The Study of Language in the Brain: Implications for Language Acquisition

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STATEMENT OF PURPOSE

How the brain engages language processes in the mind is of great interest to the field of second language acquisition. With exposure to how the brain processes languages, a learner is able to focus more attention on the areas that are most useful for acquisition. It is also meaningful to know how the brain works to store and retain language.

The purpose of this paper is to review current research in language in the brain and its implications for language acquisition. First, current studies and knowledge of how language works in the mind will be addressed. Next, we will look at how language is learned and what occurs in the brain during this process. Then, there will be a comparison with what happens to the brains of children compared to the brains of adults who learn second languages. Ultimately, the research will show how to apply this information to language acquisition for second language learners. The end goal is to have examined key components in the study of language in the brain for a better understanding of how to apply it towards language acquisition.

BRAIN STRUCTURE

The brain is composed of billions of neurons constantly firing and exchanging information among themselves. Both hemispheres have specialized functions, but there is a great amount of fluidity between the two of them. It is believed that the right hemisphere of the brain stores information regarding images, symbols, sense, and metaphors, while the left hemisphere makes sense of this information and formulates the right hemisphere's images into words for communication. Therefore it is in the right hemisphere that formulates new ideas, total contexts, and where the creation of meaning occurs. However, it is the left hemisphere that is essential to encode, understand and communicate (Hatcher 1983).

LANGUAGE AREAS OF THE BRAIN

The perisylvian cortex, an area of the brain often referred to as the epicenter of language activity, generally lies within the left hemisphere and is associated with language acquisition and processing (Caplan 1987). It is important to clarify that language does not always lie in the left hemisphere at all times: There have been studies (Catani, 2007) of exceptional cases where it can be found in the right hemisphere with some people.

Within this perisylvan cortex, the Broca's Area and Wernicke's Area can be found (Mateer, 1983). Broca's Area is involved with the production of language and is more grammar-based, whereas Wernicke's Area is involved with the role of accessing words and funneling them to other areas, and is more vocabulary-based (Caplan 1987). There have been many studies of people who have been affected by aphasia (damage to one of these regions). They either lose their ability to use grammar correctly as well as the motor aspect of speech, as in the case of Broca's Aphasia, or they are unable to retrieve nouns, as in the case of Wernicke's Aphasia.

CURRENT TOOLS FOR ACQUIRING BRAIN MAPPING

Many current studies on the brain and language are being made with PETs (position emission tomography) and fMRIs (functional Magnetic Resonance Imaging). MRIs use a computer algorithm to reconstruct images of a living section of the brain. PETs are when a volunteer either injects or inhales a mildly radioactive gas or liquid similar in dosage to an X-Ray, and then proceed to place his or her head inside a ring of gamma-ray detectors (Pinker, 1994). These new tools map images of blood flow within the brain during specific activities. For example, 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

In addition to these methods, neurosurgeons who were originally focusing on finding the best ways to remove brain tissue to cure epilepsy or brain tumors began to map out the brain in a 'cortical stimulation map' (Calvin and

Ojemann, 1994), which ultimately assisted the study of language in the brain. Damaging one of these language areas in surgery means the patient will become temporarily or permanently aphasiac, or unable to recall words or use grammar correctly. During these operations, as the neurosurgeon has mapped the brain, they have discovered each brain's map is different; there is no set map for all people. These neurosurgeons discovered that if certain parts of the brain are stimulated, the subject will be unable to name things or be unable to produce grammatically correctly sentences. Electrodes on the scalp record electroencephalograms (EEG's) as the patient hears or reads words. Wilder Penfield (1978) was a pioneer in this method, and George Ojemann followed up on these methods on conscious, exposed brains. He found that stimulating certain areas of the brain could disrupt functions like repeating or completing a sentence, naming an object, or reading a word (Calvin and Ojemann, 1994).

BILINGUAL SPEAKERS AND THEIR BRAINS

There have been studies on bilinguals, and researchers have investigated how multiple languages are represented in a human brain. In one study (Kim , Relkin, Lee & Hirsch, 1997), researchers conducted a functional MRI study of six fluent early bilinguals who learned their L2s (second language) as young childrin, and six fluent late bilinguals who learned their L2s in early adulthood. The researchers discovered that in the Broca's Area, production was drastically different between the two groups. Late bilinguals' native L1 grammar and phonology motor maps (Broca's Area) had developed in close proximity to each other, whereas in their L2 they developed in a separate area, as if the native language area had already been fully connected and mapped out. This is in contrast to early bilinguals who did not exhibit two distinct regions for different languages. The Wernicke's Area, the location where names of things are retrieved, was similar in the two groups as both groups had similar locations of their L1 and L2 in their phonology motor map. The implication is that for second language learners, there is a separate space in the brain for the second language's grammar, rules and structure. When fMRI studies were made, it was discovered that distinct loci of second languages lie along the periphery of Broca's and Wernicke's regions in the case of late learners, but not in the case of early learners (Kim, et al, 1997). 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 a first language as a young child.

CHILDREN RAISED IN ISOLATION, THE CPH, and SYNAPTOGENISIS

There have also been cases where children have never learned a first language during their youth. A well-known example is that of "Genie" who was isolated since birth from any linguistic input because of abusive parents (Curtiss, 1977) and the "Wild Boy of Aveyron" (Shattuck, 1980) among others. Neither Genie, nor the Wild Boy of Aveyron, was raised in an environment exposed to language. Because of their situation, their brains were not able to map out a language area in the brain's network, presumably due to lack of input (Lenneberg, 1964, 1984). As human beings mature, they reach a "critical period" which states that to a certain age, no instruction is needed to learn a language, and then at a critical period, the acquisition of native-like fluency becomes highly unlikely if not impossible. However, in the case studies of "Genie" and the "Wild Boy of Aveyron", their brains were never able to map out these synapses of a native tongue, and therefore they were unable to communicate effectively throughout their lives. In adulthood, both were completely unable to master things like verb tense, word order, prepositions, or pronouns.

Consistent with the critical period hypothesis, infants have a great capacity to acquire a new language, significantly more so than adults. At birth, there are trillions of neurons, but there are no connections between them at birth. However, up until the age of three, human brains are constantly forming neuron connections in a process called synoptogenesis (Kuhl, 2002). These synapses create three times more activity than what is active in the brain of an adult. They will continue to create connections until the child reaches the age of puberty. At that time, synapses begin to prune off the excessive connections that are not used (Kuhl, 2002). "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" (Doidge, 2007: p. 59), so therefore, the more we use the target language, the more brain space is allocated for it.

During this infant stage, synapses create what Kuhl (1998) has called the 'native language magnet' theory. This is what occurs between universal perception (when a newborn is open to any and all languages) and language-specific perception (when the infant maps the acoustic dimensions of speech while producing a complex network through which language is perceived). Once this is formed, language specific filters make it more difficult to learn a second language as the mapping of the primary language is completely different from the mapping of a second language (Bosch, Costa, Sebastian-Galles, 2000).

LANGUAGE INPUT (PARENTESE) AND THE BRAIN

Studies show that caretakers who speak 'parentese' do help children learn the parameters of the native language (Kuhl, 2002). Parentese is babytalk, or the way that a child's parents might speak over-emphasizing their syllables and words for the baby to understand. Additionally, it has been observed that infants, while mapping their native language, will initially be able to recognize all sounds, but later lose their ability to do so, as they become more selective with their first, native language. For example, Kuhl (2002) has been done a study on infants between the age of six to eight months old from the U.S. and from Japan, and again with infants between the ages of ten to twelve months old. From six to eight months old, both sets of babies can distinguish the sounds /l/ and /r/; at ten to twelve months old, only the U.S. babies can. The Japanese babies have become more culture-bound and adult-like and more selective to their native language (Kuhl, 2002).

SECOND LANGUAGE AND CRITICAL PERIOD

Once a child has formed their neural networks for language, (most researchers place this at about the age of ten or puberty), it becomes difficult to learn a new language, as the brain has formed its native language patterns (Chugani, 1996). Therefore, the ages between four to ten years old are the most productive for learning languages. At this time, a distinction emerges between implicit knowledge and explicit knowledge of the second language.

Implicit refers to a subconscious and internalized set of rules that permits a speaker to assign a grammatical structure to strings of words in a manner comparable with how other native speakers assign structures to those strings (Paradis, 2004). This occurs in the perisylvian cortex, where the Broca's Area is found, as it is involved in grammatical processing. Studies (Pinker, 1994) using Positron Emission Tomography (PET) have shown where distinct electrical activity in the brain is picked up at the point when a sentence becomes ungrammatical. This implies that the grammar section of the brain can implicitly sense when the sentence ceases to make grammatical sense.

In contrast, while implicit knowledge is available by procedural memory, which is effortless and automatic, explicit knowledge is available only by declarative memory: adult second language learners must rely on declarative memory or explicit knowledge to compensate for what is missing from procedural memory. There becomes a need to assign grammatical structure to a sentence using cognitive thinking (Paradis, 2004). However, with second and/or third language acquisition and use, the human brain undergoes cortical adaptation to accommodate the language either by recruiting existing regions used for the native language, or more likely, recruiting distinct adjacent areas of the cortex (Goggins, et al., 2004).

Additionally, research has found a prominent growth in the language cortex itself, suggesting a key maturational phase in brain regions that support the learning of new languages (Dimond, et al., 1977). There is also evidence that the structure of the human brain is altered by the experience of acquiring a second language. Structural neuroimaging studies show it structurally changes in response to environmental demands. These studies even suggest there is more grey-matter density in the brain of a bilingual person (Mechelli, et al., 2004).

PLASTICITY OR THE MALLEABLE BRAIN AND AGE

Specialized functions of specific regions of the brain are not fixed at birth, but shaped by experience and learning. As a person studies and learns even in adulthood, the cortical map can change. In one study (Sur, Pallas & Roe, 1990), researchers learned that input determines the function of specific areas of the brain. One study (O'Leary & Stanfielf, 1985) that supports this was carried out on animals. The researchers took the neurons in the visual cortex of rodents and transplanted them to regions of the brain that are normally linked to bodily and sensory functions. The transplanted tissue lost its capacity to process visual information, and instead took on the functions of somato-sensory neurons; for example, it might assume the role of neurons involved with the sense of touching something, as opposed to its previous visual properties. This indicates that the brain is malleable and able to change according to the input it receives.

For second language learners, there is direct evidence that when learning occurs over time, neuro-chemical communication between neurons is facilitated, and less input is required to activate established connections (Genesee, 2000). For example, exposure to unfamiliar speech sounds is initially registered as undifferentiated neural activity. As exposure continues, the brain learns to differentiate between the sounds that correspond to words. Neural connections reflect this learning process and create circuits that associate the visual image with the sound of the word. In early stages of learning, neural circuits are often incomplete or weak. As exposure is repeated, less input is needed to activate the entire network. With time, activation and recognition are nearly automatic. Goldman-Rakic (1996) observes that while children's brains acquire a tremendous amount of information during the early years, most learning takes place after synaptic formation stabilizes. This implies that we easily acquire information when we are young, but as adults we must gain the ability to learn (as opposed to naturally acquiring information) as our synaptic formation stabilizes.

LEARNING IN THE BRAIN

Students learn and remember what they actively construct mentally. It is important to construct sentences, images, inferences, and metaphors in order to learn the information and encode it into long-term memory. This is called a 'generative process' of learning (Wittrock, 1981). The brain operates best when it is active. Only when students are actively engaged in learning and not simply passive recipients of the teacher's words will they be motivated, and only active learning will develop their cognitive functions (Frostig & Maslow, 1979). As one famous philosopher of education, Alfred North Whitehead, has said, "Get your knowledge quickly, and then use it. If you can use it, you will retain it" (Whitehead, 1927: p. 272). Whitehead also warns, "In training a child to activity of thought, above all things we must beware of what I will call 'inert ideas' — that is to say, ideas that are merely received into the mind without being realized, or tested, or thrown into fresh combinations" (Whitehead, 1927: p. 262). Therefore it is important for students to actively use what they learn to create the neuron connections that strengthen the usage of the foreign language, making it more natural and fluid.

IMPLICATION FOR TEACHING

Foreign language students must actively talk to learn. For example, Hart (1979) has said a "stop talking" class is likely to be a "stop learning" environment. The reason for talking is that a significant portion of the brain is structured towards oral language, as well as writing and reading, and that thinking aloud is necessary to expand brain capacity. Teachers that design classes centered on actively using the target language will most help students to improve those particular skills.

Overall, we have learned that a person's L1 is easily acquired and mapped out in the brain even if that person is exposed to multiple languages as a child, but a person's L2, particularly when learned later in life, must create and expand new brain networks for the L2, and the person must be actively using the language to make those synapses stronger. Production of language is critical to increasing these neural networks in the L2. Production "may force the learner to move from semantic processing to syntactic processing" (Swain, 1985, p. 249). It is said that "processing language only at the level of meaning will not and cannot serve the purpose of understanding the syntax of the language, a level of knowledge that is essential to the production of language. In sum, output provides learners the opportunity to produce language and gain feedback" (Gass & Selinker, 2001, p. 290). To become most accustomed to using a foreign language involves "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).

CONCLUSION

The main objective of this study was to look at current knowledge of research into the brain and language to help us understand language acquisition. Understanding how language works in the brain can better help us understand how we can learn and retain languages more effectively. One of the main points to remember for learning languages, in reference to the studies of language and brain, is the importance of actively using language to become more familiar and natural with its usage. For adults, who may not be able to acquire a second language as easily as children, it is critical to be involved in conversation to map out the neurons in the brain so that language is more easily retrieved. Additionally, they should be actively involved in output so that they use the target language. This process should most effectively assist them in acquiring it.

REFERENCES:

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.

Caplan, D. (1987). *Neurolinguistics and Linguistic Aphasiology*. New York: Cambridge University Press.

Calvin, W. & Ojemann, G. (1994). *Conversations with Neil's Brain*. New York: Addison-Wesley.

Chugani, H. (1996). Neuroimaging of Developmental Ninlinearity and Development Pathologies, in Thatcher, R., *Neuroimaging*. San Diego: Academic Press, pp. 187-195.

Coggins, P., Kennedy, T., & Armstrong, T. (2004). Bilingual Corpus Callosum Variability. *Brain and Language*, 89, 69-75.

Curtiss, S. (1977). *Genie: Psycholinguistic Study of a Modern-day "Wild Child"*. London: Academic Press Inc.

Dimond, S., Scammell, R., Brouwers, E. & Weeks, R. (1977). Functions of the Centre Section (Trunk) of the Corpus Callosum in Man. *Brain*, 100, 543-562.

Doidge, N. (2007). *The Brain that Changes Itself.* New York: Penguin Books.

Frostig, M. & Maslow, P. (1979). Neurological Contributions to Education. *Journal of Learning Disabilities*, 12, 538-552.

Gass, S. & Selinker, L. (2001). *Second Language Acquisition: An Introductory Course*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc., Publishers.

Genesee, F. (2000). *Brain Research: Implications for Second Language Learning*. ERIC Document #ED447727.

Goldman-Rakic, P. (1996). *Bridging the Gap Between Neuroscience and Education: Summary of a Workshop Cosponsored by the Education Commission of the States and the Charles A. Dana Foundation*. Denver: Education Commission of the States, p. 5.

Hart, L. (1979). Brain, Language, and New Concepts of Learning. *Educational Leadership*, 38, 443-445.

Hatcher, M. (1983). Whole Brain Learning, *School Administrator*, 40(5), 8-11.

Kandel, E. & Hawkins, R. (1992). The Biological Basis of Learning and Individuality. *Scientific American*. Pp. 79-86. September

Kim, K., Relkin, N., Lee, K., & Hirsch, J. (1997). Distinct cortical areas associated with native and second languages. *Nature*, 388, 171-174.

Kuhl, P. (1998). In *Mechanistic Relationships Between Development and Language*, eds. Carew T., Menzel, R. & Shutz, C. Wiley: New York, pp. 53-73.

Kuhl, P. (2002). *Born to Learn: Language, Reading, and the Brain of the Child*, paper presented at the Early Learning Summit in Boise, Idaho, June 9-10.

Lennebrge, E. (1964). *New Directions in the Study of Language*. Cambridge, MA: Harvard University Press.

Lenneberg, E. (1984). *Biological Foundations of Language*. Malabar, FL: R.E. Krieger.

Mateer, C. (1983). Motor and Perceptual Functions of the Left Hemisphere and their Interaction. In Segalowitz, S. (Ed.), *Language Functions and Brain Organization*. New York: Academic Press.

McLaughlin, B. and Heredia, R. (1996). Information Processing Approaches to Research on Second Language Acquisition and Use. In *The Handbook of Second Language Acquisition*, eds. William C Ritchie and Tej K Bhatia. San Diego: Academic Press. Pp. 213-228.

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.

Paradis, M. (2004). *A Neurolinguistic Theorty of Bilingualism*. Amsterdam/Philadelphia: John Benjamins Publishing Company.

Penfield, W. (1978). *The Mystery of the Mind: A Critical Study of Consciousness and the Human Brain*. Princeton, NJ: Princeton University Press.

Pinker, S. (1994). *The Language Instinct*. New York: HarperCollins.

O'Leary, D. & Stanfield, B. (1985). Occipital Cortical Neurons with Transient Pyramidal tract Axons Extend and Maintain Collaterals to Subcortical but not Intracortical Targets. *Brain Research*, 336, pp. 326-333.

Shattuck, R. (1980). *The Forbidden Experiment: The Story of the Wild Boy of Aveyron*. New York: Kodansha International.

Swain, M. (1985). Communicative Competence: Some Roles of Comprehensible Input and Comprehensible Output in its Development. In Cass, S. & Madden C. (Eds.), *Input in Second Language Acquisition*, pp. 235-253. Rowley, MA: Newbury House.

Sur, M., Pallas, S., & Roe, A. (1990). Cross-modal plasticity in cortical development: Differentiation and Specification of Sensory Neocortex. *Trends in Neuroscience*, 13, pp. 227-233.

Whitehead, A. (1927). The Aims of Education and Other Essays (1929). In S. Cahn, ed. *Classical and Contemporary Readings in the Philosophy of Education* (pp 197-222). New York: McGraw Hill, pp. 262-273.

Wittrock, M. (1981). Educational Implications of Recent Brain Research. *Educational Leadership*, 39(1), pp. 6-9.