proposed that the thalamus has some role in activating or arousing the cortex.

Lesions of the ventrolateral thalamus and/or pulvinar on the left have been associated with a variety of disturbances of speech and language processes. Symptoms include postoperative dysphasia, which is usually transitory; increased verbal-response latency; decreases in voice volume; alterations in speaking rate and slurring or hesitation in speech; and impaired performance on tests of verbal IQ and memory.

Speech Zones Mapped by Regional Blood Flow

With the development of sophisticated PET procedures, cognitive psychologists have become more interested in the neural correlates of language processing. To interpret the PET cognitive studies, we must first briefly consider a popular cognitive model of language comprehension. Suppose the word "cake" is presented visually. This sensory input is hypothesized to be analyzed in several ways. First, we can analyze the surface visual characteristics of the word (for example, the shapes of the letters). We can also consider what are called the phonological aspects of the word. That is, we can consider the sound of the word and whether it rhymes with "bake." Finally, we can assess the meaning of the word, which is referred to as its semantic code. A question of considerable interest in cognitive psychology is whether these three types of analysis are done serially and thus depend upon preceding levels of analysis, or are done in parallel. This question is not trivial, because if the analyses are done serially, it means that words must be sounded mentally before they are understood. Furthermore, it means that nonwords that can be pronounced will be analyzed differently from nonwords that cannot be pronounced. That is, the nonword "twips" can be analyzed phonologically, but the nonword "tzpws" cannot be. In both cases it should be possible to show that the brain activity produced during the processing is distinctive and, since there is no semantic code in either case, it should be the case that blood flow is different again when words are processed. This division of visual language inputs into visual patterns, phonological aspects, and semantic properties can be applied to the auditory system, too. In this case, the words would be analyzed by their frequency, phonemes, and semantics. We can now turn to the PET studies.

We shall describe the experiments of Peterson and his colleagues in St. Louis in some detail, but similar experiments have been performed at Hammersmith Hospital in London by Wise and his colleagues. (See Demont et al.'s comparison of the similarities and differences in results from the two laboratories.) Peterson's group asked subjects to perform four different tasks. In the first two, words were passively presented either visually or aurally. The task was to process the word but to do nothing (a sensory task). The key difference between the tasks is that one is visual and the other is auditory. In the next task, the subject was to repeat the word (an output task). In the final one (an association task), the subject generated a use for the target word (for example, if "cake" was presented, the subject might say "eat"). The authors monitored blood flow using PET and analyzed their data using a subtraction technique. Thus, in the sensory tasks they looked for changes from baseline blood flow by taking the difference between the activity in the two states. In the output task they subtracted the sensory activity, and in the association task they subtracted the output activity. Their results (Figure 17.6) lead to several conclusions.

First, in the passive task there was increased blood flow bilaterally in the primary and secondary visual areas for the visual stimulus and in the primary and secondary auditory areas for the auditory stimulus. More dramatically, pronounceable words and nonwords activated a region in the left occipital cortex that was not activated by unpronounceable letter strings. Thus, the brain treated visual information that appeared to be language differently from how it treated nonwords. Stated another way, the brain categorized the input into either words or nonwords. Hearing pronounceable words and nonwords appeared to

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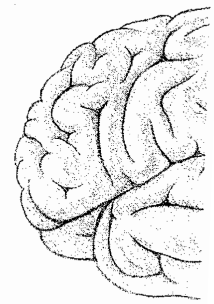

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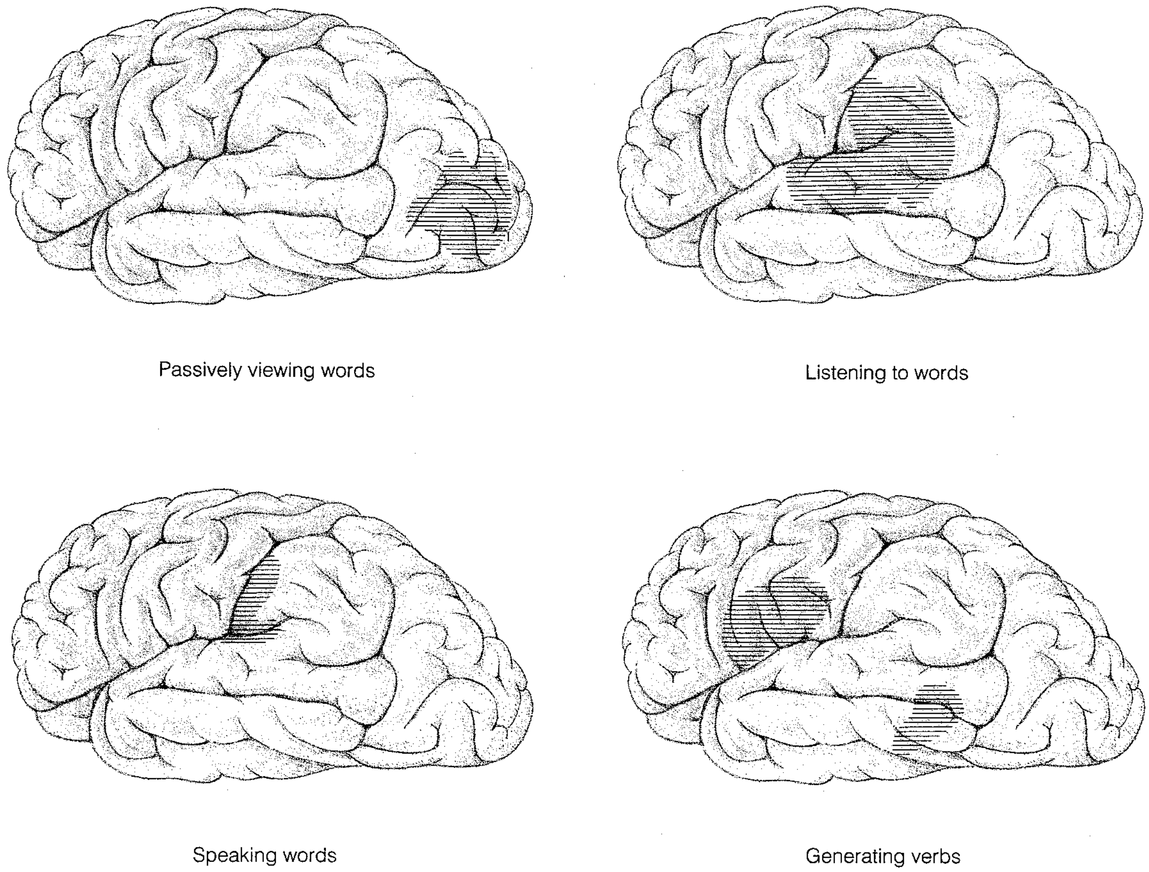


FIGURE 17.6. Each of the tasks in the word-generation experiment activates a distinct set of brain areas. (After Posner and Raichle, 1994.)

activate Wernicke's area (area 22), whereas listening to simple tones and vowels did not. Again, this suggests that the brain classifies the input as word versus nonword. The recognition of language-like material must have been learned, because there is nothing inherently different about some combinations of letters. This result is important because it shows that there is a part of the brain whose activity is based upon experience-dependent changes.

Second, there was absolutely no overlap in the visual and auditory activation during the passive task, implying that the processing of the word forms in the two modalities was completely independent. This finding would seem logical, except that it seems to contradict the view of language comprehension holding that visual input is converted into a phonological code. To test whether this latter idea is true, Posner and Raichle performed an experiment in which subjects were presented with two words visually and asked to press a key to indicate if the words rhymed or not. Some of the pairs did not look alike (for example, "row" and "though"), and some looked alike but did not rhyme (for example, "lint" and "pint"), so at least theoretically the subjects had to activate phonological codes by way of the visual input. The results showed that when subjects performed this task they activated regions normally only activated by auditory presentation.

Third, during the output task there was bilateral activation of the motor and sensory face areas, as well as bilateral activation of the supplementary speech area and activation of the right cerebellum. In addition, there was activation of the insular cortex. Surprisingly, neither Broca's area nor Wernicke's area was active during the repetition task. The activation of the cerebellum presumably reflects its role in motor behavior.

Fourth, for the association task there was activation of the frontal lobe, especially the left inferior region, including Broca's area. The critical difference between this task and the word-repetition task is that the choice of answer must be selected on the basis of external input. For example, hearing the noun "cake" leads to production of the verb "eat." Recall that the frontal lobe is hypothesized to have this function (see Chapter 14).

Fifth, the association task also activated the posterior temporal cortex, the anterior cingulate cortex, and the cerebellum. The posterior temporal region activated appears to be more ventral than Wernicke's area, and Posner and Raichle suggest that it may reflect the fact that several left posterior temporal regions are involved in processing words. The anterior cingulate activation has also been observed in studies by others, but the reason for it is unclear. Posner believes the anterior cingulate cortex to be important in some aspects of attention.

Two questions arise from the PET studies: (1) Why does damage to Broca's area and the left posterior temporal area produce aphasia, in the absence of activation of these areas in the speech-repetition task? (2) What is the role of the insular cortex? These questions were addressed in another experiment by the St. Louis group. First, they gave subjects nouns and asked for a verb generation, much as before. Second, they gave subjects nouns after the subjects had been given 15 min to practice the verb-generation responses. The results showed that when subjects had an opportunity to practice their responses, so that they were no longer searching for a verb to give during the test, they no longer showed activation of the inferior frontal, anterior cingulate, and posterior temporal regions. Instead, they showed enhanced activation of the insular cortex. The researchers conclude that there are two distinct pathways involved in the generation task. One pathway, which includes the inferior frontal and posterior temporal cortex, is necessary for selecting novel responses; the other uses the insular cortex to produce "automatic" speech (Figure 17.7).

In summary, studies of this sort are confirming the role of the classical anterior and posterior speech zones in language, but they also show that other regions are involved as well. Furthermore, they suggest that the posterior speech zone may be devoted largely to the analysis of auditory input, since there was no increase in blood flow in this region for visual stimuli, and it appears that Broca's area is not simply a cortical representation

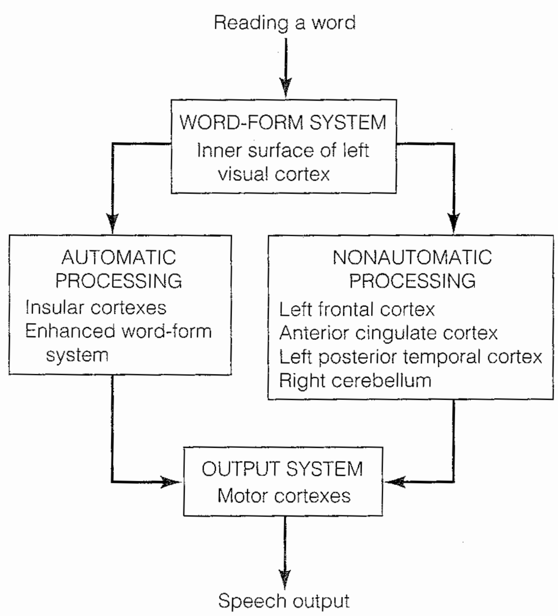
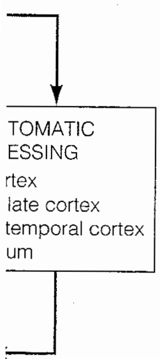


FIGURE 17.7. Posner and Raichle's two pathways for generating words. One pathway, which involves the insular areas, is used in automatic processing. The other pathway, which involves frontal and posterior temporal areas, is used in the generation of unlearned (or novel) responses.



of the movements of speech, as has been traditionally believed.

DISORDERS OF LANGUAGE

Before the neurology of language is given a theoretical description, the disorders of language must be considered, since theoretical formulations of language function must be able to account for the disorders observed. We first describe the types of deficits observed in language and then consider the classification of aphasia. Our discussion is brief, and readers are directed to recent reviews by Caplan and by Benson for more extensive discussions.

Language Deficits and Neurological Damage

Normal language depends on a complex interaction among sensory integration and symbolic association, motor skills, learned syntactic patterns, and verbal memory. **Aphasia** refers to a disorder of language apparent in speech, writing *(agaraphia)*, or reading *(alexia)* produced by injury to brain areas specialized for these functions. Thus, disturbances of language due to severe intellectual impairment, loss of sensory input (especially vision and hearing), or paralysis or incoordination of the musculature of the mouth (**anarthria**) or hand (for writing) are not considered to be aphasic disturbances. These disorders may accompany aphasia, and they complicate the study of it.

Goodglass and Kaplan have broken down language disturbances into 10 basic types, which we have subgrouped into disorders of comprehension and disorders of production and summarized in Table 17.3. We have encountered most of these language disorders already in our discussion of parietal, temporal, and frontal lobe functions. The one exception is **paraphasia,** which is the production of unintended syllables, words, or phrases during the effort to speak. Paraphasia differs from difficulties in articulation in that sounds are correctly articulated, but they are the wrong sounds; people with paraphasia either distort the intended word (for example, "pike" instead of "pipe") or produce a completely unintended word (for example, "my mother" instead of "my wife").

TABLE 17.3. Summary of symptoms of disorders of language

Disorders of comprehension
Poor auditory comprehension
Poor visual comprehension
Disorders of production
Poor articulation
Word-finding deficit (anomia)
Unintended words or phrases (paraphasia)
Loss of grammar and syntax
Inability to repeat aurally presented material
Low verbal fluency
Inability to write (agraphia)
Loss of tone in voice (aprosidia)

Classification of Aphasias

Since the time of Wernicke, people have attempted to describe identifying clusters of symptoms associated with particular brain lesions. This has proved to be a difficult task, partly because so few cases are thoroughly studied and partly because so few well-studied cases ever come to autopsy. In fact, Kimura has pointed out that the focus of attention in such studies has been upon the description of speech disorders rather than on the brain. It is rare for investigators to begin with a series of patients with similar lesions and then try to determine what the common language problem actually is. As a result, there is considerable controversy in the neurological literature over the nature and types of aphasia.

Despite disagreement over the number of types of aphasias, there are classification systems that are widely used. An example of one is given in Table 17.4. Broadly defined, aphasias are classified into three general categories: **fluent aphasias,** in which there is fluent speech but difficulties either in auditory verbal comprehension or in the repetition of words, phrases, or sentences spoken by others; **nonfluent aphasias,** in which there are