9

Linking Cognition and Brain: The Cognitive Neuroscience of Language

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The pioneering investigations of Broca (chapter 5, this volume) and Wernicke (chapter 6, this volume) provided exemplars of how to relate brain structures and psychological function in domains outside of language. Language itself, however, has been one of the most difficult domains of cognition to *understand* in terms of brain activities. As a result, the most developed approaches to the study of language are found in other disciplines – linguistics, psycholinguistics, and philosophy of language – that draw little if at all on information about the neural structures underlying language. There are several reasons for this. One is the fact that fully developed linguistic abilities are only found in humans, rendering it difficult to employ animal models in understanding language. Yet much of our understanding of the brain mechanisms involved in other psychological activities, such as seeing, resulted from studies in other species where it is possible to induce lesions or record from individual cells (see chapter 13, this volume). A second is that, until the recent emergence of neuroimaging techniques, language deficits resulting from naturally occurring lesions provided virtually the only avenue to studying how the human brain performed cognitive functions, including those involved in language. Naturally occurring lesions, however, generally do not damage single functional components of the brain. A final factor is that, for most humans, thinking is so dependent on language that it has been hard to conceive of more basic cognitive activities that might explain language itself. This motivation for seeing language as relying on special cognitive processes has been buttressed by the arguments of some linguists who argue for a special language module or language instinct (Chomsky, 1988; Pinker, 1994).

My goal in this chapter is to provide a philosophical perspective on neuroscience research on language. I begin with the question of the relation between language and thought, and lay out two proposals, one of which makes language foundational for thought, while the other makes thought foundational for language. I show that these different proposals provide different frameworks of understanding the project of relating language to the brain. I then turn to the multidisciplinary character of research on language, examining the differences in the way linguistics, psycholinguistics, and neuropsychology have approached the study of language. Next I examine how the study of neural processes has been related to various disciplinary inquiries into language. Finally, I take up three currently controversial issues concerning brain and language – whether linguistic ability (a) is a unique human adaptation, (b) results from a special module, and (c) is innate.

1 Language and Thought

As humans, we are often aware of covertly formulating our thoughts in language and phenomenologically it often seems as if we are *hearing* ourselves speak when we think to ourselves. In such situations, we use natural language sentences, privately rehearsed, as vehicles for representing information. For example, in solving problems, we privately construct sentences that identify the features of the problem, advance hypotheses for solving the problem, and identify evidence that supports or undercuts the hypotheses. (This is not to imply that our whole private life is linguistic. Most people are also aware of manipulating images, and employing such images in solving problems. There appear to be substantial individual differences with respect to how much different people rely in problem solving on talking to themselves and manipulating images.) Thus, language and thought seem closely related. But theorists differ significantly in the way in which they have envisaged language and thought to be related.

The philosopher Jerry Fodor has defended one extreme position. For Fodor (1975), thought is itself a linguistic activity, involving the formulation of hypotheses and evaluation of evidence. This would seem to have the striking consequence of denying thought to all creatures lacking a language, including human infants who are just learning language. (Other philosophers, such as Donald Davidson (1982), do not blanch at such a suggestion, arguing that unless a creature is able to make the sort of distinctions that can be represented in language, it lacks thought.) But for Fodor the language required for thought is not a *natural* language such as English or German, but an internal language which he terms *the language of thought*. Creatures who cannot learn natural languages, such as cats and dogs, can still possess a language of thought in which they can contemplate hypotheses and weigh evidence. In creatures who can learn a natural language, the language of thought provides the vehicle in which they can formulate and test hypotheses about the meanings of natural language expressions and the syntactic rules governing them. One way to think about Fodor's proposal is that for him the language of thought constitutes the innate machine language of the human information-processing system and any natural language must be compiled or interpreted in terms of it. Fodor's proposal resonates with theorists who have construed the von Neumann computer (a computer which carries out symbol manipulation using a stored program) as a model for understanding cognition.

Theorists at the opposite pole dissociate thought from language, construing thinking as a quite different sort of activity than the manipulation of linguistic items.

One alternative construal is that thinking without language involves perceptual processes, such as the ability to recognize perceptual patterns and relate them to each other. The emergence of connectionist or neural network models of information processing, where the primitive operations are not operations on language-like (symbolic) representations but excitations and inhibitions between neural type units, has provided a powerful alternative model to the von Neumann computer. Connectionist research suggests how a system could carry out intelligent processes by recognizing and transforming patterns without using the medium of language (see Rumelhart et al., 1986; Bechtel and Abrahamsen, in press). This renders the relation between thought and language more complex. One possibility is that learning to communicate in a natural language is not analogous to translating into a different language, but perhaps consists in creating a string of words as a result of complex neural activity involving interactions between a large number of units (see Churchland, 1995). Another is that acquisition of language provides a vehicle for radically transforming the thought process, allowing the thinker to take advantage of some of the special characteristics of language, such as productivity and systematicity (Bechtel, 1996; Clark, 1987). From this perspective, some human thought is indeed linguistic in nature, but the language in question is not a language of thought, but a natural language such as English. A related view is that language is first acquired as an interpersonal communication system and only later transformed into an internal representational system that can be invoked in activities such as problem solving (Vygotsky, 1962).[1]

These different proposals as to the relation of language and thought generate very different perspectives on the task of relating language to the brain. On the language of thought model, a major objective is to determine how the brain generally implements linguistic representations and operations on them. The task of explaining natural languages focuses on how the brain translates between natural language representations and representations in the language of thought. If, on the other hand, language is viewed as an acquired capacity, then the challenge is to determine how other cognitive capacities implemented in the brain are recruited to provide for the acquisition and use of language.

2 Disciplinary Perspectives on Language: Linguistics, Psycholinguistics, and Neuropsychology[2]

One of the intriguing things about language is that it has been studied from many different perspectives in a variety of disciplines, each of which brings different tools to bear in analyzing it. Here I focus on three of the disciplinary approaches that are most likely to be influenced by results in neuroscience, but these do not exhaust the possibilities. Yet another disciplinary approach is found in philosophy, where philosophy of language was a central area of investigation during the twentieth century. A central interest of philosophers has been the meaning of linguistic structures, and it was the philosopher Gottlob Frege who introduced the important distinction between the *sense* or connotation of an expression and its *reference* or denotation. To date, however, research in philosophy of language has been theoretical in nature and has been conducted largely in isolation from more empirical investigations of language. Accordingly, it is unlikely to be influenced in the short term by results in neuroscience. In this section I review the recent contributions of three disciplines that have played a central role in the empirical study of language – linguistics, psycholinguistics, and neuropsychology – in which the impact of discoveries about brain mechanisms might be expected to have the greatest impact.

Linguistics

Linguistics itself is a multifaceted discipline and practicing linguists approach the phenomena of language from a variety of different perspectives. Some linguists focus on the diversity of languages and the specific, often distinctive, features of particular languages. Others focus on the historical relations between languages (e.g. reconstructing the long extinct Proto-Indo-European language and tracing its divergence into contemporary languages of Europe, Iran, and northern India). Yet other linguists focus more abstractly on the distinctive features of language that are found in all languages. During the first half of the twentieth century a tradition known as *structural* linguistics attempted to characterize linguistic phenomena, introducing critical concepts such as *morpheme* (the smallest unit carrying meaning) and *phoneme* (a unit of sound) to characterize linguistic structures. For structuralists, the analysis of *syntax* (the arrangement of morphological units into sentences) proved challenging. In an effort to make syntax tractable, Zellig Harris advanced the idea of normalizing complex sentences by using *transformations* to relate them to simpler kernel sentences. For example, the passive sentence *the home run was hit by McGwire* is a transformation of the kernel sentence *McGwire hit the home run*. The potent idea of transformations was further developed by Harris's student Noam Chomsky (1957, 1965), who advanced the idea of a *grammar* as a *generative system* comprising a set of rules that would generate all and only members of the infinite set of grammatically well-formed sentences of a language.

Chomsky's early grammars employed phrase structure rules. Two examples of phrase structure rules are $S \rightarrow NP\ VP$ and $NP \rightarrow Adj\ N$; the first specifies that a sentence can be composed of a noun phrase followed by verb phrase while the second states that a noun phrase can be composed of an adjective followed by a noun. Application of phrase structure rules generates what Chomsky referred to as *deep structures*. Transformation rules could then be applied to deep structures to generate *surface structures*, which constitute the grammatical structures of actual sentences. Because of the role of transformation rules, Chomsky's early grammars were known as *transformational grammars*. Over the subsequent half century of periodic revisions in his grammatical theories, Chomsky has come to minimize the role of transformational rules, replacing them with specifications in the lexicon which constrain permissible movements of lexical items within grammatical structures. Despite these changes in the actual grammars he has proposed, Chomsky's goal throughout his career has been to identify principles that could account for the well-formed sentences in any natural language. These principles would constitute a *Universal Grammar*. For Chomsky, specific natural languages, such as English and Turkish, all employ the same Universal Grammar but implement various features of it in different ways. In Chomsky's more recent grammars, this involves setting values for specific parameters identified in the Universal Grammar.

Chomsky clearly set the agenda for many linguists during the second half of the twentieth century and the idea of a generative system exercised considerable influence on the emergence of cognitive science. His approach offered an answer to Descartes, who had claimed that mere physical devices, such as the brain, could not produce human thought because they could not exhibit the flexible use of the potentially infinite set of sentences found in any natural language (this was a major argument Descartes advanced for dualism – see chapter 1, this volume). Chomsky contended that by implementing phrase structure and transformational rules a machine could generate any sentence of a language.[3] Chomsky also bestowed other very influential ideas on the emerging cognitive sciences which had a profound impact on the manner in which linguistic ability was analyzed. I introduce three of these ideas here: (1) that linguistic ability is found only in humans, (2) that it is dependent upon a specialized module, and (3) that basic grammatical knowledge is innate. I return to these in the last section of this chapter.

As I will describe in the next section, Chomskian analyses of language have had a major impact on the analysis of brain mechanisms underlying language ability. Gradually, however, other approaches to linguistic analysis that developed largely in the shadow of Chomsky are also beginning to influence that analysis of neural findings. One of the major alternatives is referred to as *cognitive linguistics*; it rejects the autonomy given to syntax in Chomskian approaches, and attempts to derive linguistic forms from semantically grounded cognitive processes that are not unique to language (Langacker, 1987; Tomasello, 1998).

Psycholinguistics

Efforts to understand the psychological processing involved in comprehending and producing linguistic structures has had a complex relation to linguistic theory. Many of the nineteenth-century pioneers in developing an experimental psychology (such as Wilhelm Wundt and Hermann Paul) proposed accounts of psychological processes involved in language (Wundt emphasized the sentence as a basic unit whereas Paul emphasized a process of construction from individual words – see Blumenthal, 1987). During the first decades of the twentieth century, this psychological interest in language was largely eclipsed as behaviorists focused on general models of learning that could equally explain animal and human behavior. Modern psycholinguistics, though, was inaugurated in the period just prior to Chomsky's appearance on the intellectual stage. In an eight-week summer seminar sponsored by the Social Science Research Council in 1953 an ambitious agenda for collaboration between psychologists and linguists was formulated (Osgood and Sebeok, 1954). A representative endeavor was the attempt to establish the *psychological reality* of linguistic constructs, such as the *phoneme*, through analysis of speech errors. This enterprise of evaluating psychological reality was naturally extended in the wake of Chomsky's proposals of transformational grammars by attempts to demonstrate, either through reaction time studies or memory studies, that sentences requiring more transformations were harder to process than sentences with fewer (Miller, 1962). This specific attempt was relatively short-lived, partly due to results indicating that not all transformations in the grammar resulted in longer processing time and partly due to the fact that Chomsky periodically changed his grammar, rendering previous psychological studies uninterpretable (Reber, 1987). Nonetheless, psycholinguistics has remained an active pursuit in which researchers, primarily psychologists, interested in processing models, have periodically drawn upon and reformulated ideas in linguistics to account for psychological processes (Abrahamsen, 1987).

In addition to adapting frameworks from linguists, psycholinguists have also relied on ideas of mental representation and processing in their research. One of the more powerful tools for analyzing language processing has been semantic networks, first proposed by Ross Quillian (1968). These employ networks of nodes to represent relations between word meanings. Each sense of a word would be represented by a type node, which would be related to token nodes for other concepts that figured in its definition, and these to nodes that figured in their definitions. By employing a process of *spreading activation* from one node to another, Quillian showed how one could compare two related concepts (figure 9.1). Other theorists have put semantic networks to other uses, such as explaining what are known as *priming effects*. Priming is exhibited when reaction times for words are shortened by prior presentation of other related words. Suppose, for example, one has to decide whether the second item in a pair is a word (this is known as a *lexical decision task*). Subjects will respond affirmatively faster to *truck* in *car-truck* than in *snake-truck*; a plausible explanation is that the subject represents meanings of words in a semantic network, and activation spreads quickly from *car* to *truck*, priming it and making access faster when *truck* was presented after *car* than after *snake*.

Neuropsychology

While the root *neuro-* suggests that *neuropsychology* refers to a general integration of neuroscience and psychology, neuropsychology has traditionally focused on what can be learned about psychological processing from patterns of deficits found in instances of brain damage (and, on the applied side, on tests for evaluating brain-damaged patients). Out of necessity in the era before neuroimaging, neuropsychology often proceeded on a purely behavioral level, advancing detailed analyses of the deficits exhibited by patients without specific information about the locus and extent of underlying brain damage. An important strategy in neuropsychology has been to try to establish the independence of cognitive processes from each other by showing that each can be damaged independently. Neuropsychologists refer to this as *disso-*

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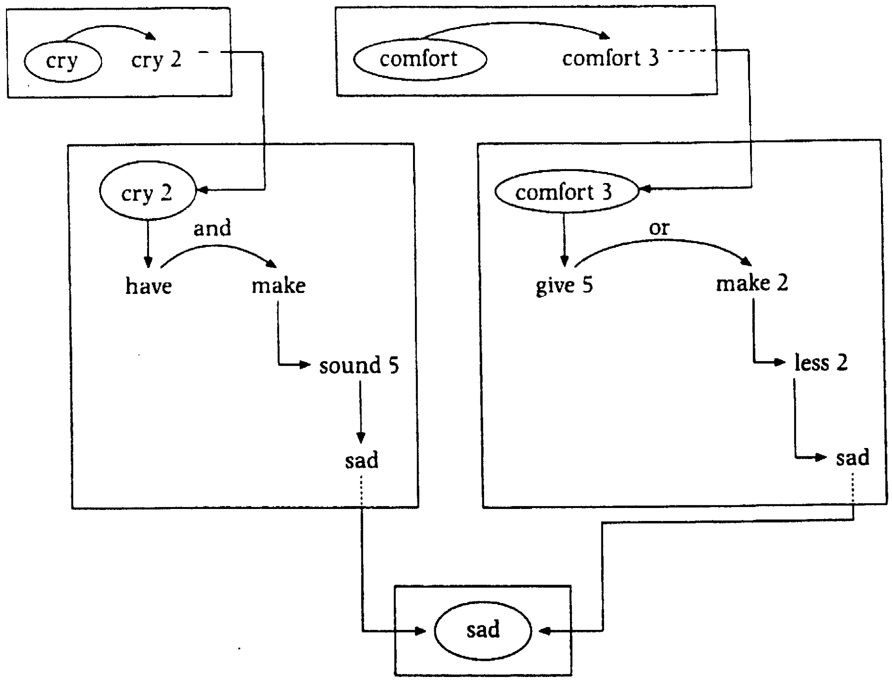

Figure 9.1 A portion of a semantic network as explored by Quillian (1968). Two concepts, *cry* and *comfort*, are shown to be related in that paths lead from both of them to *sad*.

ciating: one cognitive capacity can be abolished while another is retained. A ***double dissociation*** obtains when each can be separately abolished while retaining the other. A double dissociation of two capacities is often taken to be strong evidence that the two capacities rely on different resources and are carried out by different components in the brain (Shallice, 1988).

The differing patterns of deficits exhibited by Broca's and Wernicke's aphasics appeared to provide an example of a double dissociation between comprehension and production (although, as I shall discuss shortly, there have been several alternative proposals as to just what the alternative capacities are). An even more powerful example of a double dissociation is provided by different types of reading disorders or dyslexias. Individuals with ***surface dyslexia***, for example, tend to regularize the pronunciation of words which have exceptional pronunciations in English. For example, they may pronounce *pint* to rhyme with the regularly pronounced words *hint* and *lint* rather than producing the irregular but correct pronunciation. Their tendency to overregularize the pronunciation of these words suggests that they are processing written words only as letter strings (not as lexical items that have predetermined pronunciations). In contrast, individuals with ***phonological dyslexia*** are able to pronounce words correctly (whether regular or irregular), but experience great difficulty when they attempt to pronounce non-words (such as *zat*). The ability to read regular and irregular words but not even simple non-words suggests that their reading is mediated by recognition of words as items in their lexicon. As a result of these different patterns of deficits, theorists such as Max Coltheart (1987) have proposed that there are two routes to reading, one through a lexicon and one employing grapheme-to-phoneme transition rules. Normal readers have both routes available to them, but the two forms of dyslexia just discussed result when one of these routes is disrupted, leaving only the other. Such an interpretation of double dissociations has recently been challenged by those developing connectionist models – which are designed to use only one processing pathway but which, when lesioned in different ways, exhibit double dissociations (Hinton and Shallice, 1991; van Orden et al., 2001).

3 Relating Brain Structures and Language Functions

The three approaches to understanding language identified in the previous section have historically been pursued with little input from direct investigations of the brain. Increasingly, however, researchers are integrating pursuits in these other disciplines with research on the brain. In this section I will examine several attempts to link linguistic functions, especially those having to do with syntax and semantics, with brain processes. But before doing so, though, it is important to note that these are not the only aspects of language that might be related to brain processes. Comprehending language, for example, requires analysis of auditory or visual stimuli. Like primary visual cortex, primary auditory cortex has a distinct topography, but in this case different tones are mapped on to different parts of primary auditory cortex (generating a tonotopic organization). Neuroimaging studies in humans have revealed several areas that are activated by both words and other sounds, and two areas in the anterior superior temporal cortex and temporal parietal cortex were activated with words but not other sounds (Petersen et al., 1988). This suggests a complex auditory processing system in which common processing areas interact with areas dedicated to speech processing. Thus, although I am emphasizing syntactic and semantic processing, one should not overlook the potential for brain-level research on other linguistic abilities.

The pioneering research of Broca (chapter 5, this volume) and Wernicke (chapter 6, this volume) provided compelling evidence that areas in the (left) inferior frontal lobe and in the (left) superior temporal gyrus were critically involved in language functions. It is worth drawing attention to the differences in the way they construed their contributions. In accordance with the idea that separate faculties were responsible for different psychological functions, Broca took himself to have identified the locus of articulate speech (but not of language generally, since he recognized that Tan was capable of comprehending speech even while he could not produce it). In this he offered a direct or simple localization of the faculty, and his concern was to specify more precisely the locus of this faculty (in part, by trying to identify where Tan's lesion originated). Wernicke operated out of the quite different framework of associationism, according to which cognitive performance depended upon connections between different cognitive capacities. He took the superior temporal gyrus, located adjacent to the primary auditory cortex, to be the center for acoustic speech imagery, responsible for the acoustic recognition of words. He proposed that knowledge of the actual meaning of words depended on connections to visual, auditory, and other sensory images stored elsewhere in the brain. Thus, only two of the aphasias he identified (see figure 6.4) involve damage to localized centers; the others all involve disruptions of various connection pathways.

Despite the initial promise, the efforts to find localized centers of language function were soon abandoned. An attitude decidedly opposed to seeking brain loci for any functions but the most basic sensory ones dominated research in the first decades of the twentieth century (Franz, 1917; Head, 1918; Lashley, 1929, 1950). But beginning in the 1960s, Norman Geschwind at the Boston Veterans Administration Hospital began to resurrect the Wernicke model and it soon came to provide the dominant neurological framework for understanding aphasias. To Wernicke's model, Geschwind added the idea that sensory domains other than speech provided input to the language system through projections to the angular gyrus. Geschwind then proposed a multistage processing system that figured in either speaking a written word or repeating a heard word (see figure 9.2). Geschwind describes the process of speaking a word as involving the building up of a motor program as structure is passed from Wernicke's area to Broca's and then to motor cortex:

> In this model the underlying structure of an utterance arises in Wernicke's area. It is then transferred through the arcuate fasciculus to Broca's area, where it evokes a detailed and coordinated program for vocalization. The program is passed on to the adjacent face area of the motor cortex, which activates the appropriate muscles of the mouth, the lips, the tongue, the larynx, and so on. (Geschwind, 1979)

The traditional differentiation of Wernicke's and Broca's areas characterized the primary contribution of each area in terms of what we do with language – we comprehend it and we produce it. As natural as the decomposition into comprehension and production is from one point of view, it is orthogonal to the linguist's decomposition, which is grounded in the types of knowledge one must have of one's language – knowledge of phonology, morphology, syntax, semantics, pragmatics, and so on. Both comprehension and production require competency in all of these; for example, to comprehend and to produce a sentence one must know what the units of meaning are (morphology) and how they sound (phonology). If the brain organized language processing in terms of comprehension and production, then it would seem that the brain would have separate stores for phonological, morphological, syntactic, semantic, and pragmatic knowledge for comprehension and production. On this scheme, an individual could develop completely different phonological, syntactical, and semantic processes for comprehension and production.

Finding the comprehension/production perspective problematic, a number of Geschwind's younger colleagues, including David Caplan, Mary-Louise Kean, and

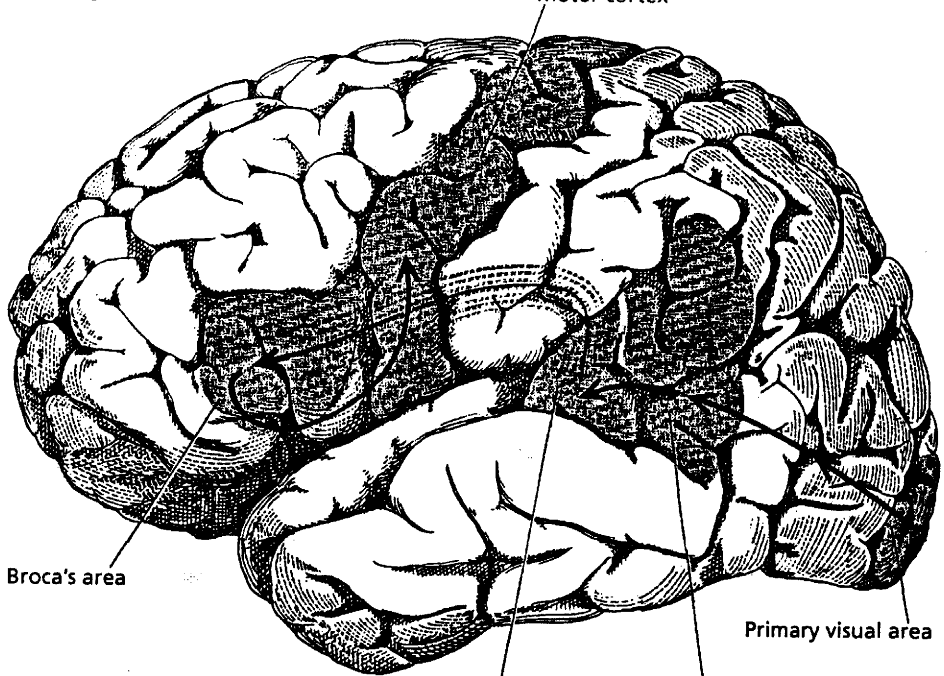

Figure 9.2 Geschwind's adaptation of Wernicke's model of speaking a written word. Geschwind proposed that the sensation is first registered by the primary visual cortex and then relayed to the angular gyrus. The visual form of the word is then associated with the corresponding auditory pattern in Wernicke's area. A representation is then transmitted from Wernicke's area to Broca's area, through a bundle of nerve fibers called the arcuate fasciculus. In Broca's area the word evokes a detailed program for articulation, which is supplied to the face area of the motor cortex. Figure adapted from N. Geschwind, Specializations of the human brain, *Scientific American*, 238, 1979, p. 164.

Edgar Zurif, began to develop an alternative decomposition. They thought in terms of systems for processing phonology, syntax, and semantics, with these systems subserving both comprehension and production. Deficits in Wernicke's area had long been associated with deficits in both comprehension and production, since language production in Wernicke's aphasics often consisted in paraphasic speech in which syntax is preserved but the utterances do not make sense (sometimes referred to as cocktail chatter). This suggested that Wernicke's area played a role in processing word meanings in both comprehension and production. The key to prompting an overall re-examination of the Wernicke-Geschwind model was a re-analysis of the deficits found in Broca's aphasics which suggested it too played a role in both comprehension and production. This re-analysis resulted from a fine-grained examination of the speech of Broca's aphasics which revealed that they tend to omit a particular class of words, known as *closed-class* vocabulary, which often serve as grammatical markers.[4] A similar careful examination of comprehension revealed that when comprehension depended upon such closed-class markers, Broca's aphasics exhibited comprehension deficits. For example, Caramazza and Zurif employed sentences with a complex syntactic structure known as *center embedding* in which one or more relative clauses intervene between a noun and its associated verb (e.g. "The girl that the boy is chasing is tall"). To understand this sentence correctly one must attend to the relative clause marker *that*. Caramazza and Zurif (1976) found that Broca's aphasics made errors on such sentences, indicating that they were not processing the syntactic indicators. This comprehension deficit is often masked in other sentences such as "The apple that the boy is eating is red," where Broca's aphasics are able to employ semantic cues to understand the sentence correctly (that is, they rely on the semantic information that *red* is more likely to describe a fruit than a person).

These and other studies suggested that Broca's area was primarily involved in syntactic analysis and Wernicke's area in semantic processing. This decomposition is further supported by evidence of patients with more posterior damage (i.e. in Wernicke's area) who have difficulty processing word stems (*walk* in *walked*) but not the inflectional suffix (*-ed*) and patients with more anterior damage (i.e. in Broca's area) with the reverse pattern of deficits.

Despite the plausibility of this decomposition into syntax and semantics, subsequent data have not been fully consistent with the attempt to map these phenomena on to Broca's and Wernicke's areas. Particularly influential in indicating a much more complex pattern of localization of deficits was the introduction, beginning in the 1970s, of CT-scans to identify the locus of brain damage in various aphasic patients.[5] Mohr (1976), for example, found that patients with lesions restricted to Broca's area did not exhibit Broca's aphasia; rather, much more extensive damage was required to yield the symptoms of Broca's aphasia. Subsequent studies (de Bleser, 1988; Willmes and Poeck, 1993) have provided additional evidence that damage to Broca's and Wernicke's areas does not necessarily result in Broca's and Wernicke's aphasias, and that the damage in patients with those aphasias may be located elsewhere, including in the right hemisphere (Caplan et al., 1996). This may be due simply to individual variability in brain development, but it does make establishing correlations between brain activity and linguistic function more difficult.

Perhaps the central issue, though, is whether decomposition into processes such as syntactic analysis and semantic analysis is the correct decomposition. Grodzinsky (2000) argues that it is not the ability to process syntax *per se* that is damaged by lesions in Broca's area. Rather, the deficit affects very specific syntactic forms whose linguistic analysis involves transformational movements in which a constituent of a sentence is moved from one position in the sentence to another but where a trace is

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left at the original position. The trace continues to play a syntactic role in the sentence such as in the assignment of thematic roles, but is not phonetically voiced. For example, the structure to the right of the verb *liked* is assigned the thematic role of Theme (recipient of the action) in

(1) Mary liked t_i.

When this is transformed into a relative clause, as in (2),

(2) [*which man*]$_i$ did Mary like t_i

the trace t_i is left in its original position.

Grodzinsky proposes that Broca's aphasics delete the trace and attempt to rely on other information to interpret the sentence. The following pair of sentences illustrates his analysis:

(3) The boy who pushed the girl was tall.

(4) The boy who the girl pushed was tall.

The linguistic derivation of (4) begins with

(5) The girl pushed the boy.

The phrase *the boy* is then moved but, in normal processing, a trace is left to indicate that *the boy* is the theme of *pushed*. But in Broca's aphasics, no trace is left and there appear to be two candidates for agent of *pushed*: *the boy* and *the girl*. The result, according to this analysis, is that Broca's aphasics must guess which is the agent, and are at chance in arriving at the correct interpretation of (4). Since (3) does not involve such a transformation, they process it normally.

Chapters 7 and 8, this volume, further develop the case for rethinking the identification of semantic processing with Wernicke's area, and syntactic processing with Broca's area. Bates points to two additional psycholinguistic sources of evidence that challenge the association of grammatical capacity with Broca's area. The first are studies showing that Broca's aphasics can make fine-grained grammaticality judgments, thereby indicating that they retain much linguistic knowledge. The second are comparative psycholinguistic studies indicating that Wernicke's aphasics who speak more highly inflected languages substitute grammatical markers. From this she proposes that the more general pattern is that Broca's aphasics make errors of omission while Wernicke's aphasics make errors of commission (Elman et al., 1996). Petersen and Fiez review evidence, much of it originating with the early PET studies of Petersen and his colleagues (Petersen et al., 1989, 1988) indicating that semantic tasks such as generating verbs appropriate for particular nouns activate areas in dorsolateral prefrontal cortex, suggesting that semantic processing occurs in frontal cortex, not Wernicke's area. As we discuss in chapter 4, this volume, this alternative localization of semantic processing proved controversial, although it coheres with reports of difficulty in processing verbs as well as closed-class vocabulary in patients with left frontal lobe damage (Caramazza and Shelton, 1991).

A major direction of recent research on brain and language has been to expand the number of brain regions thought to have a role in language processing. Petersen's work not only introduces dorsolateral prefrontal cortex as an area involved in language processing, but also identifies an area in extrastriate cortex that is more active when subjects read words or word-like letter strings (i.e. strings that follow the spelling rules of English) than when they read random letter strings or false-font stimuli, indicating that that area is involved in some manner in language processing. More fine-grained analysis of patients with lexical difficulties has revealed patients with temporal lobe lesions who exhibit deficits in processing particular categories of words (e.g. names for living things, or sometimes more specifically names for plants – see Caramazza and Shelton, 1998). Neuroimaging studies on intact subjects support this decomposition by semantic category, indicating increased activation in the inferior temporal lobe and occipital lobe in response to animal pictures and increased activation in more dorsal parts of the temporal lobe and parts of the frontal lobe in response to artifacts. There is also evidence of modality-specific deficits involving particular grammatical categories (e.g. impairment in producing verbs only in speech, not writing) that suggest even more differentiation of language-related functions.

As researchers press on, they are continuing to identify more brain areas involved in language processing, including areas in the right hemisphere where damage manifests itself in deficits in comprehension above the sentence level – with jokes, etc. – and with prosodic features of speech. The picture that emerges is that language processing involves a complex, integrated system in which a host of brain areas contribute. As the analysis develops, it may prove increasingly difficult to characterize what each of these areas contributes in terms of large-scale language tasks (e.g. comprehension or syntactic processing); rather, each will carry out more specific tasks that are employed in language processing. Moreover, some investigators propose that these processes need not be exclusively linguistic; rather, language processing may recruit brain areas originally dedicated to other psychological activities:

> though language processing recruits specialized localized structures in the left cerebral hemisphere, there may be no one-to-one correlation of individual brain regions with functions defined in linguistic terms. Instead of neural modules being specialized for specific classes of linguistic functions, it appears that many language processes are distributed as component neural computations, performed in concert in many different brain structures. Specific classes of linguistic operations might better be identified with specific signature patterns of distributed activity. (Deacon, 1998, p. 216)

4 Major Issues in the Study of Language: Uniqueness, Modularity, and Nativism

I noted in section 2, above, that in addition to his specific proposals for linguistic analysis, Chomsky took stances on three issues: (1) whether language processing is a uniquely human ability, (2) whether it involves a special module, and (3) whether the capacity for language is innate. All of these themes are related and were developed in a critique Chomsky (1959) published of B. F. Skinner's book *Verbal Behavior*, a large-scale effort to explain linguistic performances using the behaviorist principles of operant conditioning. For most behaviorists, including Skinner, linguistic abilities were the product of the same underlying capacities for learning that account for all behavior. In contrast, Chomsky argued that linguistic abilities are distinctive, relying on specialized rules for constructing and modifying linguistic structures. Chomsky denied that one could train up a linguistic capacity through conditioning. Accordingly, he and his followers have been critics of claims that training programs employed with other species (e.g. chimpanzees) could yield even primitive linguistic abilities. In contrast, he attributes language to a special module that embodies the special grammatical knowledge on which real linguistic ability relies (see also Pinker, 1994). The same arguments against the potential for training language abilities in other species apply equally to humans, and thus Chomsky commits himself to the knowledge being innate, not learned.

As just indicated, one way to assess whether language is a uniquely human ability has been to focus on other species and ask whether they exhibit anything like a language or whether they can be trained to use human languages (or humanly constructed artificial languages). Ethological research has revealed that other species have complex signaling and call systems. Bees, for example, are able to communicate the location of sources of nectar to each other, but this system has limited expressive capacity and is not productive – it does not provide the capacity for continually generating novel sentences, as do human languages (von Frisch, 1967). Vervet monkeys have a set of calls which specify different types of danger (eagle, snake, etc.), but again, their capacity is not productive (Cheney and Seyfarth, 1990). Moreover, as Deacon argues, call systems rely on very different neural components, particularly ones in the limbic system, from the ones used in human language processing (Deacon, 1997).

Since the 1930s, researchers have attempted to train a variety of non-human species, including dolphins and sea lions as well as several higher primates such as common and bonobo chimpanzees, in the use of artificial linguistic systems. In one of the most successful of these efforts, Sue Savage-Rumbaugh (1986) taught two common chimpanzees to use a system of lexigrams (non-iconographic visual symbols, often mounted on a computer keyboard) to designate objects and use them in a variety of activities, including ones in which the two animals coordinate their behaviors by communicating with lexigrams. In subsequent research, she demonstrated, first with bonobos (especially Kanzi) and then with common chimpanzees,

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that these primates could acquire the use of lexigrams and comprehension of some spoken English without rigorous conditioning when lexigrams were made available to facilitate the animal's own objectives (e.g. negotiating subsequent activities – Savage-Rumbaugh and Lewin, 1994).

Critics of language research with animals (Pinker, 1994) note that even by the best assessment, apes only acquire the linguistic skills of very young children (Kanzi's comprehension was comparable to that of a 2½-year-old child). Their vocabularies do not grow rapidly, as do those of human children, and they do not acquire the complex syntax of human languages. But these observations only indirectly address the core question of uniqueness, which concerns whether language acquisition relies on cognitive capacities that are shared with other species (but more developed in humans), or whether it depends on new, specialized language abilities. Thus, this question links back to the modularity question.

A distinctive approach that holds the potential for finally advancing this often stalled debate is found in Deacon's *The Symbolic Species*. On the one hand, Deacon points to a capacity that seems to be only exhibited naturally in humans: the capacity for symbolic reference. His emphasis is on *symbolic*. Reference is exhibited in bee and monkey communication – members of both species produce behaviors that are appropriately linked to a referent. What is distinctive of human languages is that words comprise a structured but open-ended semantic system. Words stand in relation to one another such that when a new word is introduced into a person's vocabulary, it immediately takes up relations to existing words:

> words refer to things indirectly, by virtue of an implicit system of relationships between them. This requires that they work in combination (even if only implicitly), referring to one another and modifying one another's reference, to produce a kind of *virtual reference* in which each is associated not so much with some specific concrete object or event, but with kinds, abstract classes, or predicates that can be applied to things. (Deacon, 1998, p. 220)

While emphasizing the distinctiveness of symbolic reference as exhibited in human languages, Deacon also maintains that it derives through evolutionary changes from capacities present in primate brains. Of particular note in the evolution of the human brain from that of primates is the disproportionate expansion of prefrontal areas. One result of increased prefrontal cells in human brains is that these cells send out more processes to cells elsewhere than do cells in these areas of primate brains, with the result that these cells win the competition for developing processing pathways to other brain areas. Research on monkeys by Goldman-Rakic (1987) shows that lesions to prefrontal areas in monkeys destroy their ability to carry out delayed non-match to sample tasks. In these tasks, monkeys must retain information about stimuli seen previously and then inhibit the natural tendency to choose those stimuli in subsequent choice situations. Humans and members of other species with damage to similar areas exhibit deficits of perseveration – they are unable to repress previous response strategies when shifts are called for. Deacon proposes that amplification of such capacities (which would result from disproportionate expansion of relevant brain areas) may be critical to establishing a network of semantically related symbols required for symbolic reference. For him, a semantic network sets word meanings off from one another by negation so that different words cover different parts of semantic space. If so, then at least this proto-linguistic capacity is grounded in cognitive capacities shared with other species (Deacon, 1997).

By grounding linguistic capacities in cognitive abilities shared with other species, Deacon's approach also rejects the modularity of language. While advocates of the Chomskian tradition still argue for the modularity of language (Fodor, 1983), the discoveries of more and more brain areas involved in language processing suggest that it is a distributed process, and less likely to be due to a segregated module (see chapter 8, this volume). But until research reveals just what brain areas are involved in language, how they are connected to other brain areas, and what kind of information processing each performs, it will not be possible to fully settle just how modular language mechanisms are.

Our final controversial issue concerns whether the capacity for language is innate. Those committed to strong nativism claims, such as Chomsky, Fodor, and Pinker, often appeal to the fact that linguistic capacities seem to be acquired in the absence of environmental inputs sufficient for learning. This is often referred to as the *poverty of the stimulus* argument. Related evidence is found in research on deaf children of hearing parents who create their own signed language (Goldin-Meadow et al., 1994) and of deaf children who develop a more systematically grammatical form of American Sign Language than their parents (Singleton and Newport, 1994). Nativists account for these abilities by proposing that the representations employed in language processing (i.e. the principles of Universal Grammar) are pre-wired into the brain and only need to be triggered by appropriate experience. For Pinker, these neural representations must in turn be specified by the genome.

Although Skinner's (1957) anti-nativism denied any specific genetic or brain structure specifically dedicated to language, contemporary opponents to nativism generally do not deny that some particular brain structures are more suited to handle language processing than others and that the human genome specifies a pattern of development highly suited to acquisition of language. What they reject is the claim that genes could specify neurocircuitry at the level of detail required for innate representations. Rather, like Elman et al. (1996), they propose that the genome provides architectural and chronological constraints that, in the course of normal development as the organism interacts with its environment, result in a brain with areas predisposed to learning specific types of information. Thus, Bates (chapter 8, this volume) proposes that the left temporal cortex is predisposed to extract perceptual detail and that this bias, under normal development, results in specialization for language. But because other brain areas can perform these functions if this area is destroyed early in development, Bates and Elman reject the nativist claim that it encodes innate representations used for language processing. Current discussion of nativism thus turns on the question of what is innately specified and how it figures in the development of normal language capacity.

Although questions about the modularity of language, its uniqueness in humans, and what aspects of it are innate remain controversial, there has been a change in how these questions are investigated. Investigators are increasingly relying on information about the brain and how it supports language function. Partly as a result of this additional potent constraint on theorizing, the positions on both sides of each issue are being refined and moderated.

Conclusions

Language remains our most fascinating cognitive capacity. As I have discussed, it has been the focus of inquiry in a number of different disciplines. The early promise of determining what specific brain areas contribute to language has not yet been fulfilled, but the near future promises to be exciting. New tools, including neuroimaging, are pointing to more brain areas involved in language processing. The challenge is to determine the different processing contributions each makes. Continuing progress in this effort will also likely reduce the differences on such polarizing issues as the uniqueness, modularity, and nativism of language.

Notes

1 A challenge from this perspective is to explain how a child first develops the intention to communicate when it lacks any prior propositional representation of what it intends to communicate. An intriguing suggestion, developed by Andrew Lock (1980), is that the child's first communications (often in the form of gestures) are not intentional from the child's perspective, but interpreted as such by the hearer, and that only after it recognizes the efficacy of its behavior does the child produce gestures and linguistic structures with communicative intent.

2 Material for this section was partly adapted from Bechtel, Abrahamsen, and Graham, (1998).

3 As enticing as this idea is, that the mind might employ the same operations as posited in a linguist's grammar, it is important to bear in mind that the tasks of the linguist in developing a grammar (accounting for all the well-formed sentences of a language) and of a psychologist in explaining linguistic behavior (accounting for linguistic production and comprehension) are different and that different ways of representing language may be required for the two pursuits (Abrahamsen, 1987).

4 Bradley, Garrett, and Zurif distinguish *open-* and *closed*-class vocabularies as follows: "The closed-class (grammatical morphemes, minor grammatical categories, nonphonological words) includes sentence elements that, by and large, are vehicles of phrasal construction rather than primary agents of reference, as is the case with open-classed words (content words, major grammatical categories)" (Bradley et al., 1980, p. 277).

5 It is important to note that while CT-scans provide reliable information as to regions of dead tissue in the brain, it is possible that processing in areas where tissue has not died is nonetheless disrupted, perhaps as a result of their connectivity to areas where the tissue has died.

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