

# The Bilingual Brain

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## ABSTRACT

Increased understanding of the ways in which multiple languages are represented in bilingual speakers' brains would undoubtedly advance several theoretical issues in areas such as language acquisition and performance theory. The progress of science forces linguists to draw upon relevant data from neurolinguistics and opens a new avenue for SLA researchers. This literature review will examine neurolinguistic models that have been proposed as an explanation for the coexistence of multiple languages in a single brain and the mechanisms of linguistic segregation. An overview of the study of language localization will be presented, followed by a discussion of neurolinguistic studies investigating the cerebral representation of language in bilinguals. A particular area of focus will be factors affecting language representation in the bilingual brain.

## INTRODUCTION

In the field of psycholinguistics, the study of the acquisition of the native language (L1) has given rise to a large number of models. The parameter setting approach has become the leading model for many investigators (Gass & Selinker, 1994). Linguistic parameters, i.e., sets of possible grammatical and phonological variations (values) within a frame of invariant principles, are considered to be part of the innate endowment of Universal Grammar (Chomsky, 1968). Exposure to a specific linguistic environment results in the fixation of one of the possible values of each parameter. Some researchers believe that language acquisition radically alters the brain through some kind of symmetry breaking, so that it ultimately becomes exquisitely tuned to one language (Dehaene, 1999).

Within such an approach, one may very well ask what happens when the acquisition of an L1 requires the fixation of a parameter at one value, while the acquisition of a second language (L2) requires a different value for the same parameter. The interdisciplinary character of the field of second language acquisition and the realization that with the progress of science we may come to know something of the physical representation of the grammar and the language faculty,

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led my quest into the field of neurolinguistics. The everyday experience of storing and using three languages contributed to my fervent interest in the bilingual brain.

A number of researchers have suggested that in the pursuit of a language faculty, linguists must draw upon relevant experimental data from neurolinguistics, and carry out their research from that perspective (Selinker & Lamendella, 1981; Hatch, 1983; Chomsky, 1988). Chomsky (1988) notes: “In the study of language we proceed abstractly, at the level of mind, and we 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” (p. 8).

It is the purpose of this paper to relate the parameter setting approach to the neural substrate used to represent the knowledge of L1, and eventually of L2, and present a review of the literature on neurolinguistic models that have been proposed as an explanation for the co-existence of multiple languages in a single brain and the mechanisms of linguistic segregation. In my search for the *language switch* I will outline models of language localization. I will also review a series of up-to-date neurolinguistic studies attempting to determine whether the cerebral representation of language in bilinguals differs from that of unilinguals. Following a description of specific factors such as age, manner of acquisition/learning of a language, level of proficiency and linguistic environment, discussion on the findings from the neurolinguistics field will ensue.

## THE REPRESENTATION OF LANGUAGE IN THE BRAIN

Before functional imaging, and before brain stimulation and mapping, it was the conical bullet that played a major role in the advancement of modern neurology. A conical bullet, unlike a musket ball that tended to shatter the skull, causing massive damage to the brain beneath, was able to create a surgically clean hole in the skull and a focused wound in the underlying brain tissue. As a result of this technological advance, young doctors, Broca in France, and Wernicke in Austria, obtained a sizable group of patients whose injuries to a relatively limited area of the left half of the brain disturbed their language ability. It was determined, therefore, that the left cerebral hemisphere provides the neural substrate for languages in humans.

The brain is not a monolithic organ, but a series of organs, and it is possible to describe the anatomy of each. But language teachers like myself are not so much interested in the descriptions as they are in understanding the functions of the parts – specifically, can we locate various language functions in the brain? Unfortunately, it is precisely when one assigns functions to locations that the field of neurolinguistics runs into the most disagreement. The classical model assigns language functions to two regions in the left hemisphere, the inferior frontal region and the temporo-parietal region of the brain. Injuries in the general boundaries of these cortical areas have resulted in clinically and linguistically different aphasic syndromes, referred to as agrammatic (Broca’s aphasia) and paragrammatic (Wernicke’s aphasia). Whereas Broca’s aphasics have difficulty speaking but relatively little difficulty comprehending language, Wernicke’s aphasics have no difficulty speaking but great difficulty comprehending. This standard model comes from the least revealing method of language physiology, the study of stroke patients (Bhatnagar, Mandybur, Buckingham, & Andy, 2000).

As the research into the localization of language progressed, the proposition that the left cerebral hemisphere in humans has an innate predisposition for language lost its categorical power. Language modules like Broca’s area and Wernicke’s area appear more and more elusive,

indistinct, and variable. Indeed, there was found to exist a small population of otherwise normal people whose language is localized in the right hemisphere. A large minority (most left-handed) was found to have language fairly evenly distributed across both hemispheres. Then there were the cases of aphasic children. For adult aphasics, the prognosis is bleak. Once the language hemisphere is damaged, recovery is usually incomplete and often minimal. But for child aphasics, the prognosis is miraculously good. Within several years, the other hemisphere or a spared gyrus takes over the language functions of the damaged region, and recovery is often – even usually – complete (Loritz, 1999).

The study of patients with language disorders caused by localized cerebral lesions (the *undoing* of language) is only one of the methods used to gather information about the organization of language in the human brain. To the field of first and second language acquisition the newest neuroimaging techniques (PET scans, functional MRI) are of much greater significance, as they can be used in the study of normal subjects. Growing evidence from modern techniques has suggested that the classical model of language localization based on the dichotomy of production and comprehension is no longer supported by the available evidence. A large lateral region of the cortex was found to be involved with language processing. It extends beyond the limits of the traditional language cortex (Bhatnagar et al., 2000). The resulting anatomical representation emphasizes two points: selective localization and multilevel columnar representation where some, but not all, language functions are overlaid on the areas of the brain that also serve other functions (Ojemann, 1983).

## THE NEUROLINGUISTICS OF BILINGUALISM

The issue of cerebral organization of languages in bilinguals essentially concerns the question of whether two different languages are localized in the same area or in distinct areas of the brain. Stunningly diverse patterns of bilingual aphasia and recovery have been reported, impeding neuropsychologists' efforts to propose general rules of organization of the bilingual brain. When aphasic impairments in polyglots occur, languages have been shown to behave differently, with unequal extent of interference and substitution. The literature abounds in a great number of views, often contradictory (Aglioti, Beltramelli, Girardi, & Fabbro, 1996; Chernigovskaya, Balonov, & Deglin, 1983; Hatch, 1983; Ojemann, 1983).

Advanced by many neurologists in the past was the hypothesis suggesting that all languages known by a bilingual or a polyglot are localized in the same cerebral areas. Parallel recovery of both languages in bilingual aphasics is rather common. It led to a subsequent conclusion that there is no basis for postulating a separate cerebral organization of different languages in the bilingual brain (Fabbro, 1999).

The diametrically opposed hypothesis was put forward by a different group of investigators at the end of the 1970s. Presented with instances of pathological patterns of bilingual aphasia, those researchers have reached the conclusion that different cerebral networks support L1 and L2 acquisition (Fabbro, 1999). Antagonistic recovery, when a patient's performance in one language improves while performance in another language deteriorates, or differential aphasia, in which patients show Broca's aphasia in one language and Wernicke's aphasia in another, both provide support for distinct and largely separate neural bases for different languages. Ojemann (1983) presented a piece of evidence in support of differences between L1 and L2 processing in a normal subject. Electrical stimulation mapping of six

language-related functions at nine sites in the lateral peri-Sylvian cortex of a 30-year old female, bilingual in English and Greek, showed dissociation of the sites related to the naming of simple objects in pictures in two different languages. Stimulation in the central region of Broca's or Wernicke's area tended to disrupt language functions for both languages, but in some areas stimulation disrupted only Greek or only English. The researcher suggested that the brain areas recruited for L1 learning and processing are different from those recruited for L2. However, ensuing experimental studies have not corroborated the idea that language is organized differently in monolinguals and bilinguals.

## FACTORS AFFECTING LANGUAGE REPRESENTATION IN THE BILINGUAL BRAIN

A large series of recent studies led investigators to the formulation of the hypothesis currently dominating in the field of neurolinguistics, namely that different languages are organized partly in common areas and partly in specific and separate areas of the brain. The differences in cerebral representation have been attributed to a natural variability in the linguistic experience of individuals. Specific factors such as age, manner of acquisition/learning of a language, level of proficiency, and linguistic environment are believed to be responsible for the biological differences in language localization in the bilingual brain. Paraphrasing the Chomskian paradigm, Strozer (cited in Evans, Workman, Mayer, & Crawley, 2002) comments that "adults still have access to the invariant principles of language, but they do not have access to the direct re-setting of parameters" (p. 293).

A study by Kim, Relkin, Lee, and Hirsch (1997) on early and late bilinguals is a case in point. The researchers investigated how multiple languages are represented in a human brain. They conducted a functional MRI study of six fluent *early* bilinguals who learned their L2s early in their development and six fluent *late* bilinguals who learned their L2s in early adulthood. While alternating languages, subjects performed sentence-generation tasks describing events that occurred during a specified period of the previous day. The task was practiced before the imaging sessions and executed silently to minimize head movements. MRI scans of the late bilingual subjects revealed significantly distinct regions of activation, separated by a mean of 7.9 mm, for each language within Broca's area. Little or no separation was registered within Wernicke's area. Moreover, the late bilinguals' L1 grammar and phonology motor maps had developed in close proximity, as if their extent were limited by some factor like an inhibitory radius. Their L2s developed in a separate area, as if the L1 area were already fully connected. On the other hand, early bilinguals did not exhibit two distinct regions for different languages; presumably, their grammar and phonology motor maps for both languages developed together in a single area. The researchers hypothesized that young children fix several values for each grammatical or phonological parameter simultaneously owing to early and repeated exposure to both languages. The investigators also assumed that the mother tongues are used implicitly, i.e., according to automatic rules that are largely impervious to consciousness. By contrast, a second language, particularly if learned in adulthood, is probably learned and used explicitly, i.e., mainly by consciously applying rules. It has to be pointed out that existing clinical and neuroimaging studies suggest that implicit and explicit memory systems do rely upon different neural structures (Aglioti et al., 1996). Therefore, Kim et al. (1997) concluded that, perhaps, representations of languages in Broca's area in early bilinguals are not subsequently modified.

This finding implies that late bilinguals need to utilize the adjacent cortical areas for an L2 learned as an adult. In sum, the study yielded two key findings: the anatomical separation of grammar and phonology in bilinguals varies according to the age and manner of language acquisition.

A weak consensus in the field seems to be emerging to suggest that the level of proficiency is a critical determinant of brain activation patterns in language tasks. A strong body of evidence exists to suggest a common cortical representation for L1 and L2 when levels of proficiency in both languages are comparable. As shown above, Kim et al. (1997) argued for a single area and no spatial separation of L1 and L2 when both languages are acquired early, implying high levels of proficiency in both languages. Klein, Milner, Zatorre, Zhao, and Nikelski (1999) compared cerebral organization of two typologically distant languages: English and Mandarin Chinese. The subjects, proficient in both languages, had learned their L2s during adolescence. Mandarin was chosen as it differs from English in its specified use of pitch and tone. The study examined the influence of linguistic structure on cerebral blood flow (CBF) patterns in subjects when they performed a noun-verb generation task. The task conditions consisted of repeating nouns in Mandarin, repeating nouns in English, generating a verb for a noun in Mandarin, and generating a verb for a noun in English.

Overall, the pattern of CBF increase seen in response to the L1 was strikingly similar to that seen for the L2. This finding led to the conclusion that in fluent bilinguals who use both languages in daily life lexical search utilizes common cortical areas. Moreover, similar brain regions are active even when languages are distinct, and even when the L2 is acquired later in life. Partially overlapping findings were presented in a study on the influence of linguistic environment (mono- or bilingual) on the patterns of second language location in the brains of teenage, bilingual English and Welsh speakers (Evans et al., 2002). One hundred and twenty participants formed four distinct groups, differing in age of acquisition of Welsh as a second language and in general linguistic environment. One group of participants acquired Welsh before five or six years old, and another one at a later age. Subsequently, each age group was divided according to their linguistic environment: dual-language areas and English-only areas of Wales. Subjects completed the same split-visual field test for single word recognition (half English, half Welsh). All target stimuli were familiar, regular, high frequency, concrete nouns.

Evans et al. (2002) found that for participants from a dual-language environment, both early and late acquisition of a second language resulted in a left hemisphere localization of the L2. The age of exposure to the second language played a decisive role only in the case of bilinguals from a single-language environment. The data revealed increased right-hemisphere involvement for later-learned Welsh in an English single-language environment. The researcher concluded that age of acquisition alone was not a sufficient factor in explaining the pattern of L2 localization. It was suggested that an interaction between age and language environment mediates the lateralized representation of early and later learned languages. The researchers speculated that, perhaps, the left hemisphere has become adapted to select language parameters from the linguistic environment during an early period in life. If, however, a language is not learned or even heard until beyond this period, then more bilateral or even right-hemisphere representation may develop.

Illes, Francis, Desmond, Gabrieli, Glover, Poldrack, Lee, and Wagner (1999) were more categorical in their conclusions. The researchers examined brain activation in bilingual participants who sequentially learned English and Spanish (or vice versa). The participants became fluent in their L2s a decade after L1 acquisition but were proficient in both languages.

Subjects were presented with 480 concrete and abstract English nouns and their Spanish translations. Participants performed tasks that required semantic and non-semantic decisions about those words. The semantic activation for both languages occurred in the same cortical locations. Further, no activation difference was observed in a direct comparison of semantic judgments in English and Spanish. The researchers suggested that, according to the resolution provided by functional MRI, a common neural system mediates semantic processes for the two languages in the bilingual brain. They also inferred that learning a new language, even after the age of ten, does not require the addition of a new semantic processing system or the recruitment of new cortical regions.

## DISCUSSION

What the neurolinguistic data shows is that when proficiency is kept constant, age of acquisition per se does not seem to have an impact on the macroscopic brain representation of an L2. A possible interpretation of what brain imaging shows is that, in the case of low proficiency individuals, multiple and variable brain regions are recruited to handle as far as possible the dimensions of L2 which are different from L1. As proficiency increases, highly proficient bilinguals use the same neural machinery to deal with L1 and L2.

However, this anatomical overlap cannot exclude the possibility that the brain network is using the linguistic structures of L1 to assimilate the dimensions of L2 less than perfectly. The above interpretation allows the researchers (Perani, Paulesu, Galles, Dupoux, Dehaene, Bettinardi, Cappa, Fazio, & Mehler, 1998) to accept apparent discrepancies between brain imaging studies showing lack of differences between the cerebral activations associated with L1 and L2 in highly proficient individuals and behavioral data demonstrating that unless a child is precociously exposed to two languages he/she will become dominant in one of them and consequently will not process the L2 like native speakers (hence flawed grammaticality judgments and detectable foreign accents).

Another possible explanation of the discrepancies between brain imaging data and behavioral data is that processing differences between L1 and L2 in highly proficient individuals are supported by differences in cerebral micro-circuitry that are hardly visible with the present resolution of brain-imaging methods. Working within this paradigm, one has to come to the conclusion that each language is coded differently at some level in the brain. In spite of their own findings (conducted with the present technologies), some researchers vigorously advance this view (Hernandez, Martinez, & Kohnert, 2000). They argue that we do not have the spatial resolution to detect the subtle differences that occur in language processing as “using neuroimaging is like using satellite photos to understand how telecommunication lines are interconnected” (p. 429). They also suggest that perhaps the differences in processing may be the result of fine timing distinctions, which, again, cannot be detected by the available neuroimaging methods.

Several circumstances limit what we can learn from the present studies. First of all, each of the techniques used in the described studies – static or dynamic – had its limitations. The main criticism should also address the fact that the researchers rarely attempted to distinguish between syntactic, semantic, and phonological properties of language chunks presented to the subjects. The design of the language tasks did not allow the researchers to simultaneously localize the representations of those properties. In a similar vein, it was absolutely impossible

with the language tasks at hand to advance the search for the cortical representations of particular UG parameters. Moreover, none of the studies has focused on what happens when speakers produce completely novel sentences, i.e., utterances unrehearsed and unknown to the researcher. In addition, most studies limited themselves to adult bilingual speakers. And finally, none of them presented any method of control over the levels of proficiency of their participants, who were always introduced as “fluent bilinguals”. In sum, all of the studies would have benefited from linguistic expertise.

## CONCLUSION

There is no doubt in my mind that there will be more studies implementing the latest state-of-the-art instruments in a quest for answers on how the bilingual brain handles L1 and L2s on-line. Increased understanding of the ways in which multiple languages are represented in bilingual speakers’ brains is undoubtedly advancing several theoretical issues in areas such as language acquisition and performance theory. Almost all of the work in modern linguistics and second language acquisition has been done on overt rather than covert linguistic performance. The linguists organize the overt spoken and written speech behavior into relevant categories, infer significant relationships, posit explanations, and attempt to discover relevant research variables accounting for variance in performance across different individuals and for the same individual over time (Selinker & Lamendella, 1981). However, there is much experimental and clinical data in neurolinguistics which is clearly relevant, and very little work has been done on first or second language acquisition from the neurolinguistic perspective.

In the light of above, I will argue for inclusion of the neurofunctional perspective as a comprehensive basis for the discussion of many issues in second language acquisition, e.g., UG theory, critical periods, fossilization, ultimate attainment, etc. Language teachers like myself should not be satisfied with the widespread belief that loss of brain plasticity disables adult learners from ever mastering their L2s (Lenneberg, 1967). Linguists must turn to neurological areas if they are ever to understand the nature of language acquisition and language processing.

It is my belief that knowledge of such issues can be useful not only to physicians and psychologists, but also to teachers in general. After all, teachers deal every day with one of the most typical features of the human brain, namely the ability to learn.

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