Neurolinguistic perspectives on ESL: English learners and bilinguals

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Abstract

The rapid development of neuroscientific technology enables us researchers to demonstrate delineate the regions of the brain and the activation while performing the second language tasks. Through this new method, the second language acquisition (SLA) research is obtaining new insights about the human brain and language learning. As researchers explore the cognitive processes underlying language acquisition, an deeper understanding of the brain becomes more important. It is suggested that language acquisition researchers must begin to incorporate a degree of neurobiological reality into their perception theories and ideas of the language acquisition process. Such a neurally inspired view helps to provide a common ground for evaluating and integrating various language acquisition perspectives. This paper describes two neurolinguistic perspectives on SLA: First, it discusses possibilities for investigating how SLA theory aligns with neuroscientific findings. Second, it discusses the brain regions and functions that operates in first (L1) and second languages (L2), integrating SLA theory and brain data. In order to describe two perspectives, this paper has four goals (1) to clarify the development of brain technology; (2) to highlight neurobiological research of relevance to language acquisition research; (3) to discuss attention, automaticity, and brain activation of Japanese language learners and (4) to explore the relationship between the brain and SLA in the language classrooms.

Keywords

SLA, Automatization, neurolinguistics, bilingual brain

1 Introduction

Advanced noninvasive neuro-imaging techniques such as functional magnetic resonance imaging (fMRI), near infrared spectroscopy (NIRS), positron emission tomography (PET), electroencephalography (EEG) allow researchers to directly observe brain activities while subjects are performing various cognitive/language tasks. By combining functional brain imaging with traditional experimental designs and data analysis methods, functions of brain regions and degree of activity can be viewed.

Neuroscience regarding SLA has recently attracted a lot of attention as a result of the success of applications of functional brain imaging techniques in the study of SLA. In this article, we provide an overview of brain imaging techniques, focusing on recent developments in utilizing SLA research; recent research presents new types of data on SLA. Several studies on automaticity have focused attention on the illustration of how neuro-imaging techniques can be used to advance SLA and bilingual research. We discuss challenges and future directions regarding brain and SLA studies.

2 Background of neuroscience in SLA

2.1 Development of Technology

Since the early 1990s, the rapid development of functional neuro-imaging techniques has enabled researchers to visualize cortical activity during the performance of tasks. Many brain imaging devices are available to cognitive neuroscientists or linguists, including fMRI, NIRS, PET, and EEG.

The most common types of brain mapping devices we can use for SLA research are fMRI and NIRS. Such studies are the preferred method in the examination of the human brain, as they are less invasive without the risk of radiation. These devices allow us to measure the performance of tasks while simulating authentic language learning environments. They are used to measure the change in blood flow in relation to neural activity in the brain. With these devices, neurolinguists, other than psychologists, medical researchers, can see what parts of a learner's brain are activated when they are reading, writing, speaking, and listening. Thus such advancement of technology widens linguistic research from the perspective of neuroscience.

2.2 New research data on SLA

Here we provide an overview of the recent advances in neuro-imaging techniques and their applications in the study of SLA. In the research field of SLA, researchers have been using quantitative and qualitative methods to investigate language learners. In terms of quantitative tests, language comprehension tests and questionnaires have been used. Such quantitative research generally employs an experimental design to obtain the data to support or reject a hypothesis. Then some analysis is carried out comparing students' test results before and after taking instructions. Qualitative research, on the other hand, uses a diary study where students record their feelings or attitudes, and an observation study, where instructors observe students' attitudes and progress during the English classes. The data analysis is interpreted based on the qualitative data rather than the statistical information (Maher, 2013).

Neurolinguistics is a multidisciplinary field of research that incorporates neuroscience, linguistics, language learning, and psychology. According to Jacobs & Schumann (1994), thanks to the recent development of technology, it has been suggested that SLA research should incorporate neuroscientific findings more directly into its perspectives. They even mentioned how a basic level of understanding of neuroscience could find many keys to new research. Different perspectives extend to all areas of inquiry into the human condition and provide a common ground in terms of the integration of various perspectives of the language acquisition process. Ellis (2002) also mentioned "there are important connections between SLA theory and the neuroscience of learning and memory." We are now at a stage where we should make connections between SLA theory and the neuroscience of learning.

Thus, combining newly developed brain research, which is based on objective/unconscious data, with traditional subjective/conscious data, we hope to obtain more comprehensive findings than ever before in SLA. We can clearly say that research into the brain opens up new possibilities of studying the role of attention and automatic processes in SLA. With such techniques from cognitive neuroscience and experimental linguistics, SLA studies examine how real-time brain activities are associated with various language learning processes, such as listening, reading, conversation, and so on with the goal of building a new type of language acquisition model (Figure 1).

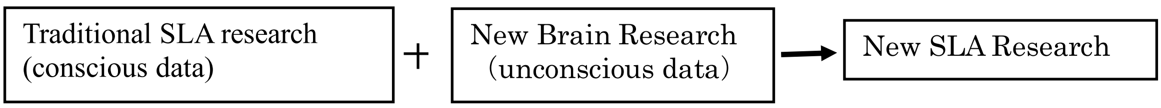


Figure 1. New SLA research

3 SLA Theory and Brain Science

3.1 Attention and Brain Activity

Before going on to discuss studies about the role of attention in SLA, here the study briefly reviews some of the research that investigates the nature of attention itself and the relationship between attention and brain activity. This can lead us to a better understanding of how the cognitive notion of attention has been employed in SLA. Applying brain science to linguistic research has so far mainly focused on the regions of the human brain which are used. Such research identifies the role of specific regions of the cortex for certain language functions. Broca's area and Wernicke's area are the two most well-known examples of language areas in the brain.

According to researchers who specialize in attention, such as Posner & Peterson (1990), and Posner and Carr (1992), there is a correlation between attention and blood flow in the brain; the blood flow increases as human attention increases. Attention here is the cognitive process of selectively focusing on one thing while ignoring other things. Segalowitz (1993) states that most complex cognitive skills require cognitive efforts. Practice leads to faster, less effortful, and more stable performance; that is to say, when the skill become automatic, there is no requirement for attentional effort. Segalowitz & Segalowitz (1994) also state that the recent developments in brain imaging technology have made it possible to obtain brain data related to automaticity. Fischler (1998) states that as a learner becomes more skilled and more automatic, the size of the brain area used becomes smaller. Posner et al (2007) showed that the brains of unpracticed performers were most activated in the PET study. Gatbonton and Segalowitz (2005) believe that automatic processing consumes fewer attentional resources than does controlled processing. Therefore, the more performance becomes automatic in terms of the perception of words, the more attentional resources can be stored for other activities.

Posner & Petersen (1990) and Posner & Rothbart (1992) report that monitoring electrical activity and blood flow in the brain using fMRI and fNIRS has enabled researchers to relate attentional networks to certain regions of the brain. Neuro-imaging evidence seems to support the description of attention; as learners' attention moves from control to an automatic process, the blood flow in the brain decreases while performing language tasks. The findings of attention research in SLA could now be supported by neuroscientific data from neuro-imaging techniques.

3.2 Attention and Automaticity

Before the emergence of these brain imaging technologies, researchers in SLA had developed various models to describe, predict, and guide effective language learning in students. In the Acquisition-Learning Hypothesis, Krashen (1982) distinguishes two ways in which people acquire language, acquisition, and learning. Acquisition is a subconscious process that leads to fluency. Learning, on the other hand, is a conscious process of gaining linguistic rules and structures. The first one happens by informally "picking up" a language in a natural setting. This is often the case with young learners before puberty. The second happens through formal language instruction in a classroom environment. The learners consciously practice using the rules. Krashen claims that these processes are not totally intertwined.

In contrast, McLaughlin's (1987) Attention-Processing Model views SLA as the acquisition of skills. In learning and acquisition processes, learners' attention moves from control to an automatic process as skills improve. The concept of attention in language learning has become particularly important from many aspects, such as input processing, development, and instruction; moreover, the cocktail party effect also describes the ability to focus one's listening attention on a single speaker among a mixture of conversations and background noises. For example, at a noisy party, most people can listen to and understand the person they are talking with while simultaneously ignoring background noise and other conversations.

Generally, SLA research findings have suggested the importance of automatization and cognitive attention. The relationship between attention, consciousness, and learning has for a long time focused on the research in cognitive psychology and SLA. Automaticity identifies an initial learning stage in which the performance of tasks requires controlled processing and relatively large amounts of cognitive attention. As learners become more proficient in L2, attention becomes gradually less focused, and language processes become increasingly automatic. The main features of automaticity are considered here as faster performance, less cognitive demand, and higher accuracy. Thus, attention is necessary to the understanding of language tasks.

4 Brain Activation: Japanese Learners of English

4.1 Optimal Brain Activation Viewed from Optical Topography

The models mentioned above mainly focus on automaticity and attention to figure out optimal learning. Using the technique of optical topography, Oishi's study (2006) investigated the brains of Japanese learners of English to clarify optimal cortical activation patterns while they performed English reading and listening tasks. Participants included three levels of Japanese learners of English: beginner, intermediate, and advanced. While they were performing language tasks, their brain activations were measured. I

The functions of language are often too broad to be categorized into particular areas. The individual roles of these areas are still being debated, and the exact correlation between cortical language areas and the subcomponents of the linguistic system have not yet been established (Sakai, 2005,). According to Brodmann's language map, there is Wernicke's area for understanding, the angular gyrus for processing letters and supramarginal gyrus for remembering—and Broca's area for production. Oishi (2006) investigated these language areas.

One of Oishi's (2006) results showed that as the level of English proficiency increased, the blood flow to the brain increased to a certain point; after the proficiency level rose beyond a certain point, the blood flow to the brain decreased. In her research, the images of optical topography show that there are four brain patterns of Japanese learners of English as in SLA -ABC model (Figure 2); 1) less activation, 2) excessive activation, 3) selective activation, and 4) automatic activation (Figure 3). We can see that the beginner's pattern is a sort of less -activation if a task is too difficult for learners, their blood flow to the brain does not increase because they do not pay attention to the task or because they simply give up. On the other hand, the intermediate learner's pattern is one of excessive blood flow, unlike that of the beginners—not only language areas but almost all areas of the brain become activated, which could be rather stressful, and the advanced learner's pattern is one of selective activation, only language areas are activated, which is a type of optimal pattern. Finally, the native speaker's pattern is one of automatic activation, which appears to be similar to the beginner's pattern, but it falls in the category of less-activation. Nevertheless, the meanings of the two extremes are completely different.

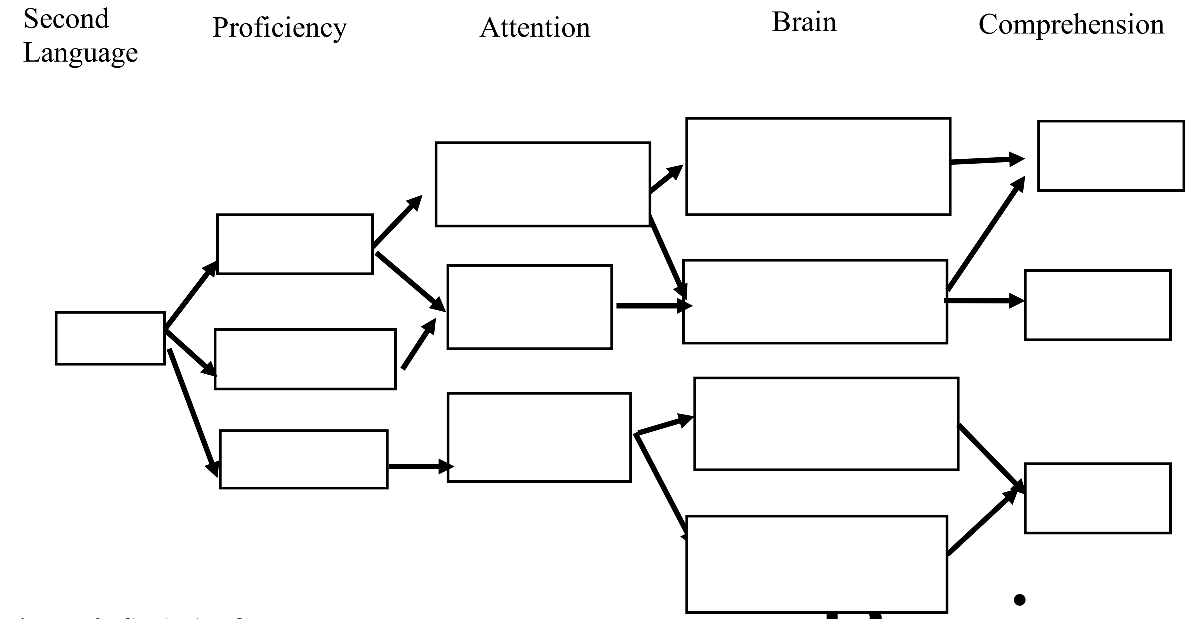


Figure 2. SLA-ABC model

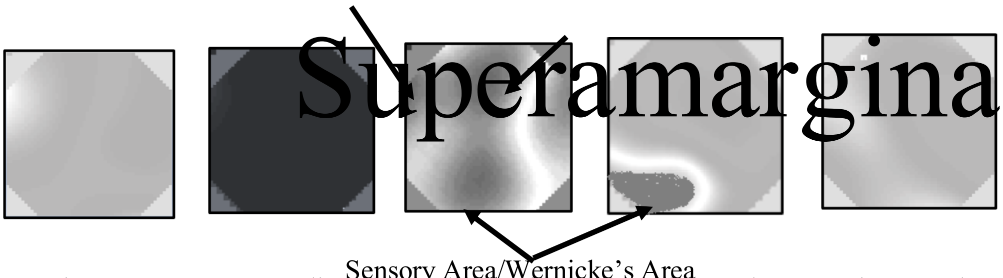


Figure 3. Images of brain activation (Oishi, 2006)

4.2 Non-Interface and Interface Regarding Brain Research

The Acquisition-Learning Hypothesis of Krashen (1981), non-interface position, mentioned above claims that "adults have two independent competences in SLA, acquired competence which is subconscious, and learned competence, which is conscious". Acquired knowledge in language acquisition is similar to the knowledge of a child's first language. Language acquisition takes place in natural settings.

Language learning, on the other hand, refers to the conscious knowledge of a second language, knowing the rules, and being aware of the laws of grammar. This happens mainly in formal instruction. Therefore, Krashen claims that these processes remain disparate. He assumes that learning does not turn into acquisition. It is a non-interface model. The Monitor model (Krashen, 1982, 1985) also explains the differences between acquisition and learning in his model. There is a monitor only in the learning process for the learner's output, whereas acquisition processing does not have a monitor.

In contrast, McLaughlin's (1987) Attention-Processing Model, interface position, views SLA as skill acquisition. In learning and acquisition processes, learners' attention moves from control to an automatic process as skills improve. SLA research on automaticity identifies an initial learning stage in which the performance of tasks requires controlled processing and relatively large amounts of cognitive attention. As learners become more proficient in L2, attention becomes gradually less focused, and language processes become increasingly automatic. In the model, the initial learning stage is considered as a controlled process with much attention to the demand of the task, limited capacity, conscious learning, time taken to understand information, and so on. As the learner practices in a repetitive way, and becomes more familiar with the task, they do not need to give so much attention to the task. It becomes effortless; there is less time taken to understand information, a faster performance, less cognitive demand, and higher accuracy.

Findings also imply that brain activation patterns tend to change from controlled to automatic processing; this supports findings by McLaughlin et al (1987), while providing evidence against Krashen's distinction between learning and acquisition.

In Oishi's study (2006), findings imply that brain activation patterns gradually evolve from beginners to advanced learners, in a similar way to the patterns of native English speakers. Findings also imply that brain activation patterns tend to change from controlled to automatic processing; this supports findings by McLaughlin et al (1987), while providing evidence against Krashen's distinction between learning and acquisition. Thus, this result provides opportunities for researchers to investigate effective teaching methods. We can say that an optimal result is achieved with an appropriate increase in blood flow and attention. We can also say that this result would suggest that while learners face a very difficult task, the blood flow to the brain does not increase due to a loss of attention. A very easy task for learners does not equate to an increase in blood flow to the brain.

As this result indicates, automaticity refers to a significant change in the way language processes are carried out. We have to distinguish between fast automatic processes and fast non-automatic processes which we here refer to as less activation, in other words, an area of the brain which is less activated. The findings suggest that good learners activate their brains selectively, whereas, poor learners make too much effort or do not make an effort at all.

Here, we would like to think again about automaticity. Automaticity is not only used as a synonym for fast processing. As this result indicates, automaticity refers to a significant change in the way language processes are carried out. We have to distinguish between fast automatic processes and fast non-automatic processes which we call less-activation. The findings suggest that good learners activate their brain selectively, whereas poor learners make excessive efforts or do not make an effort at all.

We, however, found the different features between brain patterns of poor learners and advanced learners/bilinguals. In the next section, the features of bilingual brain activation will be discussed.

5 Brain Activation: Bilinguals

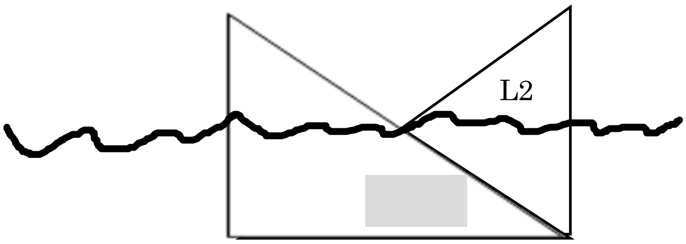
5.1 The Iceberg Model and Bilingual Switch

This section discusses the nonvisible brain structure in terms of SLA studies and brain science. Cummins (2001) proposed a common underlying proficiency (CUP) model (Figure 4), stating aspects of a bilingual's proficiency in L1 and L2 as common or interdependent between the two languages. Looking at bilingual research, brain mechanisms for processing L1 and L2 have been discussed as in Cummins (2001). An fMRI study by Crinion et al. (2006) found a common area of functioning for the two languages in caudate nucleus. It lies in the depth of the brain hemispheres.

The CUP model is illustrated metaphorically as an iceberg. In the iceberg model, complete bilinguals have two equally visible peaks above the sea. These peaks, however, are only "the tip of the iceberg." two languages are separated above the surface but underneath the surface they are integrated. Both languages do not function separately, but operate through the same underlying cognitive system, even if above the sea, the two languages are visibly different. The CUP model suggests that when a person speaks two languages, there is only one integrated source of thought and memory. Baker (1993) mentions "Cognitive functioning and school achievement may be fed through one monolingual channel or equally successfully through two well developed language channels. Both channels feed the same central processor." The CUP controls the conceptual knowledge of two languages.

Similar findings are reported in research into brain science. Crinion et al. (2006) investigated German–English and Japanese–English bilinguals. Participants looked at pairs of words while undergoing brain scans, either PET or fMRI. Results suggest that the left caudate (Figure 5) monitors the language in use and increases its activation when a switch occurs between L1 and L2 in the performance of language tasks. This shows that the left caudate is sending a signal to switch between the two languages. The findings also imply bilingual brain is activated depth of the brain rather than the surface.

What is below the surface is more important to the acquisition of languages than the iceberg's tip: cognitive academic language proficiency. In this model, we can see the function of higher skills such as the thinking skills of inference, analysis, synthesis, integration, reasoning, generalizing, and transferring. The surface features of L1 and L2 are those that have become relatively automatized or were less cognitively demanding. On the other hand, underlying proficiency is involved in cognitively demanding tasks. Although the surface aspects of the languages are separated for L1 and L2, common underlying cognitive/academic proficiency lies across the two languages, but “below sea level” in the iceberg model. Cummins argues that although the two languages may seem separate on the surface, they are actually quite interdependent at the deeper level of cognitive functions. It is well established that students who learn to read and write in their first language are able to readily transfer those abilities to a second language.



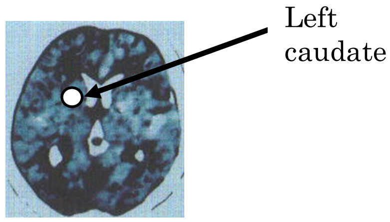


Figure 4. Iceberg model (Cummins, 2001)

Figure 5. Bilingual switch (Crinion, et al. 2006)

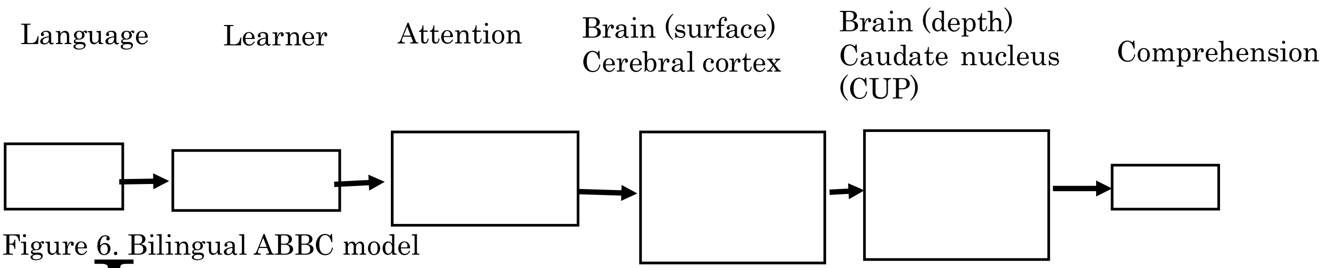


Figure 6. Bilingual ABBC model

5.2 Balloon Model and Bilingual brain

Cummins also describes theories of bilingualism as the “Separate Underlying Proficiency Model” (Figure 7) which states that two languages function separately without transfer and with a limited room. It is believed that the two languages exist together in a brain. The monolingual individual has one large balloon whereas the bilingual individual has two smaller ones.

A similar finding is reported in a study by Kim, et al. (1997). To explore where languages lie in the brain, an fMRI study was conducted on six early bilinguals and six late bilinguals. The early bilingual had learned their L2 when they are young children, and six late bilinguals had learned their L2 after puberty. They discovered that the late bilinguals’L1 grammar and phonology motor maps in the Broca’s area, in close regions to each other, whereas those of their L2 had developed in a separate area.

In the brain of people who had learned both languages in young children, there was only one Broca's area for both languages. Among those who had learned a second language after puberty, however, Broca's area seemed to be divided into two distinct areas. Only one area was activated for each language. These two areas lay close to each other but were always separate, and the second language area was always about the same size as the first language area (Figure 8).

Another study by Lui, et al. (2016) found L2 processing involved more additional regions than L1 for late bilinguals in comparison to early bilinguals. The study also shows L2 processing is more demanding in late bilinguals. It also provides direct evidence that that early bilinguals had greater activation in the left brain than late bilinguals during L1 processing. In addition, they found that the L2 languages indicates different brain activation patterns（Figure 8）.

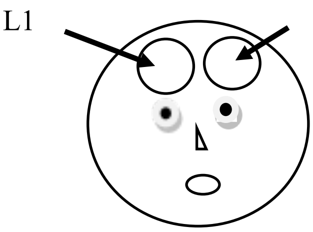


Figure 7.　Balloom Model

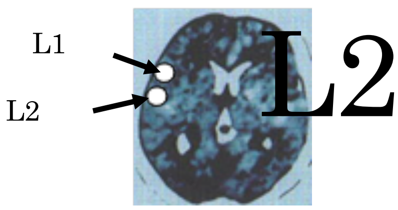


Figure 8.　Broca’s area

6 Implication to the classroom

Advances in modern technology in the scientific field of neuroscience can complement our knowledge of SLA. Through this, we can connect the findings to language acquisition. Based on the findings from current brain research, we see connections between SLA classroom activities and brain activities. Findings that are most applicable to SLA can be seen through the evidence such as in Oishi (2006).

Many practices and a lot of exposure in an English classroom help students to increase their ability to automatic process of the target language. Processing the language more fluently can only be developed through a lot of practices (Nation & Newton, 2008). Moreover, automaticity and using large amount of language can create optimal activation pattern within learners' brain, which is a key to successful learning. Students actively using the language in the classroom will have more active the states of language areas of brain, thereby they will be prepared to more readily provide language output. In this way, practice is critical to integrate newly acquired language into automatic processes and change the state of brain more optimal.

How to change the state of brain optimal in the classrooms? According to O'Malley and Chamot (1990), metacognitive strategies in learning include giving selective attention to the task. Johnston & Dark (1986) claims selective attention refers to the ability to selectively process some sources of information while ignoring others. This technique is quite effective in filtering relevant information. As for selective attention, the metaphor we can use here is a filter, a gate, or a bottle-neck in human information processing as well as interactions at a cocktail party. Bialystok, (1994) has also argued that the basis of fluency is the ability to focus attention on relevant parts of a task to understand information. As we pay large amount of attention to certain tasks, the states of our brains become active and optimal in language learning.

7 Conclusion

This paper presents new perspectives on SLA. With the rapid development of brain measuring technology, SLA studies have been able to find new evidence in brain science as well as in cognitive and psychological approaches. Evidence by Oishi supports findings by McLaughlin and others. Other evidence from bilingual research clarifies a common brain structure between L1 and L2. These new neuroscientific perspectives can shed light on future SLA research, with the possibility of extending instructional methods in the near future.

In conclusion, we see a connection between the research of both SLA and studies in neuroscience. As language researching and teaching, we can make it applicable to our classroom practice and make our classroom activities effective. One thing we can do is encouraging our learners to pay selective attention to any language tasks listening, speaking, reading, and writing. By using the selective attention to target language and creating optimal brain activation patterns of learners, we as teachers can implement the findings into our own teaching. The research into neuroscience regarding SLA has been increasing, further research should be done in actual classroom settings, and this could improve our research findings of brain and SLA.

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