Available online at:
http://dergipark.ulakbim.gov.tr/eltrj/
International Association of Research
in Foreign Language Education and Applied Linguistics
ELT Research Journal
2015, 4(2), 147-155
ISSN: 2146-9814

Current issues in the neurolinguistics of bilingualism[1]

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Abstract

Neurolinguistics is the study of the neural mechanisms in the human brain that control the comprehension and production of language. It also deals with neurological correlates of language acquisition and language loss. Neurolinguistic research is traditionally based on data from populations with impaired language in order to identify the nature of human language. To this end, the field of aphasiology has made a major contribution towards attainment of empirical knowledge as it has provided linguistic characterization of various types of aphasic syndromes in monolingual and bilingual individuals. With the advent of neuroimaging techniques, neurolinguists can now obtain language processing data from healthy individuals to answer more advanced questions about language in the brain. The neurolinguistic aspects of second language (L2) acquisition have been examined for decades to identify two central issues: the cerebral representation of language in monolinguals and bilinguals, and neurological correlates of sensitive (or critical) period that limits L2 acquisition in adulthood. Nevertheless, recent neurolinguistic research discusses not only what neurological changes lead to constraints in L2 attainment but also what changes L2 attainment generates in brain structures. This brief review aims to highlight these major issues in neurolinguistic and neuropsychological research as it relates to L2 acquisition and L2 pedagogy.

Keywords: Neurolinguistics, bilingualism, L2 acquisition

[1] To Prof. Cem Alptekin, who sparked my and many other students' interest in the field of neurolinguistics.

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Introduction

Neurolinguistics is a branch of linguistics studying the relationship between language and the brain. It examines the specific brain structures and neuronal mechanisms responsible for language comprehension and production (Ahlsén, 2006). Research in this field has initially included merely neurolinguistic work with brain impaired populations, who experience different types of language impairments. Nevertheless, with the advent of neuroimaging and electrophysiological technologies, it is now possible to explore language-related brain functioning in people with intact brains. Neurolinguistic work with bilinguals dates back to Pitres (1895/1983), which provided data on selective loss and recovery in bilingual aphasia. Since then the representation of multiple languages in the human brain has been a topic of much discussion in this field (Abutalebi, Tettamanti, & Perani, 2009). Exploring the impaired or the intact brain in bilinguals or multilinguals has no doubt been revealing for understanding the complexities of the human mind. Neurolinguistic research on the intact bilingual brain has also provided insights into our understanding of how second language (L2) acquisition occurs and how it interacts with the first language (L1) under different learning conditions. Broadly speaking neurolinguistic research on bilingualism in nonpathological cases focuses on the following questions: 1) how are multiple languages localized/organized in the brain?; 2) (how) does the organization of multiple languages in the brain change depending on the age of onset of an L2?; 3) (why) are different aspects of grammar represented or processed differently in the human memory systems?; 4) (how) does learning an L2 influence the brain structure?

This paper aims to provide a brief review of recent research findings on these questions and to discuss their pedagogical implications, which will be of relevance to all applied linguists who are interested in L2 learning and teaching (see Gürel, in press for an extensive review on this).

The organization of the two languages in the brain

The representation of two languages in the brain has been investigated for many years. As noted in the introduction, early work on bilingual aphasia has contributed to this line of research by exploring the order and/or the degree of recovery of the two languages after a brain injury. The question here is whether or not the patient displays a similar degree of language impairment in two languages subsequent to damage in a certain brain region. Aphasiologists also looked at the order in which two languages recover (i.e., whether or not the L1 or the L2 recovers first) and the extent of recovery in two languages. On the basis of aphasia data, researchers attempted to make an inference as to whether or not the two languages are located in the same areas of the brain (Lambert & Fillenbaum, 1959; Pitres, 1895/1983; Paradis, 1977; Paradis, 1983). Cross-linguistic research findings revealed no consistent pattern either in the severity of language disorder or the order or the extent of recovery in two languages of bilingual aphasic patients. It has been suggested that factors such as the frequency of language use, the proficiency level, the level of motivation of the speaker to communicate in a particular language before and after the aphasic injury and the language of the therapy received after aphasia affect the degree of language disturbance and the recovery rate and pattern in two languages, which were once at the disposal of the bilingual individual. The finding that damage in a particular brain region can cause differential impairment in two languages paved the way for the idea that L1 and L2 are possibly represented in different anatomical regions of the brain. This view, as discussed below, has been revisited on the basis of recent neuroimaging studies, which suggest that there is not a gross anatomical difference in the location of two (or more) languages in the brain (see Paradis, 2004 for extensive discussion on this).

Related with this issue is the question of whether or not the age of onset of L2 acquisition makes an impact on the representation of two languages in the brain. Recent studies using different neuroimaging and electrophysiological techniques revealed certain differences in the brain regions involved in the processing of the L1 and late-acquired L2. For example, in a series of studies, Neville, Mills, & Lawson (1992), Neville et al. (1997), Weber-Fox and Neville (1996) found that in early L2 learners, while closed-class function words are processed in the frontal lobe of the left hemisphere, open class content words are processed in the posterior part of the Rolandic fissure. In late L2 learners, however, both groups of words are represented in the posterior part of the Rolandic fissure. Differential left frontal lobe involvement in early and late L2 learners is taken as neurolinguistic evidence for the Critical Period Hypothesis, originally proposed by Penfield and Roberts (1959) and Lenneberg (1967). Similar findings have also been reported in Kim, Relkin, Lee, & Hirsch (1997), which found similar activation of Wernicke's area but differential involvement of Broca's area in early and late bilinguals' processing of L1 and L2. This suggests that Broca's area, which has traditionally been associated with handling syntactic information, seems to be differentially involved in processing of sentences in the L1 and L2 depending on the age of first L2 exposure. In a similar neuroimaging study, Perani et al. (1996) found that larger and more diverse cortical areas are involved in lower L2-proficiency-learners during story encoding in the L2.

Unlike neuroimaging studies on processing syntax, studies examining the representation of simple lexical items in early and late bilinguals in comparison to monolinguals revealed that late L2 acquisition does not cause any differential neuroanatomical organization of words in monolinguals and bilinguals (Chee, Tan, & Thiel, 1999). Depending on the L2 proficiency of the learner, L2 words can be processed in similar brain regions in bilinguals or native speaker monolinguals (Klein et al., 1994; Klein et al., 1999). In line with these findings, in a functional magnetic resonance imaging study with Italian-German bilinguals, Wartenburger et al. (2003) found that while the age of onset of the L2 affected the cortical representation of grammatical processes, the ability to make semantic judgments remained largely unaffected by this. The pattern of semantic judgment was dependent mostly on the level of L2 proficiency.

These neurolinguistic findings suggest that different aspects of grammar might be influenced from early and late onset of L2 differently (Fabbro, 2001; see also Sabourin, 2014 for a recent review of functional magnetic resonance imaging research on the bilingual brain). The quality and efficiency in syntactic processing and the brain structures involved in it seems to be subject to age effects more than lexical and semantic access/representation does. As discussed in the following section, this difference has also been accounted for on the basis of the involvement of different memory systems in processing these two domains of grammar.

Memory systems involved in L2 acquisition

Extensive research on human memory has revealed that memory is not a unitary faculty of the human mind but consists of several subcomponents. One attribute on which memory systems are differentiated is the extent and the type of conscious awareness involved in their operations (Tulving, 1985). Within this context, the two main types of memory are procedural and declarative memory. Procedural memory is sometimes referred to as implicit memory (Graf & Schacter, 1985; Schacter, 1987) or memory without awareness (Jacoby & Witherspoon, 1982). Procedural memory includes cognitive and motor skill learning and it is contrasted with declarative memory, which includes facts, episodes of one's life. Unlike procedural memory, declarative memory is explicit and accessible to conscious awareness. Neuropsychological research on memory has also provided neuroanatomical and neurophysiological validation for declarative and procedural memory systems. The explicit memory system involves the limbic-diencephalic brain structures. The hippocampus together with anatomically related structures is essential for declarative memory (Squire, 1982). Procedural memory, on the other hand, is subserved by basal ganglia, cerebellum along with other subcortical structures and circuits connected largely with the frontal cortex (Cohen & Squire, 1980; Schacter & Tulving, 1994; Tulving & Schacter, 1990).

Neurolinguistic studies examining the role of explicit and implicit memory systems in L1 and L2 acquisition suggest that L1 and late-acquired L2 are controlled by different memory systems (Paradis, 1994; 2009; Ullman, 2001a; 2001b; 2006; Ullman et al., 1997). While L1 structural forms are largely subserved by procedural memory systems, late- and formally-learned L2 is represented in declarative memory systems. Crucially, a distinction has been made between the acquisition of syntactic forms and lexical items in the L1 and L2. While the acquisition of both L1 and L2 lexicon is associated with declarative memory systems, the acquisition of L1 syntactic properties is linked with procedural memory systems. However, it is not procedural but declarative memory, which is involved in L2 syntax in case of late acquisition. The assumption here is that since linguistic information learned via declarative memory is subject to forgetting and needs conscious attention and constant consolidation, it will never be readily available to late L2 learners (Paradis, 1994, 2009). Reliance on declarative memory for processing L2 syntactic forms as opposed L1 syntax is believed to cause native-nonnative differences in L2 acquisition. For example, in the domain of inflectional morphology in L2 English, it is suggested that unlike native speakers, late L2 learners do not have access to implicit linguistic computations. Therefore, they represent a regularly inflected form such as *walk-ed* as a chunk and store it in declarative memory because they cannot access online decompositional procedures (Ullman, 2001a, 2001b). In this view, while native speakers represent regular form (*walked*) in procedural memory and irregular forms (*went*) in declarative memory, L2 learners store both regular and irregular forms in declarative memory. The declarative/procedural memory models (Paradis, 1994, 2004; 2009; Ullman 2001a, 2001b) can be interpreted as a memory-based account of the Critical Period Hypothesis as they assume a decline in the function and the involvement of procedural memory systems in L2 acquisition after a certain age.

Structural changes in the human brain due to L2 acquisition

As noted earlier, much L2 work has been conducted in reference to the Critical Period Hypothesis to answer the question of whether or not failure to acquire native-like competence in the L2 is due to neurologically-determined changes in the brain. In recent years, researchers have delved into a new but related line of research in this area. The new issue that occupies recent research agendas of neuroscientists is potential L2 influence on changes in the brain structure. In other words, the question is whether or not neuronal and structural changes occur in the brain as a consequence of L2 learning.

In a study comparing monolinguals and bilinguals, Mechelli et al. (2004: 757) found that learning an L2 increases the density of grey matter in the left inferior parietal lobe, an area that has previously been shown by functional imaging to become activated during verbal-fluency tasks. Mechelli et al. (2004) also reported that although the increased density in this area was observed both in early and late bilinguals, the effect was greater in early bilinguals. Nevertheless, it is important to note that the density is found to be increased with L2 proficiency, suggesting a potential for experience-based changes in the human brain. In a magnetic resonance imaging study, Coggins, Kennedy and Armstrong (2004) found significant differences between the monolingual and bilingual groups in the corpus callosum midsagittal anterior midbody regional area. This has been interpreted as an adaptive response of bilinguals to accommodate multiple languages. Similarly, in their review of preliminary data from bilinguals, Osterhout et al. (2008) suggest that classroom-based L2 instruction can result in electrophysiological as well as structural changes in learners' brains. In a recent study, Schlegel, Rudelson and Tse (2012) also observed a progressive reorganization in white matter as adults study a new language. These changes occurred mostly in the traditional left hemisphere language areas and their right hemisphere analogs. The most significant changes are found in frontal lobe tracts crossing the genu of the corpus callosum. Their findings indicate the importance of plasticity of white matter in adult language learning.

This new line of research has provided promising data supporting the view that the brain can benefit, throughout much of life, from the neuronal changes that occur in response to complex stimulation by an enriched environment (van Praag, Kempermann and Gage, 2000). These recent neuroimaging studies also seem to provide support for earlier L2 data coming from traditional L2 experiments indicating that L2 acquisition can be native-like and identical to L1 acquisition even after a certain age (Birdsong, 1999; White & Genesee, 1996).

Conclusion and implications for L2 pedagogy

This review has discussed some of the current issues in the field of neurolinguistics in relation to early or late bilingualism. Although some research findings indicate neurofunctional and neuroanatomical differences between L1 and late L2 acquisition, there is research evidence suggesting that L2 is acquired through the same neural devices responsible for L1 acquisition (Perani & Abutalebi, 2005). Thus although the neural networks involved in the L1 and L2 are fundamentally the same, bilingualism might bring higher cognitive demands for processing multiple languages and this might lead to increased brain activity in bilinguals (Costa & Sebastián-Gallés, 2014). Recent findings also suggest that neuroanatomical and neurophysiological reflections of late L2 acquisition can be compensated/changed by extensive L2 exposure and subsequently obtained high L2 proficiency (see Vega-Mendoza, West, Sorace, & Bak, 2015 for recent findings on this). In other words, brain circuits that subserve language acquisition may not lose plasticity completely and remain responsive to subsequent experience and environmental demands.

Although this line of research has so far provided remarkable data, there is still need for further research to identify clearly the role of factors such as L2 proficiency, the age of L2 acquisition, and the amount of exposure in the cerebral (re)organization of each language. It is also essential for us to understand the complex way these factors interact with different domains grammar and with modalities of language performance in the L1 and the L2 (Perani & Abutalebi, 2005).

Research on the neurolinguistics of bilingualism can also provide insights into some of the major issues in the field of L2 teaching. For example, the following questions that have occupied language pedagogists seem to have found answers in substantial research in neuroscience.

1. At what age should we begin to teach a foreign language? Why?
2. Is it possible for adult learners to learn a foreign language at a native-like level in all components of grammar?
3. What are the neurophysiological and neuropsychological factors determining native-like attainment in L2 acquisition?
4. Can the negative effects of late L2 learning be compensated on the basis of prolonged and enriched L2 input/instruction?
5. How do the quality and the quantity of the input play a role in ultimate attainment in L2 acquisition?
6. Why are different aspects of grammar (i.e., phonology, morphology, syntax, semantics) subject to differential age effects? What implications would this have for teaching different domains of grammar in the classroom?
7. (How) do different memory systems play a role in acquisition of an L2?
8. Do particular L2 teaching methodologies tap exclusively explicit or implicit memory systems?
9. What impact does the acquisition of two or more languages make in the brain structure in young and old learners? What implications would this have for bilingual or multilingual education?

As discussed above, advances in neurolinguistic research can help us identify some of the major questions in L1 and L2 acquisition. Many of the L2-related phenomena that pedagogists and teachers observe in their learners may have a neurolinguistic and neuropsychological explanation. Therefore, it is necessary for foreign language practitioners to remain adequately informed about the findings of neurolinguistic research.

Acknowledgements

I would like to thank Neal Snape for his suggestions on an earlier version of this paper.

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