

Neurolinguistics Aspects of Second Language Acquisition

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Abstract

Fundamental breakthroughs in the neurosciences, combined with technical innovations for measuring brain activity, are shedding new light on the neural basis of second language (L2) processing, and on its relationship to native language processing (L1) (Perani & Abutalebi, 2005). Over the past two decades, a large body of neuroimaging studies has been devoted to the study of the neural organization of language (De´monet, Thierry, & Cardebat, 2005; Indefrey & Levelt, 2004; Price, 2000 as cited in Abutalebi, 2008). The value that functional neuroimaging adds to language research is to improve the perspective on the distributed anatomy of language. Thus, it can be used with considerable precision to identify the neural networks underlying the different domains of language processing. In this paper some main issues related to neurolinguistics and second language acquisition with a focus on bilingualism will be discussed.

Keywords: Bimodality, Bilingualism, Critical Period Hypothesis, Lateralization, Neuroimaging

1. Introduction

Available evidence indicates that the L2 seems to be acquired through the same neural structures responsible for L1 acquisition (Abutalebi, 2008). This fact is also observed for grammar acquisition in late L2 learners contrary to what one may expect from critical period accounts. However, neural differences for an L2 may be observed, in terms of more extended activity of the neural system mediating L1 processing (Abutalebi, 2008). These differences may disappear once a more ‘native-like’ proficiency is established, reflecting a change in language processing mechanisms: from controlled processing for a weak L2 system (i.e., a less proficient L2) to more automatic processing.

The neuroimaging data reviewed by Abutalebi (2008) supported the notion that language control is a crucial aspect specific to the bilingual language system. The activity of brain areas related to cognitive control during the processing of a ‘weak’ L2 may reflect competition and conflict between languages which may be resolved with the intervention of these areas.

In general, functional neuroimaging studies have not only confirmed the anatomical knowledge gained from anatomo-clinical studies, but have indeed led to a number of new discoveries leading to substantial revisions of traditional concepts. Consider, for instance, Broca’s area: recent imaging evidence reports not only that the traditional Broca’s area located in the left inferior frontal gyrus can be functionally sub-divided into three regions, respectively, for phonology, semantics, and syntax (Bookheimer, 2002, cited in Abutalebi, 2008), but that it also plays a critical role in nonlinguistic functions such as cognitive control (Koechlin & Jubault, 2006; Koechlin, Ody, & Kouneiher, 2003, cited in Abutalebi, 2008). Hence, hemodynamic studies offer a unique opportunity to properly assess the organization of language and cognitive functions in the human brain.

2. Lateralization and biomodality

A great deal of research has focused on brain lateralization and the organization of language functions. For example, Goldberg and Costa (1981) examined evidence for neuroanatomical differences of the cerebral hemispheres and their possible effects on cognitive processing (Kim-Rivera, 1998). They hypothesized that the left hemisphere is superior in using multiple descriptive

systems that are already available in the cognitive faculties, while the right hemisphere plays an important role in processing materials for which there are no pre-existing descriptive systems.

In the early 1970s, neuroscientists started to discuss the possibility of the involvement of the right hemisphere in language, and in the early 1980s the notion that the RH plays an important role in processing new stimuli became a workable hypothesis (Danesi, 1994, cited in Kim-Rivera, 1998). Albert and Obler (1978, cited in Kim-Rivera, 1998) observed that language organization is more bilateral in bilingual children than in monolingual children, and that the RH is crucial in SLA.

According to Kim-Rivera (1998) few studies have approached second language teaching from a neurolinguistic perspective. An exception is Marcel Danesi's educational construct of neurological bimodality, an attempt to find a neurological foundation for classroom language instruction. The underlying hypothesis is that there is a natural flow of information processing from the right to the left hemispheres of the brain during language learning; therefore, language instruction should reflect that flow direction by providing concrete forms of instruction at early language learning stages and more formal and abstract instruction at later stages. However, the hypothesis raises questions; for example, the evidence for right-hemisphere functions in second language learning is contradictory, yet those functions are an important element in bimodality. In addition, there have been few empirical studies supporting the hypothesis.

3. Cognitive processes for reading in a second language

Reading in a second language (L2) is a complex task that entails an interaction between L2 and the native language (L1). To study the underlying mechanisms, Tan et al. (2003) used functional magnetic resonance imaging (fMRI) to visualize Chinese–English bilinguals' brain activity in phonological processing of logographic Chinese and alphabetic English, two written languages with a sharp contrast in phonology and orthography.

In one of their experiments they found that phonological processing of Chinese characters recruits a neural system involving left middle frontal and posterior parietal gyri, cortical regions that are known to contribute to spatial information representation, spatial working memory, and coordination of cognitive resources as a central executive system. They assumed that the peak activation of this system is relevant to the unique feature of Chinese that a logographic character has a square configuration that maps onto a monosyllabic unit of speech.

Equally important, when their bilingual subjects performed a phonological task on English words, this neural system was most active, whereas brain areas mediating English monolinguals' fine-grained phonemic analysis were only weakly activated. This suggests that their bilingual subjects were applying their L1 system to L2 reading and that the lack of letter-to-sound conversion rules in Chinese led Chinese readers to being less capable of processing English by recourse to an analytic reading system on which English monolinguals rely. Their brain imaging findings lend strongest support to the idea that language experience tunes the cortex.

In a study done by Nakada, Fujii, & Kwee (2001) brain activation associated with reading was investigated in ten normal Japanese volunteers (five highly literate in both Japanese and English) and ten American native English speakers (five highly literate in both English and Japanese) in order to determine the neuroanatomic substrates employed in reading the first language (L1), and to determine the effect of L1 on the neurosubstrates involved in reading the second language (L2).

The results of their study demonstrated that reading in the second language (L2) engages the identical cognitive neuroanatomic substrates employed in reading in the first language (L1). Whereas the pattern of activation associated with reading English by subjects who first acquired literacy in this language system was shown to be clearly distinct from the pattern associated with reading Japanese by subjects who first acquired literacy in Japanese, the activation pattern in those English native or Japanese native subjects who acquired literacy in the second language (L2), Japanese or English, respectively, followed that of L1. These results definitively support the hypothesis that the physiological acquisition of literacy in L1 has significant effect on the

acquisition of literacy in L2, even when L1 and L2 utilize dramatically variant coding systems, as is the case for Japanese and English.

The findings of the study also indicated that, similar to spoken language, reading may exhibit a cognitive ‘accent’. Symbol decoding strategies appears to be determined by the complexity of the written symbolic representation to which the individual is exposed during the critical developmental period. Acquisition of a second spoken language after the primary spoken language predisposes an individual to an audible accent in the second language, while literacy in a second language to a “reading accent”.

4. Bilingual brain-mapping

The long-held assumption that L1 and L2 are necessarily represented in different brain regions in bilinguals has not been confirmed (Perani & Abutalebi, 2005). On the contrary, the available evidence indicates that L1 and L2 are processed by the same neural devices. The neural differences in L1 and L2 representations are only related to the specific computational demands, which vary according to the age of acquisition, the degree of mastery and the level of exposure to each language.

The available evidence supports a dynamic view of the neural basis of L2 processing (Perani & Abutalebi, 2005). The most important contribution of brain imaging studies to the neurobiology of language in bilinguals is the observation of both invariance and plasticity. First, concerning language acquisition, L2 seems to be acquired through the same neural devices responsible for L1 acquisition. Second, regarding L2 processing, the patterns of brain activation associated with tasks that engage specific aspects of linguistic processing are remarkably consistent among different languages, which share the same brain language system (Perani & Abutalebi, 2005).

According to Perani & Abutalebi (2005) these relatively fixed brain patterns are modulated by several factors. Proficiency, age of acquisition, and amount of exposure can affect the cerebral representations of each language, interacting in a complex way with the modalities of language performance. Future studies disentangling the different language processes should always take into account these potentially important variables.

Typically, in subjects with comparable levels of proficiency, late bilinguals had a higher amount of activation in L2 than L1 (Kovelman et al., 2008; Perani et al., 2003; Vingerhoets et al., 2003, cited in Bloch et al., 2009). In contrast to most other studies, Mahendra et al. (2003, cited in Bloch et al., 2009) observed higher total activation in early bilinguals as compared to late bilinguals in both, word and sentence generation tasks.

There is evidence to suggest that second languages learned later in life end up in distinct regions of the brain, while those acquired early in life tend to be situated in regions coextensive with the L1 (Hagen, 2008). Ojemann and Whitaker (1978, cited in Hagen, 2008) reported on case studies of a late Dutch/English bilingual and a late Spanish/English bilingual who underwent electrocortical stimulation prior to surgery. In both instances, they documented an area of the brain common to both languages as well as distinct sites where languages were differentially affected by testing. Kim, Hirsch, Relkin, De Laz Paz, and Lee (1997, cited in Hagen, 2008) did an fMRI study of early and late bilinguals that revealed distinct physical loci of second languages along the periphery of Broca’s and Wernicke’s regions in the case of late learners, but not in the case of early learners.

Hernandez, Dapretto, Mazziotta, & Bookheimer (2001) studied six Spanish/English early bilinguals, all of whom had acquired both languages before the age of five. fMRI testing showed that the two languages were represented in overlapping regions of the brain. Wartenberger et al. (2003) used fMRI testing to study 32 Italian-German bilinguals in three groups, (i) eleven subjects who acquired the L2 in early childhood and were fluent native speakers, (ii) twelve subjects who acquired the L2 in adulthood but managed to attain a high level of proficiency, and (iii) nine subjects who had acquired the L2 late in life and had limited proficiency. They found that age of acquisition was a statistically significant variable in determining loci of grammatical processing in

the brain, but less so in determining semantic processing. Taken together, these studies suggest that L1/L2 acquisition differences are not simply the consequence of inadequate or incomplete learning experiences, or of any psycho-affective factors, but that they result from fundamental changes in cognitive abilities that are in some way the consequence of our biological endowment.

The relationship between thought and language and, in particular, the issue of whether and how language influences thought is still a matter of fierce debate. Fontanari & Perlovsky (2008) considered a discrimination task scenario to study language acquisition in which an agent receives linguistic input from an external teacher, in addition to sensory stimuli from the objects that exemplify the overlapping categories that make up the environment. Sensory and linguistic input signals are fused using the Neural Modelling Fields (NMF) categorization algorithm.

They find that the agent with language was capable of differentiating object features that it could not distinguish without language. In this sense, the linguistic stimuli prompt the agent to redefine and refine the discrimination capacity of its sensory channels.

5. Neural overlap in speaking words in two languages

Liu, Hu, Guoa, & Peng (2010) investigated the neural overlap and dissociation underlying overt word production in the first language (L1) and second language (L2). Twenty-four Chinese-English bilinguals named pictures in either L1 or L2 while being scanned with functional magnetic resonance imaging (fMRI).

When comparing picture naming in L2 to naming in L1, increased activity in the left inferior frontal gyrus, bilateral supplementary motor areas (SMA), left precentral gyrus, left lingual gyrus, left cuneus, bilateral putamen, bilateral globus pallidus, bilateral caudate and bilateral cerebellum were observed. This suggested that word production in L2 is less automatic and needs to recruit more neural resources for lexical retrieval, articulatory processing and cognitive control than in L1. In contrast, picture naming in L1 relative to picture naming in L2 revealed increased activity in the right putamen and right globus pallidus probably due to different phonological features between Chinese and English. In addition, the conjunction analysis, for the first time, revealed the common neural correlates underlying picture naming in L1 and L2.

6. Poor grammaticality judgment performance by late second language learners

Mc Donald(2006) believed that poor grammaticality judgments of late (age of arrival P 12) second language learners often attributed to being beyond the critical period for language acquisition can be better explained by processing difficulties due to (1) low L2 working memory capacity, (2) poor L2 decoding, and/or (3) inadequate L2 processing speed. In his Experiment, late L2 learners and native speakers performed measures of English working memory, decoding, and speed, and a grammaticality judgment task. Compared to native speakers, late L2 learners were poorer on all measures.

L2 learners tend to have lower working memory spans in their L2 than their L1, and this L2 span rather than L1 span correlates with L2 comprehension (Service, Simola, Metsanheimo, & Maury, 2002, cited in Mc Donald, 2006).

Late L2 learners evidence poorer L2 decoding and lexical access abilities than native speakers. They perform more poorly than native speakers on a phoneme detection task in their L2 (Sanders, Neville, & Woldorff, 2002, cited in Mc Donald, 2006) and have more difficulty than native speakers in identifying L2 words through noise.

There is evidence that late L2 learners are slower at processing their second language than are native speakers. For example, they manifest longer L2 grammatical judgment times than native speakers (Bialystok & Miller, 1999; Mayberry & Lock, 2003; McDonald, 2000; Murphy, 1997 cited in Mc Donald, 2006), are slower to contact the semantics of an L2 word (McElree, Jia, & Litvak, 2000, cited in Mc Donald, 2006), and have slower lexical decision times (Scherag et al., 2004, cited in Mc Donald, 2006).

7. Concluding remarks

In this paper, an attempt was made to illustrate some issues in neurolinguistics and second language acquisition and to review some recent findings gained from functional neuroimaging concerning bilingualism.

To date, the results of the brain neuroimaging studies have not only converged with the findings derived from clinical aphasiology, but have also opened a number of new perspectives to our understanding of the brain–language relationship. However, given the complexity and the limitations of the classical anatomo-clinical approach to the study of the neural basis of language, functional neuroimaging techniques represent an independent source of evidence (Abutalebi, 2008).

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