was hotly contested by those who felt that other areas of the brain were involved in language processing. Several kinds of evidence were felt to go against a strict localizationist theory. Patients were found with apparently similar lesions, yet with very different linguistic abilities; and, conversely, similar linguistic difficulties could apparently result from lesions in widely different areas. There are now cases on record of patients whose Broca's and Wernicke's areas were unaffected by lesions, but whose linguistic ability was nonetheless seriously impaired; and conversely, there are cases of patients who have even had Broca's area surgically removed in both hemispheres, and who were still able to speak.

New techniques of neuroimaging (p. 261) have brought to light many such counter-examples to the localization hypothesis. When we add to this the facts that other symptoms (especially of a psychological kind) can result from so-called 'linguistic' lesions, and that it has so far been impossible to define specific brain areas in a precise way, we can readily understand such comments as that made by the British neurologist, John Hughlings Jackson (1835–1911): 'to locate the damage which destroys speech, and to locate speech, are two different things'. There may be many points within the neuronal network that, if damaged, could have the same effect on a person's linguistic processing ability. It does not much matter whether a telephone fault exists in the hand-set, along the line, or in the telephone exchange: the resulting deathly silence in the receiver is the same.

There is now little doubt that several other areas of the brain apart from the cortex are involved in linguistic processing. Neurolinguists and neuropsychologists postulate several kinds of subcortical connection, as well as connections between the hemispheres. The areas marginal to the classically located ones are of particular interest, in this respect; but research is also focusing on other parts of the brain, such as other parts of the frontal lobes, and the thalamus (p. 260). However, this direction of research does not support a theory of opposite extremes – that there is no localization at all in the brain, and that every region is equally involved in all activities (a theory of 'equipotentiality').

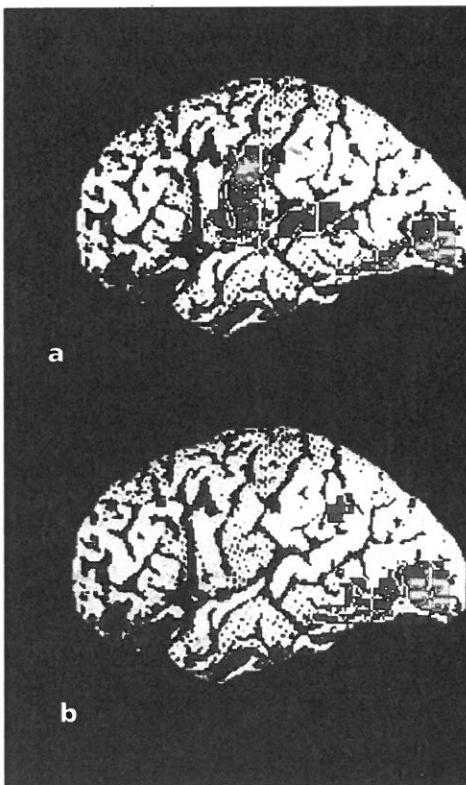
Despite the many exceptions, in the vast majority of cases where linguistic symptoms have been the result of brain damage, the lesion is in or around the areas originally identified by Broca and Wernicke. It seems that there may well be primary areas after all, but these have to be seen in the context of the brain as a whole, with other areas making a contribution to language skills. Determining the relationships between these areas is now a major goal of neurolinguistic research.



MAPPING THE CORTEX

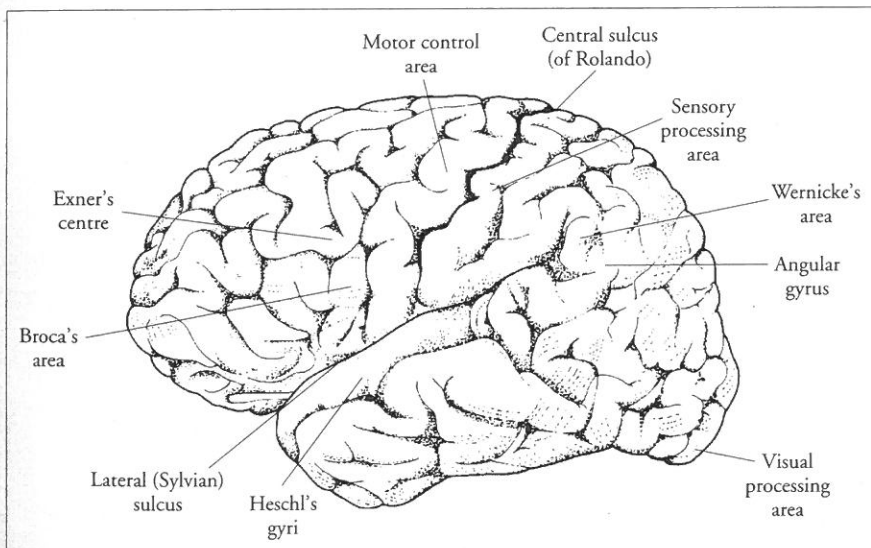
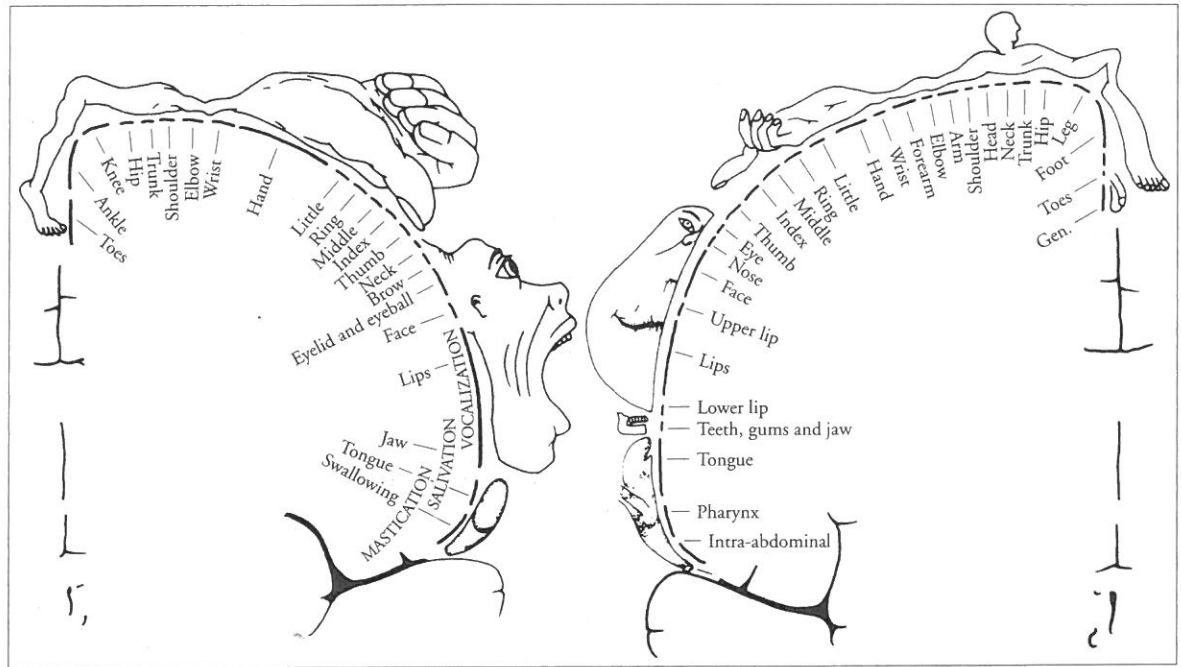
The task of mapping the areas of the cortex involved in body activities was undertaken by a team of neurosurgeons in Montreal during the 1950s. Relationships were discovered by electrically stimulating different parts of the exposed brain in epileptic patients, in order to find out which areas were involved in seizures before proceeding to surgery. The brain contains no pain receptors, so the patients were not anaesthetized and could thus report their mental and physical sensations (such as a tingling sensation or a memory of some event). Muscle contractions at various points in the body could also be observed, as could sudden involuntary vocalizations and inabilities to speak.

The photograph shows the left hemisphere of a patient's brain with the places marked where responses were obtained. Most of the effects on language were disruptive. Stimulation of points 23 and 24 halted the patient's ability to articulate or caused speech to be slurred. Symptoms similar to aphasia resulted when points 26, 27, and 28 were stimulated. (From W. G. Penfield & L. Roberts, 1959.)



Cortical blood flow Two positron emission tomography scans of the left hemisphere, showing cerebral blood flow as active areas (colour-coded green and yellow). A tiny amount of a special chemical (^{133}Xe) is injected into the carotid artery, and the gamma radiation monitored. The distribution of blood is related to the activity of the nerve cells in different regions of the cortex. In (a) the subject is reading aloud. The main active areas of the brain are the visual cortex (green at right), the areas involved in speech production, including Broca's area (green at left), and the auditory area (green at centre), as the subject hears his own voice. In (b) the subject is reading silently. The only areas noticeably involved are to do with visual processing (green at right) and comprehension (green at left).

The homunculi Many of the results of this research were summarized in the shape of two 'homunculi' – a human form, drawn against the shape of the outer surface of the brain, in which the size of the parts of the body is made proportional to the extent of the brain area involved in their control. The large area of the brain devoted to the motor control of the vocal organs and the hand is clearly seen in the drawing of the 'motor homunculus' (right). A similar drawing was made to show the areas which receive input from the senses – the 'sensory homunculus' (far right). Once again, the large area devoted to the hands and vocal tract should be noted. (From W. G. Penfield & L. Roberts, 1959.)



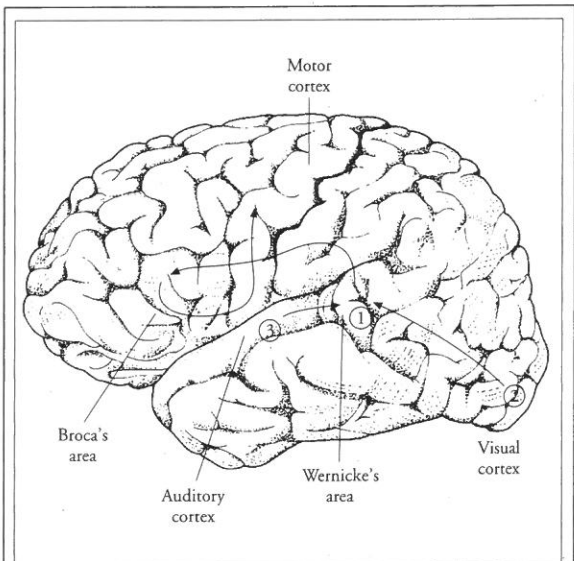
LANGUAGE AREAS

The areas which have been proposed for the processing of speaking, listening, reading, writing, and signing are mainly located at or around the Sylvian and Rolandic fissures (p. 260). Several specific areas have been identified.

- The front part of the parietal lobe, along the fissure of Rolando, is primarily involved in the processing of sensation, and may be connected with the speech and auditory areas at a deeper level.

- The area in front of the fissure of Rolando is mainly involved in motor functioning, and is thus relevant to the study of speaking and writing.
- An area in the upper back part of the temporal lobe, extending upwards into the parietal lobe, plays a major part in the comprehension of speech. This is 'Wernicke's area'.
- In the upper part of the temporal lobe is the main area involved in auditory reception, known as 'Heschl's gyri', after the Austrian pathologist R. L. Heschl (1824–81).

- The lower back part of the frontal lobe is primarily involved in the encoding of speech. This is 'Broca's area'.
- Another area towards the back of the frontal lobe may be involved in the motor control of writing. It is known as 'Exner's centre', after the German neurologist Sig-mund Exner (1846–1926).
- Part of the left parietal region, close to Wernicke's area, is involved with the control of manual signing.
- The area at the back of the occipital lobe is used mainly for the processing of visual input.



NEUROLINGUISTIC PROCESSING

Some of the neural pathways that are considered to be involved in the processing of spoken language.

1. **Speech production** The basic structure of the utterance is thought to be generated in Wernicke's area and is sent to Broca's area for encoding. The motor programme is then passed on to the adjacent motor area, which governs the articulatory organs.
2. **Reading aloud** The written form is first received by the visual cortex, then transmitted via the angular gyrus to Wernicke's area, where it is thought to be associated with an auditory representation. The utterance structure is then sent on to Broca's area, as in (1).
3. **Speech comprehension** The signals arrive in the auditory cortex from the ear (§25), and are transferred to the adjacent Wernicke's area, where they are interpreted.

NEUROPSYCHOLOGICAL MODELS OF LANGUAGE

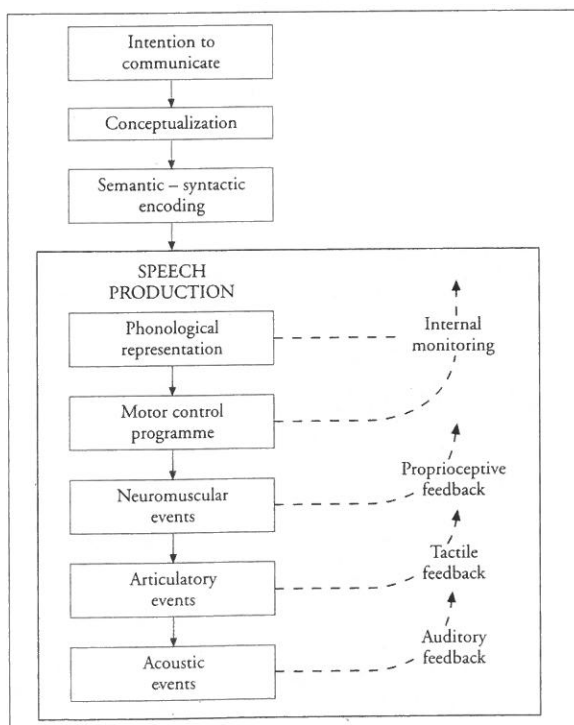
In real life, a snatch of dialogue (*How are you?*, *Fine, thanks*) takes place so quickly that it is easy to forget the complexity of the neurological planning and execution involved in the process. Any model of the production and comprehension of language – whether spoken, written, or signed – involves several steps, each of which must have some kind of neural representation. Neuropsychological models of language attempt to delineate what these steps are and how they interrelate.

In speech production, for example, an initial intention to communicate is followed (or perhaps accompanied) by some kind of conceptualization of the message. There has also to be a point at which this conceptualization is encoded into the semantic and syntactic structure of the language used by the speaker (though it is not clear how far this stage can be separated from the preceding one). If the structure is to be spoken, it must first be given some sort of phonological representation (e.g. as syllables, phonemes, or distinctive features, §28). A motor-control programme must then be used, to coordinate the multiplicity of signals that have to be sent to the appropriate muscles controlling the different parts of the vocal tract (§27). While this activity takes place, it is being constantly self-monitored: feedback is being received from the ear, from the sense of touch, and from the internal sensations generated by the movement of parts of the body ('pro-

prioceptive' feedback). Other kinds of internal monitoring, at 'higher' levels, may also take place. An analogous sequence of events would be involved if the structure were to be written or signed.

The nature of neurolinguistic programmes has attracted a great deal of research in recent years, especially in relation to speech production (§22). It is evident, for example, that the brain does not issue motor commands one segment at a time. A word such as *soup* is not neurologically transmitted as three separate steps – [s] + [u] + [p]. The articulation of [s] is lip-rounded, under the influence of the following vowel, which shows that the brain must be 'scanning ahead' while issuing commands for particular segments (coarticulation, p. 158). When we consider the whole range of factors that affect the timing of speech events (such as breathing rate, the movement and coordination of the articulators, the onset of vocal-fold vibration, the location of stress, and the placement and duration of pauses), it is evident that a highly sophisticated control system must be employed, otherwise speech would degenerate into an erratic, disorganized set of noises. It is now recognized that many areas of the brain are involved: in particular, the cerebellum and thalamus are known to assist the cortex in exercising this control (p. 260). But it is not yet possible to construct a detailed model of neurolinguistic operation that takes all speech-production variables into account.

A psycholinguistic model of speech production



SLIPS OF THE TONGUE – OR BRAIN?

Tongue slips – involuntary departures from the speaker's intended production of a sequence of language units – are very common. Sounds, syllables, morphemes (p. 90), words, and sometimes larger units of grammar can be affected. Often, the deviant performance is immediately detected by the speaker (though not always consciously) and corrected.

Several large collections of tongue-slip data have now been made (see facing page, top right), and the errors analysed from a variety of viewpoints. Sigmund Freud, for example, saw tongue slips as symptoms of unconscious forces or mental conflict within an individual, which needed careful psychoanalytic interpretation. They have also been seen as providing insights into the mechanisms of language change and evolution (§54). But most recent research has studied these errors to see what light they throw on how the brain or mind works.

The main linguistic finding is that tongue slips are not random, but are largely explicable by reference to certain basic constraints. For example, the two words involved in a tongue slip (the word containing the slip and the word that influences it) are often found within the same syntactic constituent or intonation/rhythm unit (§§16, 29). Moreover, the influencing word is



William Archibald Spooner (1844–1930)

Spooner, an Anglican clergyman and Warden of New College Oxford, had a nervous manner that led him to produce many slips of the tongue – typically, involving reversals which led to unintentional comic effects. Several of the 'spoonerisms' attributed to him are famous, such as 'queer old dean' (for 'dear old queen').

often the most strongly stressed within the tone unit. And most tongue slips involve the symmetrical substitution within a syllable of one sound by another: for example, an initial segment in the influencing word replaces the initial segment in the slipped word.

Combining such constraints, it is possible to make predictions about the form tongue slips are likely to take when they occur. Given the intended sentence 'The car missed the *bike* / but hit the *wall*' (where / marks an intonation/rhythm boundary, and the strongly stressed words are italicized), the likely slips are going to include *bar* for *car* or *wit* for *hit*. Most unlikely would be *har* for *car* (showing the influence of a less prominent word in the second tone unit) or *lit* for *hit* (showing a final consonant replacing an initial one).

Tongue slips tell us a great deal about the neuropsychological processes that underlie speech. The different kinds of errors provide indirect evidence for some of the stages recognized by models of speech production, and suggest the kinds of linguistic unit that these models need to take into account. For example, if slips tend to occur inside rather than between intonation units, it suggests that this unit has a neuropsychological reality within which the events of articulation are serially organized and integrated.

TONGUE SLIPS CLASSIFIED

An enormous variety of tongue slips occurs in everyday speech. Here are examples of some of the most frequent categories found in a corpus of over 12,000 spontaneous slips (after V. A. Fromkin, 1973). The words affected are given in the second column. (For phonetics terminology, see §27.)

Initial consonant anticipation

a reading list → leading
it's a real mystery → meal

Initial consonant perseveration

black boxes → bloxes
gave the boy → goy

Consonant reversals

well made → mell wade
baked a cake → caked a bake

Final consonants

with a brush → wish
king, queen → king, quing

Consonant deletion

below the glottis → gottis

tumbled → tubbled

Consonant addition

optimal number → moptimal
kitchen sink → kinchen

Consonant movement

pinch hit → pitch hint
bacon and eggs → acon and begs

Consonant clusters

heater switch → sweeter hitch
damage claim → clamage
dame

Consonant clusters divided

stick in the mud → smuck ... tid
fish grotto → frish gotto

Vowels

fill the pool → fool the pill
Bev and Bill → Biv and Bell

Vowel + r

foolish argument → fārlish
fight very hard → fart ... hide

Single features

spell mother → smell bother
bang the nail → mang the mail

Errors within words

relevance → revelance
whisper → whipsper

Stress changes

similarly → similarly
paying for it → pay foring it

Word reversals

a tank of gas → a gas of tank
a job for his wife → a wife for his job

Telescopic errors

Nixon witness → nitness
parking permit → parking pit

Derivational affixes (p. 90)

often → oftenly
flashing light → flasher

Blends

person/people → perple
draft/breeze → dreeze

Word substitution

I don't sleep very well in a
single bed → ... speak very
well ...

chamber music → chamber
maid

Other grammatical errors

It looks as if → I look ...
the day when I was born →
the day where ...

GENIE

The tragic case of 'Genie' bears directly on the critical period hypothesis. Genie was discovered in 1970, at the age of 13½, having been brought up in conditions of inhuman neglect and extreme isolation. She was severely disturbed and underdeveloped, and had been unable to learn language. In the course of her treatment and rehabilitation, great efforts were made to teach her to speak. She had received next to no linguistic stimulation between the ages of 2 and puberty, so the evidence of her language-learning ability would bear directly on the Lenneberg hypothesis (see right).

Analysis of the way Genie developed her linguistic skills showed several abnormalities, such as a marked gap between production and comprehension, variability in using rules, stereotyped speech, gaps in the acquisition of syntactic skills, and a generally retarded rate of development. After various psycholinguistic tests, it was concluded that Genie was using her right hemisphere for language (as well as for several other activities), and that this might have been the result of her beginning the task of language learning after the critical period of left-hemisphere involvement. The case was thus thought to support Lenneberg's hypothesis, but only in a weak form. Genie was evidently able to acquire some language from exposure after puberty (she made great progress in vocabulary, for example, and continued to make gains in morphology and syntax), but she did not do so in a normal way. (For other 'lost' children, see §49.) (After S. Curtiss, 1977.)



A CRITICAL PERIOD FOR LANGUAGE?

The notion of a 'critical period' was first used by ethologists studying the origin of species-specific behaviour. It was found that with certain species (e.g. rats, goslings) there were periods in which a particular kind of stimulus had to be present if the baby was to develop normal behaviour.

The question was therefore raised whether there were critical periods in human maturation also. The American psycholinguist Eric Lenneberg (1921–75) argued that such a period existed in the case of language acquisition. The development of language was said to be the result of brain maturation: the hemispheres were equipotential at birth, with language gradually becoming lateralized in the left hemisphere (p. 262). The process began at around the age of 2 and ended at puberty, when the brain was fully developed, and lateralization was complete. At this point, there was no longer any neural 'plasticity' which would enable the right hemisphere to take over the language function if the left hemisphere was damaged.

The argument in favour of a critical period was based largely on claims about the

patterns of recovery in brain-damaged adults and children. If adults with left-hemisphere damage failed to recover language within a few months, it was argued, they would never do so. Children, however, showed an ability to recover over a longer period – and could make a complete recovery if they were very young at the time of the damage. In such cases, even total removal of the left hemisphere did not preclude the reacquisition of language.

Controversial evidence The critical-period hypothesis has been controversial. The pathological evidence is mixed, because comparisons of adult and child cases are extremely difficult to make, and paths of recovery have not been studied in a detailed linguistic way. It may be that aspects of child recovery are helped by the involvement of the right hemisphere; but there are also cases of left-hemisphere damage producing severe and long-lasting aphasia in children.

The evidence of normal language acquisition (Part VII) is also mixed. Aspects of phonological and grammatical acquisition do continue until around puberty; however,

most of these skills are well established before the age of 5, and some linguistic skills (in semantics and pragmatics) are still developing in teenage children and young adults.

The neuropsychological evidence generally fails to support the Lenneberg hypothesis, showing lateralization to be established long before puberty – some studies suggest this may even be as early as the third year. Cerebral anatomical asymmetries have been found at birth, and several functional asymmetries have been noted in infants (e.g. a preference for rightward turning and right-hand grasping). Certain dichotic listening advantages (p. 261) are also present from a very early age, including some related to speech perception.

On the other hand, lateralization plainly takes some years before it is firmly established, and this overlaps the main period of language acquisition in a way that is not yet understood. The relationship between lateralization and language is thus an extremely complex one, and presents a continuing research challenge in developmental neuropsychology and neuro-linguistics.