

# Neuroplasticity in the SLA Classroom: Connecting Brain Research to Language Learning

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Modern advances in the scientific field of neuroplasticity can complement our knowledge of what we know about SLA. Through familiarizing ourselves with key theories in both SLA theory and neuroplasticity, we can examine what is compatible and comparable. In this paper, I define what a communicative language classroom is and how knowledge of neuroplasticity can enhance the SLA classroom. Synaptogenesis, synapses, selective attention, UG Hypothesis, Acquisition-Learning Hypothesis, automaticity, connectionism, structured focus, and Interaction Hypothesis are examined and how they relate to each respective field is explained.

現代の科学分野における神経可塑性についての研究は発展しており、この研究成果が第二言語習得(SLA)理論に関する理解に繋がることが期待されている。神経可塑性とSLA理論の両分野における重点を理解することで、両者の適合性や類似性を検証する。さらには、コミュニケーションに重きを置いた言語習得とは何か、また神経可塑性についての知識がどのようにSLA理論の習得に役立つかを明らかにする。シナプス形成、シナプスの実体、選択的注意、普遍文法仮説、習得一学習仮説、自動化、コネクションズム、焦点構造、さらには、相互交流仮説を全て検証した上で、それらがどのように互いの分野で関連付けられるかを検証する。

**A**RE THERE any scientific studies that we can use to link what we know works in the classroom with what actually happens in the brain? Modern advances in the scientific field of neuroplasticity can complement our knowledge of what we know about SLA. For language teachers, there is a lack of research connecting these two fields. This paper will address this connection, and address whether knowledge of current studies in neuroplasticity can enhance our knowledge scientifically of what we know about SLA.

In this paper I will examine current studies in neuroplasticity and how they relate to SLA. I will then examine key theories in SLA and how they might connect to what we know about neuroplasticity. Next I ask, what key features make up a communicative SLA classroom? Finally, I will question if this link is strong enough for language educators to examine further.

## Neuroplasticity Findings Most Applicable to SLA

This section will address key components from within the field of neuroplasticity. Through this we can connect the findings to language acquisition.



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## What is Neuroplasticity?

Neuroplasticity refers to the ability of the brain to structurally change in relation to input from the environment (Shaw & McEachern, 2012). This challenges the theory that the brain loses plasticity for language learning past a critical period during early childhood. The brain actually undergoes continuous change and is able to form new synapses well into adulthood. Schwartz and Begley (2002) referred to the wholesale remapping of neural real estate. We can rewire our minds. The brain has the ability to remake itself throughout our adult life, not only from outside stimuli, but also in response to direct mental effort. In this paper I will apply those findings to second language acquisition.

## Current Tools for Brain Mapping

The two most common types of brain mapping tools are Positron Emission Tomography scans (PETs) and functional Magnetic Resonance Imaging (fMRI). They are used to measure the change in blood flow in relation to neural activity in the brain or spinal cord (Pinker, 2007). Since the 1990s, fMRI's are the preferred method, as they are less invasive without the risk of radiation, unlike PETs. Additionally, MRIs use a computer algorithm to reconstruct images of a living section of the brain. With these tools, neurobiologists can see what parts of a person's brain are active when they are reading, writing, speaking, and listening (Kandel & Hawkins, 1992).

## Pioneering Brain Studies

Neurosurgeons, who focused on removing brain tissue to cure epilepsy or brain tumors, were the first to map out the brain through a "cortical stimulation map" (Calvin & Ojemann, 1994). During these operations, they found that by stimulating certain areas of the conscious, exposed brain, one could disrupt func-

tions like repeating or completing a sentence, naming an object, or reading a word. Through this, they were able to inadvertently study the relation between brain and language. Penfield (1978) was a pioneer in this method, and Ojemann followed up on these methods.

## The Brains of Bilingual Speakers

In a study by Kim, Relkin, Lee, and Hirsh (1997), an fMRI study was conducted on six early bilinguals, who had learned their L2 as young children, and six late bilinguals, who had learned their L2 in adulthood. They discovered the late bilinguals' L1 grammar and phonology motor maps in the Broca's Area, where speech production occurs, had developed in close proximity to each other, whereas those of their L2 developed in a separate area. This implied that the L1 had already been fully connected and mapped out before the L2 was acquired. However, the early bilinguals did not have two separate regions for the different languages. Their brains mapped out both languages in the same area. However, for both groups, the Wernicke's area, the place where the names of things are retrieved, was in a similar location. Essentially, late bilinguals have a separate space in the brain for L2 grammar, rules, and structure. The researchers concluded that the brain needs to map out these new grammatical language areas if the brain's language networks have already been mapped out with only an L1 as a young child.

This ties in with Kuhl's (1998) *native magnet theory*, which refers to the synapses that infants create to establish their first language. There is a *universal perception*, when a newborn is open to all languages, and a *language-specific perception*, when the infant maps out the acoustic dimensions of speech, while producing a network to perceive language. Once this network is formed, language-specific filters make it more difficult to learn an L2, as the L2 must be mapped out in a different location (Bosch, Costa,

& Sebastian-Galles, 2000). All of this ties into plasticity, as it is more difficult, but not impossible.

### **Synaptogenesis**

At birth, there are trillions of neurons in a human brain, but none of them are connected. However, until the age of 3, human brains constantly form neuron connections, or synapses, in what is called *synaptogenesis*. These synapses create three times more activity than in the brain of an adult. They will continue until the age of puberty, and then the excessive connections not used will be pruned off (Kuhl, 2002).

Doidge (2007) stated “if we stop exercising our mental skills, we do not just forget them; the brain map space for those skills is turned over to the skills we practice instead” (p. 59). Therefore, the more we use and practice the L2 we want to learn, the more brain map space is allocated to it. The less we use our L2, the more brain map space goes to other activities that we practice more.

### **Synapses**

This elasticity in brain map-space was first discovered by Canadian psychologist Donald Hebb (1949), who observed that “any two cells or systems of cells that are repeatedly active at the same time will tend to become ‘associated,’ so that activity in one facilitates activity in the other” (p. 70). Later this theory was entitled Hebbian Plasticity and popularly paraphrased into “cells that fire together, wire together” (Schwartz & Begley, 2002, p. 107; Doidge, 2007, p. 64). Essentially, this implies that postsynaptic neurons are bound together by a neurotransmitter glutamate. As these are used more, there is an increase in synaptic strength. Changes in long-term memory occur by stimulating the same chain of neurons over and over (Schwartz & Begley, 2002).

When language acquisition occurs, there is “a learned response that has been built up through the consistent mapping of the same input to the same pattern of activation over many trials” (McLaughlin & Heredia, 1996, p. 214). This is a strengthening of the synapses, which strengthens our capabilities in the target language.

### **Adult Language Learning**

Adult second language learners must rely on declarative memory or explicit knowledge to compensate for what infants can acquire effortlessly. They can apply cognitive thinking to assign and make sense of grammatical structures (Paradis, 2004). The human brain undergoes cognitive adaptation to accommodate the L2 by recruiting existing regions used for the L1, or it can recruit adjacent areas of the cortex (Coggins, Kennedy, & Armstrong, 2004). Neuroimaging studies show an actual structural shift in the brain in response to acquiring an L2 as an adult (Mechelli, et al., 2004).

For L2 learners, there is direct evidence that when learning occurs over time, neurochemical communication between neurons is facilitated. This implies that less input is required to activate established connections (Genesee, 2000). The brain learns how to differentiate the sounds of the L2 that correspond to the correct words. Neural connections in turn reflect this learning process and create circuits that associate a visual image with the sound of the word. In early stages of learning, these neural circuits are weak or incomplete. As exposure is repeated, less input is needed to activate the entire neural network. Eventually, activation and recognition are nearly automatic.

An interesting related study was done by Maguire, et al. (2000), in which they studied the brains of taxi drivers by using brain scans. They then plotted the differences between the relative experience of the drivers. They found that the more



experience a taxi driver had navigating the roads of London, the larger the hippocampus in the brain was to record this information. Acquiring navigational skills caused a stronger, thicker grey matter in this part of the brain. This was another study that showed the brain is neuroplastic and able to learn well into adulthood.

### Selective Attention

Desimone, a leading researcher in the physiology of attention, explained that selective attention can strengthen or weaken neural processing in the visual cortex (Desimone, 1998). fMRI scans show that neurons fire more actively when engaged in paying attention to a particular task. Robertson (1999) stated that attention can sculpt brain activity by increasing or decreasing the rate at which particular sets of synapses fire. Therefore attention is an important ingredient in neuroplasticity as it causes a set of synapses to grow stronger.

A group of researchers led by Passingham studied PET scans of a man's attention as he tried to figure out a sequence on a keypad (Jueptner, et al., 1997). Through this activity, his brain was lit up with activity, particularly in the areas associated with planning, thinking, and moving. Once he worked out the sequence, and he could do it effortlessly, a change was marked in his brain. Only the motor regions that commanded his fingers to move remained active. In short, paying attention involves the brain, increases learning and recall, and helps commit things to memory.

In conclusion, there are many connections between neuroplasticity and second language acquisition. This review of relevant research demonstrates how the mind neurologically acquires language through repetition, selective attention, and focus.

### SLA Theory Most Applicable to Neuroplasticity

This section will examine key SLA theories and how they might be connected to what we have learned about neuroplasticity.

### Access to the Universal Grammar Hypothesis

Universal Grammar (UG) is a theory that holds that language is innate in newborns (Chomsky, 1960s/2006). Children acquire language naturally; however, once an individual passes a certain age, it is no longer easy to acquire language.

White's (1989) theory claimed that innate language facility is operational in SLA as well; it just constrains the grammar. It is an opposing theory to the *Fundamental Difference Hypothesis* that holds that adults and children have fundamental differences in acquiring language (Bley-Vroman, 1989). White outlines five possibilities in regards to the availability of UG for L2 learners. She resorts to two variables, transfer and access, and outlines how some forms of UG are available to adult L2 learners from these variables. This theory coincides with neuroplasticity, in that our brain is continually malleable and able to learn new things well into adulthood.

### Acquisition-Learning Hypothesis

Krashen (1982) spoke about two ways people acquire language. One was through acquisition or informally "picking up" a language. The second was through formal learning of a language. In the former instance, the learners are not consciously aware of the rules of the language as they acquire it. This is often the case with very young learners. However, in the latter case, the learners are consciously familiarizing themselves with the rules and becoming metalinguistically able to discuss them. In Krashen's theory, it would be this second way in which the concepts of neuroplasticity are applicable to the acquisition of language skills in an L2.

## **Automaticity and Restructuring**

McLaughlin (1990) discussed two points that are fundamental in L2 use, automaticity and restructuring. Automaticity refers to control over one's linguistic knowledge. Learners must combine skills from perceptual, cognitive, and social domains, and routinely use them in their L2. It is "a learned response that has been built up through the consistent mapping of the same input to the same pattern of activation over many trials" (McLaughlin, 1987, p. 134). Restructuring refers to organizing that knowledge to internalize it. Using these two fundamental points, students should be practicing and organizing their language skills, in order to retain their L2.

## **Connectionism**

Gass and Selinker (2001) discussed the theory of connectionism. It is consistent with neural pathways but uses different terminology. It concerns biological pathways that are strengthened or weakened by use. Learning takes place in associations, and associations are from exposure to repeated patterns. The more often the association is made, the stronger the learning network becomes.

## **Structured Focus and Interaction**

Mackey (1999) researched learners of English in relation to communication tasks and interaction with others. In those studies it was found that learners who were more involved in structure-focused interaction were able to move further along a development path in English than those who were not. Interaction with others increased their development.

It is also to be noted from Mackey's studies that development stages could not be skipped. But the ability of students with a structured focus and interaction with the language increased

more quickly than did the ability of those students without such focus and interaction.

## **Interaction Hypothesis**

Long (1996) developed the Interaction Hypothesis. Essentially, he believed that learning takes place through interaction. There is a negotiation for meaning that takes place, which triggers interactional adjustments. Interaction facilitates learning as it involves selective attention, input, output, and internalizing.

There are other studies by Gass and Varonis (1989) that show that learners do not pick up errors from one another. Learners use positive evidence to strengthen their knowledge. Essentially, the more practice and the more interaction that there is while using the target language, the stronger the awareness of the language will become.

## **Selective Attention**

From the heart of the interaction hypothesis, Long (1996) discussed the importance of selective attention. Attention combined with negotiation are the two most crucial elements in the process of learning a language. This ties in with our knowledge of brain studies, in that as we pay attention to certain things, our brains and neurons become active and strengthened, and this therefore increases our knowledge and awareness.

## **The Communicative Classroom**

Now that we have connected SLA theories and neuroplasticity, how is this applicable for teachers within the EFL classroom? There are many key components necessary for teachers to create an interactive, communicative classroom. The following suggestions can strengthen the neural connections within their students' L2 brains.



## Fluency Building

Fluency building tasks help students increase their ability to speak the target language. Speaking more fluently can only be developed through practice (Nation & Newton, 2008).

Additionally, fluency and using language can create stronger synaptic states within your brain, which is instrumental to learning. Research by Montgomery and Madison (2004) identified five states that synapses move between. These states are *active*, *silent*, *recently-silent*, *potentiated*, and *depressed*. Students actively using the language in the classroom will have their synaptic states more active, thereby prepared to readily give language output. In this way, practice is critical to put newly acquired language into our short-term memory, and through strengthening synapses, into our long-term memory.

## Approaches Towards the Communicative Classroom

When students do pair work exercises, they are using the communicative approach to learn languages. In this approach they focus on practicing the language by communicating in the target language with others (Lewis & Hill, 1997).

There are a number of communicative approaches to study that would be ideal for this type of teaching. They include the Natural Approach, immersion, task-based learning, and content-based instruction. The common theme among all of these approaches is that “communication is at the heart of language acquisition” (VanPatten, 2003, p. 98). Harmer (2007) also discusses Communicative Language Teaching (CLT). The essential tenet in CLT is that students are involved in meaning-focused communicative tasks. All of these approaches and methods have the core belief that interaction promotes acquisition. Interaction heightens learners’ awareness of what is missing in their developing systems. It pushes them into being more active with their input processing (VanPatten, 2003).

## Language Acquisition in the Classroom

VanPatten and Cadierno (1993) argued that beginning language learners need structured input activities that enable them to focus on meaning while they pay attention to form. This will allow them to use the language to produce output. Structured input implies that acquisition is not driven by explicit rules, but by interaction with input data (VanPatten, 2003).

As learners create structured sentences to express meaning to someone else, their output becomes input for others. Language acquisition occurs when language learners are exposed to communicative input and must process it. The brain organizes the data they receive. Learners must acquire output procedures and they need to interact with other speakers.

To maximize the variety of input, it is vital to change speaking partners in the language classroom often. Maher (2011, 2012) surveyed students about changing partners often in the language-oriented classroom. According to the results of the surveys, most students believed that talking to various partners, particularly people they did not know, encouraged them to listen more attentively and participate more in conversation, thereby increasing their language abilities. They also felt they could hear and share more opinions through practicing language with various classmates than by talking to the same students regularly. In short, it increased the variety of input.

Vygotsky (1930s/1978) proposed the Zone of Proximal Development (ZPD). A learner’s language performance with others exceeds what the learner is able to do alone. Through interaction with others, learners progress to their greater potential. Problem solving under guidance or in collaboration with more capable peers increases their performance.

## Routines

Lastly, students should be exposed to the usage of what Yorio (1980) called routines. These are words, phrases, or sentences that are predictable in a typical communicative situation by members of a speech community. They may include situational phrases such as "You had to be there" when relating a humorous story or "Dearly beloved" in a ceremonial ritualistic interaction (Shrum & Glisan, 2005).

Taylor (2002) calls these routines *gambits*, or devices that help the speaker maintain the smooth flow of conversation. This includes all turn-taking queues, pause fillers, set phrases, expressions to buy time, and so forth. These many conversational strategies can be taught, but through interaction and using the language, they can be acquired and adapted.

These routines or gambits allow students to sound more natural to native speakers, and increase their confidence and ability to acquire their L2, as well as to gain more input and give out more output—all of which increases their neural networks in relation to using the target language.

## Conclusion

In conclusion, reviewing the research of both SLA and studies in neuroplasticity, we find there is a connection between the two. We can incorporate this knowledge of neuroplasticity and make it applicable for our classrooms as language teachers. Through encouraging active participation, using the target language, and strengthening neural pathways, we can implement this awareness into our own teaching.

I began by asking if these two fields were compatible and complimentary. I believe that they are, and there is much that can be learned from connecting them. Further research should be done about connecting them, and this could enhance our knowledge of SLA.

## Bio Data

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## References

- Bley-Vroman, R. (1989). What is the logical problem of foreign language learning? In S. Gass & J. Schachter (Eds.), *Linguistic perspectives on second language acquisition* (pp. 41-68). Cambridge: Cambridge University Press.
- Bosch, L., Costa, A., & Sebastian-Galles, N. (2000). First and second language vowel perception in early bilinguals. *European Journal of Cognitive Psychology*, 12, 189-221.
- Calvin, W., & Ojemann, G. (1994). *Conversations with Neil's brain: The neutral nature of thought and language*. New York: Addison-Wesley.
- Chomsky, N. (2006). *Language and mind* (3rd ed.). Cambridge: Cambridge University Press. (Original works published 1960s)
- Coggins, P., Kennedy, T., & Armstrong, T. (2004). Bilingual corpus callosum variability. *Brain and Language*, 89, 69-75.
- Desimone, R. (1998). Visual attention mediated by biased competition in extrastriate visual cortex. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 353, 1245-1255. doi:10.1098/rstb.1998.0280
- Doidge, N. (2007). *The brain that changes itself*. New York: Penguin Books.
- Dörnyei, Z., & Murphey, T. (2004). *Group dynamics in the language classroom*. Cambridge: Cambridge University Press.
- Gass, S., & Selinker, L. (2001). *Second language acquisition*. Mahwah, NJ: Erlbaum.
- Gass, S., & Varonis, E. (1989). Incorporated repairs in NNS discourse. In M. Eisenstein (Ed.), *Variation and second language acquisition* (pp. 71-86). New York: Plenum.

- Genesee, F. (2000). *Brain research: Implications for second language learning*. Berkeley, CA: UC Berkley, Center for Research on Education, Diversity, and Excellence. Retrieved from: <http://escholarship.org/uc/item/58n560k4>
- Harmer, J. (2007). *The practice of English language teaching*. London: Pearson.
- Hebb, D. (1949). *Organization of behavior: A neuropsychological theory*. New York: John Wiley and Sons.
- Jueptner, M., Stephan, K., Frith, C., Brooks, D., Frackowiak, R., and Passingham, R. (1997). Anatomy of motor learning. I. Frontal cortex and attention to action. *Journal of Neurophysiology*, 77, 1313-1324.
- Kandel, E., & Hawkins, R. (1992). The biological basis of learning and individuality. *Scientific American*, 267(3), 79-86.
- Kim, K., Relkin, N., Lee, K., & Hirsch, J. (1997). Distinct cortical areas associated with native and second languages. *Nature*, 388, 171-174.
- Krashen, S. (1982). *Principles and practice in second language acquisition*. London: Pergamon.
- Kuhl, P. (1998). The development of speech and language. In T. Carew, R. Menzel, and C. Shutz (Eds.), *Mechanistic relationships between development and language* (pp. 53-72). Wiley: New York.
- Kuhl, P. (2002, June 9-10). *Born to learn: Language, reading, and the brain of the child*. Paper presented at the Early Learning Summit, Boise, ID.
- Lewis, M., & Hill, J. (1997). *Practical techniques for language teaching*. London: Language Teaching Publications.
- Long, M. (1996). The role of the linguistic environment in second language acquisition. In W. Ritchie & T. Bhatia (Eds.), *Handbook of second language acquisition* (pp. 413-468). San Diego, CA: Academic Press.
- Maguire, E., Gadian, D., Johnsrude, I., Good, C., Ashburner, J., Frackowiak, R., & Frith, C. (2000). Navigational-related structural change in the hippocampi of taxi drivers. *Proceedings of the National Academy of Sciences of the United States of America*, 97, 4398-4403.
- Mackey, A. (1999). Input, interaction, and second language development. *Studies in Second Language Acquisition*, 21, 557-587.
- Maher, K. (2011). Intricacies of pairwork—Surveys and research. *The Bulletin of Keiwa College*, 20, 15-32.
- Maher, K. (2012). Exploring pairwork in a communicative classroom. In *NEAR Conference 2011 Proceedings*. Retrieved from <http://www.iuj.ac.jp/near/publications/pdf/NEAR-2011-03.pdf>
- McLaughlin, B. (1987). *Theories of second language learning*. London: Edward Arnold.
- McLaughlin, B. (1990). Restructuring. *Applied Linguistics*, 11, 113-128.
- McLaughlin, B., & Heredia, R. (1996). Information processing approaches to research on second language and use. In W. Ritchie & T. Bhatia (Eds.), *The Handbook of second language acquisition* (pp. 213-228). San Diego, CA: Academic Press.
- Mechelli, A., Crinion, J., Noppeney, U., O'Doherty, J., Ashburner, J., Frackowiak, R., & Price, C. (2004). Structural plasticity in the bilingual brain. *Nature*, 431, 757.
- Montgomery, J., & Madison, D. (2004). Discrete synaptic states define a major mechanism of synapse plasticity. *Trends in Neuroplasticity*, 27, 744-750.
- Nation, I. S. P., & Newton, J. (2008). *Teaching ESL/EFL listening and speaking*. London: Routledge.
- Paradis, M. (2004). *A neurolinguistic theory of bilingualism*. Amsterdam: John Benjamins.
- Penfield, W. (1978). *The mystery of the mind: A critical study of consciousness and the human brain*. Princeton, NJ: Princeton University Press.
- Pinker, S. (2007). *The language instinct: How the mind creates language*. New York: HarperCollins.
- Robertson, I. (1999). *Mind sculpture: Your brain's untapped potential*. London: Bantam Press.
- Schwartz, J., & Begley, S. (2002). *The mind & the brain: Neuroplasticity and the power of mental force*. New York: HarperCollins.
- Shaw, C., & McEachern, J. (2012). *Toward a theory of neuroplasticity*. London: Psychology Press.
- Shrum, J., & Glisan, E. (2005). *Teacher's handbook: Contextualized language instruction*. Boston, MA: Thomson Heinle.

- Taylor, G. (2002). Teaching gambits: The effect of instruction and task variation on the use of conversational strategies by intermediate Spanish students. *Foreign Language Annals*, 35, 171-189.
- VanPatten, B. (2003). *From input to output: A teacher's guide to second language acquisition*. Chicago: McGraw-Hill.
- VanPatten, B., & Cadierno, T. (1993). Input processing and second language acquisition: A role for instruction. *The Modern Language Journal*, 77, 45-57.
- White, L. (1989). *Universal grammar and second language acquisition*. Amsterdam: John Benjamins.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.). Cambridge, MA: Harvard University Press. (Original works published 1930s)
- Yorio, C. (1980). Conventionalized language forms and the development of communicative competence. *TESOL Quarterly*, 14, 433-442.