Some thoughts about the brain/mind/language interface*

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Abstract

An historical survey of the approaches to the neural basis of language and the modularity question is summarized. Evidence from aphasia, event-related potentials (ERPs), Specific Language Impairments (SLIs) in children, asymmetry of abilities as shown by linguistic 'savants', sign language, separation of conceptual and linguistic knowledge, other disorders such as prosopagnosia and visual agnosia is presented to support the view that human language ability is autonomous and independent of other cognitive abilities with which it interacts in use.

1. Introduction

In this 'decade of the brain', a number of questions concerning the nature of the human mind as reflected in human language, the relation between language and thought, and the brain/mind/language interface are being investigated by cognitive scientists, including linguists, psychologists and neurologists. While there is overlapping interest in finding an answer to the question "What are the physical mechanisms that serve as the material basis for (the) system of (linguistic knowledge) and for the use of this knowledge?" (Chomsky, 1988: 3), the different disciplines understandably approach these questions differently. "In the study of language, (linguists) proceed abstractly, at the level of mind, and ... also hope to be able to gain understanding of how the entities constructed at this abstract level and their properties and the principles that govern them can be accounted for in terms of properties of the brain" (Chomsky, 1988: 5–7).

Thus, linguists are concerned with what linguistic theory can tell us about the neurological basis for the acquisition and use of language, while psychologists conduct experiments measuring reaction times and lexical decision tasks, eye tracking and priming to see how psychological processing contributes to our understanding of the nature of human language, and neurologists, using MRI's, fMRI's, MEG's, ERPs

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and PET examine normal and lesioned brains to investigate the neural systems underlying language.

The current linguistic interest in the relationship between the human brain and cognition arose when the view of language as a cognitive system replaced the philosophy of behaviorism which dominated American linguistics in the preceding era. Only then was it possible to conceive of a linguistic theory which would delimit the class of possible grammars to those which are psychologically and neurologically real, i.e. which can be acquired, stored, and accessed in speaking (or signing) and understanding. Chomsky’s interest in the neural bases of language stimulated much of the current linguistic interest in brain and language research, in keeping with the view that “... we may think of the study of mental faculties as actually being a study of the body – specifically the brain – conducted at a certain level of abstraction” with the hope that “we (can) discover how these abstract entities are realized in physical mechanisms of a more ‘fundamental’ nature and how the principles can be grounded in this way” (Chomsky, 1980: 31).

Thus the goal was to write grammars of languages that corresponded to those that were represented in the brains/minds of the speakers rather than simply elegant descriptions of linguistic patterns. The question became sharpened with the widely distributed 1968 pre-publication of Kiparsky’s paper ‘How Abstract is Phonology?’ (Kiparsky, 1973).

From the outset, among those who adopted this view, a distinction was made between knowledge of language and the use of this knowledge in speech production and comprehension – referred to as competence and performance (Chomsky, 1965). Not all linguists agreed with this approach. Some still argue that models of linguistic knowledge are simply descriptions of linguistic data and should not be construed as being ‘psychologically real’ or mental entities (the view of, for example, Firth or Hjelmslev).

The greatest disagreements, regarding competence and performance, however, are among those who accept the view of language as a psychological system but do not distinguish between linguistic representation and processing (cf., e.g. Gazdar et al., 1984). The distinction between competence and performance implies that a generative grammar is not to be considered a linguistic processing model and its principles and/or rules are not to be considered processing rules. No isomorphism is implied between the mental grammar, conceived as an internalized mind/brain state representing one’s knowledge of language, and the processing mechanisms exploiting this knowledge in speech production and comprehension. This view does not exclude such a relation, but the nature of the relationship is considered by those who hold this view to be an empirical question.

The contrary view that explicitly or implicitly equates language with processing influenced much of the early work in psycholinguistics in the early 1960’s, leading to the derivational theory of complexity (DTC) (Fodor et al., 1968). The major assumption of the DTC was that every syntactic rule – phrase structure and transformational rule, particularly – corresponds to a specific psychological operation. According to this hypothesis, then, the more transformations the longer it should take a subject to produce or comprehend an utterance. It is no wonder that the initial
Experimental validation of the hypothesis gave way to an abandonment of this particular psycholinguistic processing model. Not only was this an impossible hypothesis to support, given the changing nature of the theory of grammar and the number of transformational rules posited according to each development in the theory, but "a generative grammar (was not conceived to be) a model for a speaker or a hearer. It attempts (rather) to characterize in the most neutral possible terms the knowledge of the language that provides the basis for actual use of language by a speaker-hearer" (Chomsky, 1965: 9). "A theory of performance" on the other hand "will necessarily incorporate the grammar, but will also attempt to study the many other factors that determine the actual physical signal. Any investigation of grammar is, then, a contribution to the study of performance, but it does not exhaust this study" (Chomsky and Halle, 1968: 110). How the grammar is related to performance and the relationship between the mental grammar and the neurological and psychological mechanisms which access it in speech production and comprehension continues to be a main concern in psycho- and neurolinguistics. The competence/performance distinction and relationship has its parallel in a distinction first made by Claude Bernard in the life sciences. He contrasted "anatomy (the stable morphological organizations or 'structures' with physiology (the dynamic processes by which an organism acts on the outside world or on itself" (Changeux and Dehaene, 1996: 128). Since Bernard, a major goal in neurobiology has been to determine the causal relationships between structure and function. Similarly in neurolinguistics we can state as a goal the establishment of the causal relationships between competence (the mental grammar) and performance (speech behavior), and, in addition, between the anatomy (neural structures) underlying the grammar and physiology (neuromuscular behavior) involved in speech production and comprehension.

2. The mental basis of language

This interest in the neural and mental representation of language has a long history despite the hiatus which occurred in linguistics and psychology during the decades when behaviorism dominated both fields in America. Chomsky's view that "The theory of language is simply that part of human psychology that is concerned with one particular 'mental organ', human language" (Chomsky, 1975) would probably have been embraced by Hermann Paul in the 19th century (1880), who summarized the neo-grammariian school of thought in Europe, emphasizing two main ideas: linguistic history and mentalism. His views of mentalism were similar to that of Wilhelm Wundt (1922) except for Wundt's notion of a group-mind which transcends the individual mind. According to Paul, "All psychical processes come to their fulfillment in individual minds, and nowhere else". Speakers, according to him, transmit their ideas by physical processes (performance). He differentiated mental processes and transmittal processes by physical means and believed that many mental processes are unconscious. Paul suggested that a large realm of unconscious processes includes phenomena related to language; all the manifestations of speech activity are stored in the unconscious mind, seen as a very complex mental structure.
consisting in manifold interlaced groups of ideas and stored images. The years of research in linguistics, psycholinguistics, and neurolinguistics provide evidence strongly supporting Paul's ideas.

These ideas were paralleled in the early years of Leonard Bloomfield. In the preface to his *Introduction to the Study of Language* published in 1914, Bloomfield's statement — "I depend entirely on Wundt for my psychology" — reflected his belief in "the mental basis of language". It is rather surprising that psycholinguistic research did not develop during Bloomfield's early mentalist period. It was a period which also saw the development of major efforts on the part of neurologists working with aphasic patients to understand the neural basis of deviant language.

But the role of linguistics in psychology was thwarted in the years from 1933 until 1957, following Bloomfield's rejection of Wundt under the influence of the psychologist, Albert Paul Weiss (1925), a disciple of the behaviorist Watson (Bloomfield, 1933).

Weiss, in a paper published in the first volume of *Language* in 1925, applied the behaviorist 'stimulus/response' theory to language. According to him, the behavior of any organism, i.e. all human and animal behavior, is a series of responses. Language, as shown in Fig. 1, is both a response and a stimulus, but does not exist except as one or the other. His views can be summed up in a few quotations: "In man ... specific types of external stimuli, in addition to releasing specific manual responses, also release verbal responses, and these become for other individuals, substitute stimuli for the original stimuli’” (p. 53). “Human behavior is reaction to present and past stimuli. No non-physical, non-biological forces need be postulated ... to explain language behavior. The assumption of a mental force, or a mind, is gratuitous” (pp. 56–57). Such a position leaves no room for a mental grammar that represents linguistic knowledge abstracted away from and distinct from stimulus/response behavior. Nor can such a view possibly account for the child's acquisition of a grammar which is not transparent in the verbal stimuli she receives.

LANGUAGE

\[
S----r----s----R
---r----r----R
\]

(pRACTICAL
stimulus)

(VERBAL
response)

(SUBSTITUTE
stimulus)

(PHYSICAL, PRACTICAL
response: action)

Fig. 1. Language: both a response and a stimulus.

Bloomfield took over Weiss's approach completely as shown by his S----r----s----R Jack and Jill diagram in *Language*. He viewed meaning as the practical (behavioral) stimulus and practical response connected with a given act of speech. i.e. an environmental definition of meaning, and he "defined the meaning of a linguistic form as the situation in which the speaker utters it and the response which it calls forth in the hearer" (p. 138) and rejected mentalism and the concept of mind:
"The mentalistic theory supposes that the variability of human conduct is due to the interference of some non-physical factor, a spirit, or will, or mind ... that is present in every human being. This spirit, according to the mentalistic view, is entirely different from material things and accordingly follows some other kind of causation or perhaps none at all ... [t]his mind or will does not follow the patterns of succession (cause and effect sequences) of the material world." (Bloomfield, 1933: 138)

This is a view of mentalism not accepted by those who believe in the material reality of the human mind. Mentalism does not negate causation. Furthermore, Bloomfield's mechanism reflected a narrow view of what is 'real' or 'physical', a view that could only prevent an investigation of the mental grammar and of its relationship to psychological processing. By 1914, in the physical sciences the quantum theory and the theory of relativity had dealt severe blows to mechanism, relegating it to the status of an approximation which was valid under a rather restricted set of conditions. The famous mechanistic conclusion of Laplace (1886) formulated in the early part of the 19th century and destined to live a few scant years in physics found a rebirth in linguistics in the 1933 publication of Language.

But as Anderson (1985) points out, Bloomfield's aim was to establish a science of linguistics, based on objective data, subject to empirical verification. This was obviously a reputable goal and Bloomfield's meticulous and insightful analyses of languages make it all the more unfortunate that he narrowed the kinds of questions that were of concern to him and to linguistics during the period of his greatest influence. For certainly, the notion of competence as "a certain system of knowledge, represented somehow in the mind, and ultimately in the brain in some physical configuration" (Chomsky, 1988) which has been "acquired by the learner and used by the speaker-hearer" (Chomsky, 1986) could have no place in pre-Chomskyan American linguistics in which language was defined as "a set of utterances, ... [a]n utterance [as] ... an act of speech" and an act of speech as "an item of human behavior with certain physiological and sociological characteristics" (Hockett, 1942).

With the demise of behaviorism and the restoration of the view of language as a cognitive system, it was possible to investigate both the mind and the brain and to do this by a study of language which, in the words of the physiologist Fournier, in 1877, "is the only window through which the physiologist can view the cerebral life". (Given the new technologies for the study of brain and behavior we can now also "view the cerebral life" by looking at other non-linguistic cognitive systems.)

Furthermore, the study of language makes it possible for the neurologist to investigate the nature of the human brain which can not be done by studying animal brains and behavior, as pointed out by the great late neurologist, Geschwind (1979):

"The nervous system of all animals have a number of basic functions in common, most notably the control of movement and the analysis of sensation. What distinguishes the human brain is the variety of more specialized activities it is capable of learning. The preeminent example is language."

The human brain appears to be particularly suited for the acquisition and use of the kinds of languages humans can learn, and, in fact, uniquely suited for this ability, as shown by the failure of the many attempts to teach language to other primates,
contrary to some recent claims. To state that the human brain is qualitatively, as well as quantitatively different, is not to deprecate non-human primates, just as recognition that certain species of song birds are innately endowed with the ability to produce songs without any exposure is not to demean the human animal who does not have this ability.

3. The neural basis of language and the modularity question

The question as to the nature of the neural basis for language acquisition and use continues to be investigated and debated. Philosophers argue over the notion of innate ideas; linguists, psychologists and neurologists argue over the neurobiology of language. Central to the argument is the issue of whether language is a genetically determined independent autonomous system or a cognitive system derived from more general human intelligence. There is growing empirical evidence to support the autonomy view of language as a separate ‘organ’ (Chomsky, 1986), independent of general cognitive abilities and of other cognitive systems with which it interacts.

Some of the evidence comes from the fact that focal injuries to different parts of the brain lead to selective cognitive disorders. That is, localized lesions reveal a dissociation of the processing of different cognitive systems, and, in fact, of the functional components of language itself. If one ability is retained and another damaged, one can conclude that these are separate systems or distinct processing mechanisms. The existence of ‘double dissociations’ make the case for the modularity of the brain even stronger. As stated by Caplan (1987: 37), “In a single dissociation, a patient is shown to have retained one ability and lost another. In a double dissociation we are dealing with two patients, one of whom has retained one ability and lost a second, and the other of whom has retained this second ability while losing the first”.

3.1. Historical overview of the language ‘module’

Recognition of this kind of dissociation and interest in the neural basis of language and cognition goes back at least 2000 years. One finds references to language loss following brain injury in both the Old and New Testaments. In the New Testament, St. Luke reports that Zacharias was unable to speak but retained his ability to write. This record of the dissociation between speech and writing predates the modern observations of the independence of linguistic components by two millennia.

Medical records written on papyrus before 1700 B.C.E. by Egyptian surgeons noted that language could be lost while other cognitive functions were retained. And for over five centuries, from ca. 400 B.C.E. to 135 C.E., the Hippocratic Treatises of the Graeco-Roman physicians revealed an impressive understanding of the modular role of the brain regarding language. They report that language and speech disorders result from cerebral trauma or brain disease and that loss of speech often occurred simultaneously with paralysis of the right side of the body (Riese, 1959). Furthermore, they pointed out that language loss may occur without the loss of speech
(articulation) and vice versa – double dissociation, recognizing the distinction between linguistic competence and performance.

They were aware that language and speech disorders result from cerebral trauma or brain disease and noted that loss of speech often occurred simultaneously with paralysis of the right side of the body. These ancient neurologists may even have understood the nature of contralateral motor control, i.e. that the right side of the brain controls the left side of the body and vice versa; they state, for example, that "an incised wound in one temple produces a spasm in the opposite side of the body". But, as pointed out by Benton and Joynt (1960), while "it is seen that the essential ingredients for relating aphasia to a lesion of the left hemisphere were present in the Hippocratic writings ... there is no evidence that the correlation was actually made".

Other writers and scholars of the ancient classical world also reveal a knowledge of language loss, i.e. aphasia; an early reference to alexia and agraphia – the loss of the ability to read and/or write following brain trauma – occurs in a paper of the Latin author, Valerius Maximus (ca. 30 C.E), who writes about an Athenian scholar who "lost his memory of letters" after being struck in the head with a stone. Pliny (23–79 C.E.) also refers to this same Athenian noting that "... with the stroke of a stone, (he) fell presently to forget his letters onely, and could read no more; otherwise his memory served him well ynough" (Benton and Joynt, 1960), showing that the 'modular conception of the mind' did not arise full blown from the head of Fodor (1983).

It has been suggested that the skeptic philosopher, Sextus Empiricus (ca. 200 CE) was the first to use the term 'aphasia', although the meaning he gave it had no reference to clinical language loss (Patrick, 1899).

Neither Plato nor Aristotle were as observant or insightful. Plato did not even recognize the role of the brain in consciousness or mental functions, and Aristotle ingeniously but wrongly viewed the brain as a cold sponge whose primary function is to cool the blood (Clarke and O'Malley, 1968). Aristotle did believe the mind was composed of specified primary faculties (i.e. the Common Sense, Imagination and Phantasy, Conceptual Thought and Reasoning, and Memory) and this view held sway from the classical period through the renaissance. Herophilus of Alexandria (ca. 300 BCE) located these cognitive functions in the ventricular system of the brain and this notion guided the work of all the major anatomists in this period.

Clinical descriptive reports of patients with language deficits and preserved non-linguistic cognitive systems were published from the 15th to the 18th century. In 1481, Antonio Guainerio's description of a patient who "rarely or never recalled the right name of anyone" was, according to Benton and Joynt (1960) the first reference to a case of anomia.

Descriptions of other kinds of aphasic disorders were reported in the 15th century by Baverius de Vaveriis, Paracelsus, Francisco Arceo, and the anatomist, Nicolo Massa.

In 1585, Johann Schenck von Grafenberg reported on a patient whose speech production was severely impaired (limited to producing only a few words) but whose comprehension seemed to be intact, and concluded that this was a case of central
brain damage rather than tongue paralysis: "I have observed in many cases of ... major diseases of the brain that, although the tongue was not paralyzed, the patient could not speak because, the faculty of memory being abolished, the words were not produced" (Benton and Joynt, 1960).

In 1676, Johann Schmidt presented a case study of a patient suffering from dyslexia (loss of ability to read) who nevertheless preserved his ability to write, and patients who could "write to dictation but could not read back what they had written" (Arbib et al., 1982).

Carl Linnaeus in 1745 published a case study of a man suffering from jargon aphasia, who spoke "as it were a foreign language, having his own names for all words" (Benton and Joynt, 1960).

An important observation regarding word substitution errors was made by Ryklof Michel von Goens in 1789 in his reference to a patient which he described as follows: "After an illness, she was suddenly afflicted with a forgetting, or, rather, an incapacity or confusion of speech ... If she desired a chair, she would ask for a table ... Sometimes she herself perceived that she misnamed objects; at other times, she was annoyed when a fan, which she had asked for, was brought to her, instead of the bonnet, which she thought she had requestcd" (Crichton, 1798; Winslow, 1868). The description of this and other similarly afflicted patients reveals that they substituted words that were semantically or phonologically similar to the intended ones, producing errors similar to normal word substitution errors such as the substitution of legs for 'tires' or rent for 'alimony' (Fromkin, 1971) or to those produced by agnosia patients.

In 1770, Johann Gesner published a summary of earlier aphasia studies, adding many of his own observations. Included were descriptions of jargon aphasia in which the patient not only produced neologisms but in writing spelled words using orthography which reflected the phonology of the spoken jargon. He also discussed bilingual asymmetry in which, for example, an abbot, following brain damage, retained his ability to read Latin but not German (Benton, 1981).

He also described an acquired dyslexic patient who, in reading aloud, substituted semantically similar words, not unlike the patient of Newcombe and Marshall (1981, 1984) who read 'cake' for bun, 'poison' for arsenic and 'pixie' for gnome. (Note the similarity of word substitutions in anomic and acquired dyslexic patients.)

Gesner did not attribute these language difficulties to either general intellectual deficits or loss of memory 'in general' but instead to a specific impairment to language memory, stating: "just as some verbal powers can become weakened without injury to others, memory also can be specifically impaired to a greater or lesser degree with respect to only certain classes of ideas".

However, Gesner failed to conclude that the neuro-anatomy of the brain underlay cognitive functions, since he also wrote: "The vessels of the brain are surely not arranged in accordance with categories of ideas and therefore it is incomprehensible that these categories could correspond to areas of destruction" (as quoted in Benton, 1981). This is a view with which Chomsky would take issue as in his statement that "... there seems to be little reason to insist that the brain is unique in the biological world in that it is unstructured and undifferentiated" referring to David Hubel 's
work on the physical basis for mammalian vision. And it is a view countered by his own cases and those occurring too regularly after brain damage. (See below for further discussion on this issue.)

Franz Joseph Gall (1791, 1810) may be considered the originator of the explicit modularity view. He argued against the view that the brain was an unstructured organ and in favor of discrete anatomical areas (or cortical organs) which were directly responsible for specific cognitive functions (or faculties), including language. Gall’s support for his ‘modularity’ view resulted in his being expelled from Vienna in 1802 and excommunicated in 1817. In the long run, however, Gall finally “convinced the scientific community that ‘the brain is the organ of the mind’ ” (Young, 1970).

Paul Broca is the name most associated with the view that language is a function of the left hemisphere, a position that is so accepted today it even served as a question for the TV program Jeopardy (e.g. Answer: The part of human anatomy which controls language. Question: What is the left side of the brain?). In 1861, Broca presented autopsy evidence showing that a localized (anterior) left hemisphere lesion (now, not surprisingly called Broca’s area) resulted in a loss of ability to speak, whereas focal lesions in similar parts of the right brain did not. He managed to convince his Parisian audience (and most of neurology) that “On parle avec l’hémisphère gauche”.

But in 1874, Carl Wernicke pointed out that damage in the posterior portion of the left temporal lobe (Wernicke’s area) results in a different form of language breakdown than that occurring after damage to the frontal cortex (now called Broca’s area). These different kinds of acquired language loss – aphasias – continue to be corroborated. But current research shows that the brain areas involved in language processing are greater than previously, see below.

The speech output of Broca’s aphasia patients is characterized by word-finding pauses, loss of grammatical morphemes, and quite often, disturbed word order. Auditory comprehension for colloquial conversation gives the impression of being generally good, although controlled testing reveals considerable impairments. The term agrammatism is almost synonymous with Broca’s aphasia, although some patients with lesions in Broca’s area are not agrammatic and some agrammatics would not classify neurologically as Broca’s aphasics.

Wernicke’s aphasia patients, on the other hand, produce fluent speech with good intonation and pronunciation, but with many word substitutions (both semantically similar and dissimilar), neologisms as well as phonological errors. They also show comprehension difficulties.

One Wernicke’s aphasia patient, for example, replied to a question about his health with: “I felt worse because I can no longer keep in mind from the mind of the minds to keep me from mind and up to the ear which can be to find among ourselves” (Kriendler et al., 1971). Another patient, when asked about his poor vision said: “My wires don’t hire right”. And an aphasic physician, asked if he was a doctor, replied: “Me? Yes, sir, I’m, a male demaploze on my own. I still know my tubaboy what for I have that’s gone hell and some of them go”. One aphasic described a fork as “a need for a schedule” and a spoon as “How many schemes on your throat”.
These fluent but uninterpretable utterances are very different from the Broca aphasic’s answer when asked what brought him to the hospital: “Yes – ah – Monday – ah – Dad and P.H. (the patient’s name) and Dad ... hospital. Two ... ah doctors ..., and ah ... thirty minutes ... and yes ... ah ... hospital. And, er Wednesday ... nine o’clock and eh Thursday, ten o’clock ... doctors. Two doctors ... and ah ... teeth. Yeah ... fine” (Badecker and Caramazza, 1985).

Although one finds general confirmation of the localized sites which result in distinct aphasias, one should not expect a one to one – aphasia type to brain site – correlation, as was pointed out in a now classic paper of Bogen’s entitled, ‘Where is Wemicke’s Area’ in which he demonstrates a wide variety of lesion sites in autopsy examinations of the brains of patients classified as having Wernicke’s aphasia (Bogen and Bogen, 1976).

Generally, however, the fact that different lesion sites produce differential language breakdowns reinforced the search for localized areas of the brain and led to the construction of diagrams and models with boxes representing anatomical and functional centers and arrows connections between them.

Wernicke insisted that these models be consistent with theories in both neuroscience and psychology (Arbib and Caplan, 1979). But given the state of the art and science in the late nineteenth century this constraint did not necessarily lead to new insights. The models did account for both lesion sites and aphasia syndromes in a descriptively adequate way, but did not go beyond such description to reach a level of explanatory adequacy. This is exemplified by Lichtheim’s 1885 model, which did little more than list the linguistic impairments that clustered to form certain aphasic syndromes. For example, motor aphasia was characterized by Lichtheim as impaired speech production with intact speech comprehension whereas he described transcortical sensory aphasia as a loss of comprehension with retention of spontaneous and repetitive speech. A major problem in Lichtheim’s approach was that he treated speech production and speech comprehension as separate and unanalyzable processes and made no attempt to relate different aphasic symptoms to the separate components of language.

Among the critics of the model makers was Pick (1913), who showed great linguistic sophistication for his time by observing the distinction between lexical and grammatical morphemes. He pointed out that Broca’s aphasics had difficulties in retrieving or using inflectional affixes and grammatical formatives while apparently having few problems with nouns, verbs, and adjectives.

The great Soviet aphasiologist, Luria (1947), in his Traumatic Aphasia suggested that it was important to propose “concrete suggestions as to the character of the disorders which are introduced into various functional systems by damage to specific focal areas”. Luria attempted to account for the fact that the kind of speech or language deficit that resulted from brain injury was dependent on the lesion site, and he designated specific psycho-physiological functions to distinct areas of the brain and applied these functions to the analysis of language. Luria’s system is an interactive modular system which relates psychological processes to the physiological mechanisms which govern motor and sensory functions. Luria recognized that certain areas of the brain were related to speech but, because he accepted the Pavlovian view of
language as a “second symbol system”, he did not posit neurophysiological or neuropsychological mechanisms that were specific only to speech or language.

Roman Jakobson (1940, 1955, 1956, 1964, 1968, 1970) was the first linguist to apply linguistic theory to aphasia research to support his notions of phonological markedness and then later his views of syntactic theory. He followed up the earlier insights of Baudouin de Courtenay in 1895 and Ferdinand de Saussure in 1879, both of whom had expressed the belief that a study of language pathology could contribute to linguistics. Jakobson also stressed the other side of the coin, the contribution of linguistics to the study of aphasia, stating that “any description and classification of aphasic syndromes must begin with the question of what aspects of language are impaired” (Jakobson, 1956: 239). He despaired over the fact that “the linguist’s contribution to the investigation of aphasia is still ignored” and also believed that “Linguists are also responsible for the delay in undertaking a joint inquiry into aphasia”. Jakobson would have been pleased to have seen the developments that have taken place in the last number of years, which have brought about increased “cooperation of linguists, psychologists, psychiatrists, neurologists” (1956: 229).

In his 1941 monograph *Child Language, Aphasia, and Phonological Universals*, Jakobson discussed the parallels between child language acquisition and the loss of linguistic knowledge in aphasia. His views on aphasia reflected the theory of linguistics connected with the Prague Linguistic Circle, of which he was a co-founder in 1926. The notion of markedness was central to his views on both child language and aphasia. Drawing on a posited hierarchy of phonological distinctive features, Jakobson suggested that the more highly marked segments would be lost first in aphasia and acquired last in child language. This hypothesis, known as the Regression Hypothesis, was also applied to non-phonological components of the grammar: “A component ... (e.g. a part of speech, a case, a verbal category) which, with respect to some other component (another part of speech, case, or verbal category) proves to be necessarily secondary, arises in children after, disappears in aphasics before, and does not occur in the languages of the world without the corresponding primary component” (Jakobson [1941] 1968: 92). His hypothesis is still the basis for much research while not completely borne out in either acquisition or aphasia studies. It illustrates Jakobson’s use of linguistic theory in his attempt to explain rather than simply describe aphasic disorders.

Jakobson’s analysis of fluent (Wernicke’s) and non-fluent (Broca’s) aphasia was based on the Praguian opposition between paradigmatic and syntagmatic aspects of language, respectively. He referred to the paradigmatic disorder of fluent aphasia and anomia (word-finding difficulties) as a ‘similarity disorder’, and syntagmatic non-fluent, Broca’s or agrammatic aphasia as a ‘continuity disorder’. He noted that in the syntagmatic deficit of agrammatism (the syntagmatic deficit), the grammatical formatives that relate content words to each other are deleted or lost. The loss of grammatical morphemes and the differences between lexical content and grammatical words was noted by others (e.g. Pick) but the cause of this deficit was often attributed to the physical difficulties that patients had in the act of speaking. Jakobson rejected this explanation pointing out that in the speech of agrammatics, in addi-
tion to the destruction of syntactic relations due to the deletion of inflections and grammatical words many lexical items were nominalized, and unmarked nominative case nouns and verb infinitives substituted for the forms produced by normals. He thus insisted that one needed to turn to linguistic explanations for what occurred. Jakobson's view against the economy of effort explanation was accepted by Luria (1970), and also by other aphasiologists (cf. e.g. Goodglass et al., 1972).

As pointed out by Grodzinsky (1990), linguistic approaches to the study of language disorders have been based either on traditional structuralism (Jakobson, 1941, 1964; Luria, 1947) or more recently on modern generative theory (Cornell et al., 1993; Fromkin, 1995b; Grodzinsky, 1984; Kean, 1977; Mauner et al., 1993, among others).

Except for Jakobson, few linguists followed up the early interest in linguistics by neurologists who drew on linguistic concepts in their investigations of aphasia. Blumstein (1973) was an early exception. Luria (1947), a neurologist, was influenced by and interested in applying linguistic concepts to explain different forms of language breakdown and the relationship between brain and language. Such an interest was also shown by Goldstein (1948) (with different interpretations of the data). Even much earlier, the years which followed Broca's and Wernicke's discoveries stimulated neurologists throughout the world such as Broadbent (1879) and Bastian (1887) in Britain, Pick (1913) and Salomon (1914) in Germany, and Moutier (1908) in France to apply linguistic analyses to aphasia data.

It is not surprising that Jakobson's pioneering work in this area lay dormant for many years, since, as mentioned above, the study of the mind and brain was outside the scope of linguistic research in the pre-Chomsky paradigm in America. Linguists were not encouraged to investigate the mental basis of brain states in a period when non-linguists were criticized for "constantly forgetting that a speaker is making noise, and credit him, instead, with the possession of impalpable 'ideas'". Linguists, instead were advised "to show, in detail, that the speaker has no 'ideas' and that the noise is sufficient" (Bloomfield, 1926).

4. The evidence for modularity

Once Chomsky put the mind back into the brain, it was possible for linguists to ask questions about the brain/mind/language interface. Dramatic changes took place in cognitive psychology and in the relatively new area of psycholinguistics and laid the ground for the development of neurolinguistics – the study of the neurobiology of language. As the psychologist George Miller noted: “I now believe that mind is something more than a four-letter, Anglo-Saxon word – human minds exist and it is our job as psychologists to study them” (Miller, 1962).

In addition, the distinction between competence and performance made it possible to investigate both and to finally understand how it was possible for patients to perform a linguistic task in one modality but not in another, a fact which is accounted for if one posits an intact competence which is neutral as to production and comprehension. This observation led Weigl and Bierwisch (1970) to suggest that "aphasia
syndromes in general are to be understood as disturbances of complexes of components or subcomponents of the system of performance, while the underlying competence remains intact”. They did, however, suggest a possible exception to this – agrammatism when it effects both speech and comprehension. They conclude that “competence and performance must be psychologically different aspects of the general phenomenon of speech behaviour ... the distinction ... is not merely a heuristic or methodological assumption but reflects a fact that can be established neuropsychologically”.

The search for the biological basis of the mental grammar and the language faculty underlies much neurolinguistic research, and was spurred on by Lenneberg’s seminal work on this question (Lenneberg, 1967).

4.1. Aphasia evidence for modularity

The current linguistic interest in aphasia is partially due to the fact that focal injuries to different parts of the brain not only lead to selective cognitive disorders, but may also lead to damage of distinct components of language or of specific linguistic processing mechanisms.

Following damage to different parts of the left hemisphere, syntax may be impaired with phonology retained, for example, or vice versa as is the case of jargon aphasics, who while producing many neologisms, properly inflect them as shown in the following examples from Buckingham (1981):

(1) The leg vilted from here down.
(2) This is the krebekacks where the frejes get out after the chew.

The aphasic disorder referred to as agrammatism – a term first used by Pick in 1913 – has been of particular interest in the attempts to understand the nature of abnormal as well as normal language. Pick observed that the sentences produced by some Broca’s aphasics were ungrammatical although the patients seemed to be aware of their ‘intended preverbal meaning’. As noted above, Pick also showed linguistic sophistication when he distinguished between lexical and grammatical formatives. This distinction has been revealed in certain patients after brain damage as shown in the different reading responses to lexical and grammatical words of an acquired dyslexic patient of Newcombe and Marshall (1981, 1984; Marshall and Newcombe, 1973). GR, as he is referred to in the literature, makes numerous errors in reading lexical content words, substituting words that are in the same semantic class. Thus for example, he read bean as ‘soup’, hour as ‘time’ and hymn as ‘Bible’. He was, however, totally unable to read any of the grammatical formatives which are homonymous with the lexical content words, e.g. been ([bin] in British English) or our or him. When shown a printed word of a grammatical morpheme he would either answer “no”; when shown the word would he responded “I hate those little words” although previously he had read wood correctly, a ‘littler’ word than would. It appears that GR had a tacit knowledge of the distinction between the two classes of words as well as an inability to access that part of the lexicon which includes the grammatical morphemes.
Agrammatism was originally considered to be a disorder of speech production in which some Broca's aphasia patients delete such grammatical formatives like auxiliaries, pronouns, determiners and some prepositions, and inflectional affixes. Up until the 1970's, it was believed that the comprehension of these patients was intact, thus suggesting that the disorder was due to a problem in processing grammatical formatives during speech production. However, controlled experimental studies showed that where comprehension depends on the syntactic structure of sentences, syntactic comprehension deficits (also referred to as asyntactic comprehension) also arise in these patients (Caramazza and Zurif, 1976; Heilman and Scholes, 1976; Kean, 1985).

The observation that asyntactic comprehension occurs with agrammatical production led to the view that agrammatism is a central deficit of the syntactic component of the grammar (Linebarger et al., 1983; Linebarger, 1989; Luketela et al., 1986; Shankweiler et al., 1989). More recently, less global theories of the deficit have been proposed which focus on some particular aspect of syntactic processing as the locus of failure (Cornell et al., 1993; Mauner et al., 1993; Grodzinsky, 1984, 1986, 1990; Hickoc, 1992; Fromkin, 1995a).

While linguists may not be specifically interested in which specific lesion sites produce different aphasic symptoms, the fact that there are such sites and that they are correlated with different linguistic difficulties is of interest. The neural architecture which is correlated with the processing of different types of aphasia and cognitive disorders is revealed by Magnetic Resonant Imaging techniques (MRI) and Positron Emission Tomography (PET).

4.2. ERP evidence

A most dramatic finding was reported on by Neville and co-researchers in experiments involving event-related potentials or ERP's. Such experiments study scalp electrical activity as recorded from electrodes placed on the scalp according to a universally agreed on set of positions following different stimuli presented to the subjects. These particular studies were concerned with whether language comprehension processes are decomposable into separate subsystems or modules, including distinct systems for semantic and syntactic processing. They found that ERP's "to syntactically well-formed but semantically anomalous sentences produced a pattern of brain activity that is distinct in timing and distribution from the patterns elicited by syntactically deviant sentences, and further, that different types of syntactic deviance produced distinct ERP patterns". As in prior research, the semantic anomalies sentences such as in (3) produced a negative potential, N400, that was bilaterally distributed and was largest over posterior regions. The phrase structure violations such as in (4) and (5) enhanced the N125 response over anterior regions of the left hemisphere, and elicited a negative response (300–500 msec) over temporal and parietal regions of the left hemisphere. The specific types of syntactic violations such as specificity constraints and subjacency constraints elicited distinct timing and distribution responses.
They conclude that "the distinct timing and distribution of these effects provide biological support for theories that distinguish between these types of grammatical rules and constraints and more generally for the proposal that semantic and grammatical processes are distinct subsystems within the language faculty.

4.3. Genetic evidence

There is ongoing research looking for the genetic basis for the human language ability. Gopnik (1992) and Gopnik and Crag0 (1991) reported on a study of a family in which, of 30 members across three generations, 16 suffered from the inability to acquire morpho-syntactic rules. Otherwise, the 16 were normal as were the unaffected family members. They suggest that this reflects a genetic based syntactic ability, which some linguists would refer to as Universal Grammar: "There is now empirical evidence that shows that a single dominant gene is associated with the ability to construct symbolic rules in the grammar". They add "Converging evidence from our study and several other recent studies has established that this genetic disorder affects the normal development of language, but does not effect other cognitive functions".

We still await, however, the actual dominant gene to be discovered biologically and there are many questions that have been raised about these conclusions. There are, however, many other studies suggesting that Specific Language Impairments (SLI) are hereditary, showing up in members of the same family, although this in itself does not mean that the deficit is hereditary.

But, whether one looks at the selective impairment or preservation of language abilities in child development or in the mature brain one can find little to support the view of language as derivative of some general intellectual capacity.

4.4. Evidence from childhood hemiplegics and hemidecorticates

Children who have suffered prenatal, perinatal, or childhood left hemisphere lesions provide evidence that the brain is differentiated in regard to language and non-language abilities. Children with acquired unilateral lesions of the brain, and who retain both hemispheres (one normal and one diseased) – called hemiplegic – were studied by Dennis and Whitaker (1976). The children with left damaged hemispheres showed deficiency in language acquisition and performance, with the greatest impairments in their syntactic ability.

In studies of hemidecorticate children, those with left hemispheres removed either within the first year of life or later in childhood, Dennis and her colleagues (1980) found that the IQ and cognitive skills were equivalent in both left and right hemidecorticates, but in visual-spatial function, the left-hemidecorticates outperform the right, and in language, the right-hemidecorticates outstrip the left. In addition,
both hemispheres appear to be equivalent in the ability to acquire the use of the sense and referential structure of common words, but the right hemisphere again shows syntactic deficits.

Such findings refute the notion that in the infant language derives from general cognitive ability but becomes independent in the mature brain.

4.5. Asymmetry of abilities

The case for an innate language faculty distinct from general intelligence is evidenced strongly by the numerous cases of intellectually handicapped individuals, traditionally known as ‘idiot savants’ (but more recently simply called ‘savants’) who, despite their disabilities in certain spheres show remarkable talents in others. The classic cases include individuals who, without the required ability to take care of themselves, are superb musicians, or artists, or draftsmen. Some of the most famous savants are human calculators who can perform complex arithmetic processes at phenomenal speed.

Until recently, most of the savants have been reported to be linguistically handicapped. While such cases strongly argue for domain specific abilities and suggest that certain talents do not require general intelligence, they do not decisively respond to the suggestion that language is one ability that is derivative of general cognitive abilities, if such individuals show little linguistic knowledge.

A more telling case can be made if there are individuals who have acquired the highly complex system which we call grammar, without parallel abilities of equal complexity. There are now a number of such studies of children who have few cognitive skills and virtually no ability to utilize language in sustained meaningful communication and yet have extensive mastery of linguistic structure. Yamada (1990) reports on one severely retarded young woman named Laura, with a nonverbal IQ of 41–44, lacking almost all number concepts including basic counting principles, drawing at a preschool level, and processing an auditory memory span limited to three units, who at the age of 16 produced syntactically complex sentences like “She does paintings, this really good friend of the kids who I went to school with last year and really loved”.

Although Laura produces sentences with multiple embeddings, can conjoin verb phrases, produce passives, inflect verbs for number and person to agree with the grammatical subject, and forms past tenses when the time adverbial structurally refers to a previous time, she can not add 2+2, read nor write nor tell time. She does not know who the president of the US is or what country she lives in and does not know her own age. Her drawings of humans resemble potatoes with stick arms and legs. Yet, in a sentence imitation task she both detected and corrected surface syntactic and morphological errors, but she is unable to tie her shoes.

Laura is but one of many examples of children who display well-developed phonological, morphological and syntactic linguistic abilities, seemingly less developed lexical, semantic, or referential aspects of language, and deficits in non-linguistic cognitive development. A number of such cases, studied at UCLA by Curtiss and Yamada (1982) and others, have been reported. One of their cases, Anthony, at
the age of 5 yrs 2 months is reported to have had a Leiter IQ of 50 and a mental age of 2 years 9 months. His non-linguistic cognitive tests scored below all the norms and or below the 2-year-old level, contrasting sharply with his high scores on language tests and his spontaneous speech, in which he used 61 of the 68 different elements and structures analyzed, including infinitival and sentential complements, relative clauses and other subordinate clauses. They conclude: “His ability to use a wide range of syntactic devices ... to encode his limited and confused thoughts, illustrates the discrepancy between Anthony’s grammatical knowledge and his conceptual/cognitive knowledge”.

These cases demonstrating that syntax can be acquired even with severely impaired or limited conceptual and cognitive development are further supported by the studies of children with internal hydrocephaly who Cromer (1991) refers to as having the ‘chatterbox syndrome’ – they talk excessively but their speech lacks content. One case studied extensively by Cromer referred to in the literature as D.H, whose “speech is fluent, appropriate and not bizarre, is filled with complex syntactic forms, shows the correct use of semantic constraints, an extensive vocabulary, and incorporates the use of normal pragmatic devices. But on a large variety of standardized tests she performs at the severely retarded level and functions in everyday life at the retarded level. She has been unable to learn to read and write in her late teenage years and cannot add or handle money, yet D.H. performs almost without error on grammaticality judgments”. Cromer’s conclusion was that “language acquisition proceeds on a different course, basically independent of general cognitive development” and suggests that such cases “seem to show that general cognitive mechanisms are neither necessary nor sufficient for the growth of language”.

Any notion that linguistic ability results simply from communicative abilities or develops to serve communication functions is also negated by studies of Blank et al. (1979), which concerns a child with fully developed structural linguistic knowledge but with almost a total absence of communicative skills, and by Cromer, who showed a dissociation between pragmatic and syntactic abilities. Similar cases of schizophrenic and autistic children are also reported. It thus seems clear that the ability to communicate in a social setting depends on different cognitive skills than the acquisition of language.

Interesting studies of genetic disorders such as Turner’s syndrome and William’s syndrome also reveal domain specificity. Five out of six children with Turner’s syndrome (a chromosomal anomaly) studied by Curtiss and Yamada (1981) and Curtiss et al. (1982) revealed normal or advanced language simultaneous with serious non-linguistic cognitive deficits. Similarly, the studies by Bellugi and her colleagues (1988) of the language development in William’s syndrome children reveal a unique, behavioral profile in which there appears to be a selective preservation of linguistic functions in the face of severe general cognitive deficits.

A similar and perhaps even more dramatic case is reported on by Smith and Tsimpli (1995) of Christopher, a 34-year-old man, who is institutionalized because he is unable to take care of himself. As Smith and Tsimpli report, he finds the tasks of buttoning a shirt, cutting his finger-nails or vacuuming the carpet too difficult. Yet when given written texts in some 15 or 16 languages he translates them immediately.
into English. The languages include Germanic languages like Danish, Dutch, and German, Romance languages like French, Italian, Portuguese, Spanish, as well as Polish, Finnish, Greek, Hindi, Turkish, and Welsh. He has a low non-verbal performance IQ (75 or 76 as compared to the average of 100) on the Raven’s Matrices tests and 42, 67, and 52 on the performance part of the Wechsler test as opposed to 89, 102, and 98 on the verbal part of the same test.

Christopher’s conversation is quite laconic, repetitive and filled with parts that appear to have been memorized from textbooks. Smith and Tsimpli therefore conducted controlled experiments to test his command of English syntax and pragmatics and syntax of other languages.

Smith and Tsimpli conclude, after a meticulous investigation of Christopher’s knowledge of English, that his “linguistic competence in his first language is as rich and as sophisticated as that of any native speaker. Moreover, despite his intellectual deficit, this linguistic knowledge is integrated into his general cognitive function sufficiently to allow him to pass some tests of his pragmatic (inferential) ability successfully. None the less, it is clear that some linguistic phenomena lie outside his capabilities [and] that these are not due to a deficit in his grammar, but rather that they arise from processing difficulties which involve the interaction of his modular, linguistic faculty with central system operations” (1995: 79).

This book provides insights into other aspects of the modularity question including the acquisition of a second language.

4.6. Evidence from sign language

Perhaps the most telling findings on the brain/language relationship which support the conception of the brain and mind as consisting of neurological and cognitive interactive but autonomous modules is revealed by the exciting research on sign language conducted by Bellugi and her colleagues (Bellugi et al., 1988; Poizner et al., 1987). The linguistic study of sign language over the last 25 years has already revealed that these languages of the deaf have all the crucial properties common to all spoken languages, including highly abstract underlying grammatical and formal principles.

Since the same abstract linguistic principles underlie all human languages – spoken or signed – regardless of the motor and perceptual mechanisms which are used in their expression, it is not surprising that deaf patients show aphasia for sign language similar to the language breakdown in hearing aphasics following damage to the left hemisphere. Furthermore, while these patients show marked sign language deficits, they can correctly process non-language visual-spatial relationships. The left cerebral hemisphere is thus not dominant for speech, as had been suggested, but for language, the cognitive system underlying both speech and sign. Hearing and speech are not necessary for the development of left hemispheric specialization for language.

This has been a crucial point in determining that the left hemisphere specialization in language acquisition is not due to its capacity for fine auditory analysis, but for language analysis per se. As long as linguists concerned themselves only with spo-
ken languages, there was no way to separate what is essential to the linguistic cognitive system from the constraints imposed, productively and perceptually, by the auditory-vocal modality, that is, to discover what the genetically, biologically determined linguistic ability of the human brain is.

4.7. Distinct categories of conceptual knowledge and lexical categories

Dramatic evidence for the separation of cognitive modules is provided by the neurological and behavioral findings that auditory agnosia (inability to recognize sounds), color agnosia, prosopagnosia (loss of the ability to recognize familiar faces) can all be distinguished from visual object agnosia (Damasio et al., 1990; Warrington and Shallice, 1984). Even within a specific agnosia we find evidence of distinct category loss. A number of studies by Warrington, Shallice, the Damasios, and others, report on agnosia patients who display difficulty in recognizing animals and less difficulty with non-animate objects. These category differences will be further discussed below.

At the University of Iowa, the Drs. Damasio and their colleagues have found that "together with data from patients with surgical ablations, or selective neuronal loss due to Alzheimer's or Pick's diseases, the retrieval of items from a previously learned lexicon depends on the integrity of neural systems located in left temporal cortices, namely in the inferotemporal region and in the polar temporal region. One component of this system, i.e. area 38 in the very anterior temporal lobe, appears to be especially dedicated to the retrieval of proper nouns, as opposed to common nouns. ... These systems do not appear necessary for phonemic and syntactic levels of language operation" (Damasio et al., 1991). They state (Damasio and Damasio, 1989) that "Patients possess the generic information about a given animal or object. They are aware of its visual and functional properties. But they cannot access the unique name label". This distinction between conceptual knowledge and linguistic forms continues to be revealed in lesion studies as well as PET research.

One patient of the Damasios shows this kind of dissociation of linguistic and conceptual knowledge. When given the name of a well-known city, e.g. Denver, and asked to say what state it is in he replies "Denver, Colorado". If he is asked to name a city in Colorado, however, he is unable to do so. Nor is he able to give any information about Denver, or Los Angeles (which he will say is "Los Angeles, California") without being able to give the name of a city in California. He responds similarly when asked what football team plays in Los Angeles – saying "Los Angeles Rams" – but if asked in what city the Rams play he cannot tell you (Damasio and Tranel, 1990).

[Denver, Colorado] appears to be a single lexical item, with a semantic representation something like 'city, state'. Boswell can access the item or the entry [Colorado], which is also in his lexicon, but the pathway between the lexical representations of these items and conceptual knowledge about their references seems to be blocked if not destroyed (Damasio et al., 1989).

Boswell also suffers from prosopagnosia, the inability to recognize familiar faces. There are cases where patients who do not seem to have trouble with naming other
visual stimuli suffer from this problem. Yet, again through controlled experimentation the Damasio group have shown that prosopagnosia patients have the same differential physiological skin responses to familiar and unfamiliar faces as do normals (Damasio et al., 1982, 1990). In other words, these patients suffer from an accessing rather than a representation loss – a difference between performance and competence. Some prosopagnosia patients can't quite get to the name but make interesting substitutions. One patient recognized a picture of Judy Garland as Liza Minelli, referred to a picture of Ronald Reagan as "John Wayne" and when shown a picture of Kruschev said on the first day of testing "I don't know but I think it's a Russian" and on the second day of testing responded "Lenin", Vladimir that is, not John.

Two parallel studies reported in Nature (Damasio et al., 1996) – the first, a study of neurological patients with brain lesions, and the second a study of normal subjects using PET – provide new insights into the modular organization of both conceptual knowledge and sub-components of the lexicon. The task for the brain-damaged patients required them to name pictures of items in three categories: (1) photographs of the faces of well-known persons; (2) animals, and (3) tools. In scoring for incorrect naming, only those items were scored as incorrect if the patient had previously shown conceptual recognition, e.g. described a picture of a skunk as a small black and white animal with a bad smell. Some subjects could name only unique faces, others only animals, and still others only tools showing dissociation of these three categories. Patients who had difficulty with naming persons had damage restricted to the left temporal pole; those who could not name animals had left inferior temporal lobe lesions, and only those with posterior inferior temporal lobe and temporo-occipito-parietal damage showed difficulty in naming tools. We therefore find that following brain lesions, in patients who have difficulties in accessing the lexicon, not all lexical categories are equally compromised. This shows that different neural systems seem to be required for the retrieval of specific semantic categories of lexical items.

This finding was followed up in a PET activation study of normals who were also asked to name famous people, animals, and tools (a subset of the pictures used in the lesion study) while their regional cerebral blood flow was measured. Those areas that were activated in normals for each category corresponded to the brain-damaged areas of the patients who could not provide names for the items in those categories.

In earlier studies, distinct neural systems were found to be required for the retrieval of words denoting actions versus those denoting objects (Damasio and Tranel, 1993). A double dissociation was found where some patients with lesions in one area of the brain could not access action words but had no problem with objects, and other patients with lesions in non-overlapping areas showed the reverse problem. Such converging evidence argues in support of a lexicon in which words are organized or connected according to semantic categories, but not necessarily limited to such an organization, since we have other evidence for phonologically connected words, and for syntactic categories, as well as for a separation, as shown above, of lexical and grammatical categories.

There is more evidence for the separation of different components of the grammar and the lexicon, and for the separation of language abilities from non-linguistic abil-
Campbell conducted lip-reading studies in which she found that the ability to process faces for verbal information can be maintained despite inability to process faces for emotional or gestural interpretation. The same perceptual processes are used for the two tasks and therefore the difficulty cannot be due to non-linguistic factors. It is language processing that is independent of other cognitive processing.

5. The future?

The more we look, whether at studies of neonates or development or lesions or blood flow studies of cognitive processes or ERP and fMRI studies, the more we find that knowledge and processing of language is separate from the ability to acquire and process other kinds of knowledge, that the asymmetry between general knowledge and linguistic knowledge shows language to be independent of general intellectual ability, and that language itself, as well as other cognitive systems are distinct both anatomically and functionally. It is through studies of the relationship between brain, mind, language, and linguistics that we are beginning to understand how to relate the neuron to the noun phrase.

In 1980, John Marshall stated: “Biologists ... have accumulated a vast body of knowledge concerning the gross anatomy of those parts of the central and peripheral nervous system which seem to be implicated in the acquisition and exercise of linguistic abilities. Some knowledge is even available about the slightly less gross physiology of the relevant brain areas. ... (P)sycholinguists ... have amassed alarming amounts of data of the progression from the birth cry to the multiply embedded relative clause. The problem is ... found in the simple fact that no one ... has the slightest idea how to relate these two domains of inquiry to each other. ... We have so far failed ... to construct ... models ... that could mediate between noun phrases and neurons”.

We have come a long way in the sixteen years since this statement appeared in print. We still are unable to connect the noun phrase to a neuron, but we have already some idea of the neural architecture underlying different lexical categories and the neural modules underlying different cognitive systems. We are beginning to find the linguistic explanations for specific aphasic disorders, and in time we may even discover the specific language genes leading to a viable model of the neurobiology of language.

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