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Research Article

NEUROSCIENCE RESEACH FOR CLASSROOM TO ENHANCE L2 VOCABULARY LEARNING

Peddipaga Rambabu*

Department of English, MANUU, Hyderabad

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ABSTRACT

This paper shed light on the importance of learning L2 vocabulary, which was not paid a serious attention in second language learning classroom. It further presented how the neuroscience was emerged and turned to be educational neuroscience. The paper focused on learning procedure between neurons in addition to critical period for language learning with special reference to second language learning and L2 vocabulary learning. The paper was concluded with an appeal to educators to follow and comprehend educational neuroscience for their professional pleasure.

INTRODUCTION

English as an international language promotes academic, social, cultural, economical, and political relations among the nations of the world. Learning or teaching English as a foreign language or second language is the common phenomenon in many parts of the world. Though English language is the composition of many language items, vocabulary is an undeniable item for quick learning of LSRW skills in English language. Vocabulary development is one of the most important aspects of students' life. It affects their thoughts, actions, aspiration, and success, particularly in academic field. In the fast growing world, every branch of study demands good amount of vocabulary for all round development. We have several approaches and methods in English language teaching to be used to enhance L2 vocabulary learning, but none of them focused on the science of learning procedure of neurons in human brain.

Historical Development of Neuroscience

History points back to the beginning of formal education between 3000 and 500 B.C.E. Though it was difficult to give exact dates, first instruction was started from parent then scribal schools, which taught not only writing but also wisdom (Curnow, 2010; Kugel, 2007). Ferrari and McBride (2011) stated that Hippocrates who lived between 460 and 380 B.C.E. was the first man to identify brain as a source for knowledge, sensation, and wisdom. After some centuries, Stoic philosophers recognized human experience to be completely embodied, though debates went on the questions whether heart or brain is primary organ of psychic life. Kemp (2007) explained that the sketches of centenarian brain of Leonardo Da Vinci during the period of renaissance and anatomical work of Andreas Vesalius not only created visual support but also named certain areas of brain. Christopher Wren's engravings *Cerebri anatome* (The Anatomy of the Brain) in 1664 for Thomas Willis were completely mind versions of brain in the first scientific journal published by Royal Society of London. John Locke's manual "*Some Thoughts Concerning Education*" on how to direct the child to virtue weaved around virtue, wisdom, breeding, and learning. His overall curriculum reiterated starting with fun of learning, plain, and simple ideas based on child's pre-existing knowledge on how subjects are interconnected (Aldirch, 1994).

Bonnet in his "*Essays on Psychology*" in 1755 particularly linked brain, mind, and education without proposing any education program. Broca (1861a) and Wernicke (1874) declared that most people have two main language areas in frontal (Broca) and parietal (Wernicke) lobes. Santiago Ramon

Corresponding author:* **Peddipaga Rambabu
Department of English, MANUU, Hyderabad

Y Cajal was considered by many people as the father of neuroscience. He was known for his famous discovery of independent neurons or cells that were building blocks in the central nervous system. He was a scientific pioneer who changed the worldview of neuroscience in 1889. He shared Nobel Prize with Golgi for medicine in 1906 (Garey, 2006). Broadmann (1909/1994) presented the primary visual motor and auditory pathways in the brain. These theories paved the way to consider the relation between brain, mind, and learning. Initially, neuroscience focused on establishing vocabulary with which the new knowledge was understood. Jenson (2008) says that it was the "first generation" of brain basics, which provided a working platform for today's generation. Later on, brain research moved from the learning of new words to the brain scans. They are three types of brain scans:

1. Functional Magnetic Resonance Image (fMRI): It registers the changes in blood flow and blood oxygenation relating to neural activity in the brain.
2. Positron Emission Tomography (PET): It also registers the blood flow relating to neural activity.
3. Electroencephalography (EEG): It measures the electrical activity of brain in natural settings, through electrodes that are placed on the scalp. It produces high temporal resolution than fMRI and PET scans (Jong *et al*, 2009).
4. Magnetoencephalography (MEG): It uses hi-tech sensors to locate faint magnetic fields, which are generated by the brain's neural networks (Jensen, 1998).

According to Geehan (2001), these scans changed the holistic view of understanding brain and mind. Before these scans, scientists used to experiment on the brains of rabbits, rats and damaged human brains for surgical intervention and they extrapolated their studies with the human brain. Now, these scans facilitated the study of brain, its nature, and functions while working. Since then, all our knowledge about brain was rebuilt in more acceptable, appropriate, and convincing way than before. For the first time neuroscientists and psychologists talked and shared their understanding of human brain. This exchange of information lead to astounding understanding and the belief that a brain arrives on the planet hardwired by genetics was soon replaced by the realization that brains are built before and after birth through experiences. This kind of understanding made the educators and organizers to know that the human brain is not precast but gradually shaped by life experiences.

The decade of 1990s was declared as "decade of brain". Many articles were published on brain research in popular press. 'News week' covered the story entitled "*your child's brain*". 'Time' magazine reported with the title "*How the child's brain develops*" (Isacson, 1997). Several conferences were held on early childhood and brain. Rob Reiner, television celebrity spearheaded the publicity campaign "*I am your child*" in USA. The publications from the Center for Educational Research and Innovations (CERI) of Organization of Economic Co-operation and Development (OECD) which set up "Brain research and learning project" in 2000, were responsible for a talk on the potential relationship between cognitive neuroscience, science and practice of education. OECD-CERI (2002) provided learning configurations; visual (using pictures, images, and spatial understanding), aural (using sound and music), verbal (using both speech and writing forms), physical (using body, hands, and sense of touch), social (learning in groups) and solitary (working alone using self-study). A book published in 2007 entitled "*Understanding and brain: The birth of learning science*" which judged the state of art knowledge and insights of cognitive psychology and neuroscience that connected to education (Jong *et al*, 2009).

Transformation of Neuroscience into Educational Neuroscience

According to Sousa (2011), the researchers gathered much information about how the brain learns in the past two decades. It led to emergence of educational neuroscience. This field explored how the findings from neuroscience, education, and psychology promote our understanding about not only teaching and learning but also implications for educational practice. It reflected on the research and decided whether the particular study had impact on educational practices. This interdisciplinary approach confirmed the solid scientific research support to recommended teaching practices besides ensuring smart working of teachers rather than hard working.

Neuroscience on Learning Procedure

Howard (1994) studied that brain and spinal cord were formed by the cells of central nervous system (CNS). They regulate most of the functions of the body along with endocrine system. They are two types of cells; neurons and glial cells. Neurons can be found in both brain and spinal cord. Brain contains 90% of glial cells and 10% neurons. Generally, human beings have 100 billion neurons. Many brain cells will be lost every day through attrition, decay, and disuse. In spite of the debate on the number, it is estimated that human beings lose the brain cells from 10,000 to 1,00,000 per day. Jensen (1998) in his book "*Teaching with the brain in mind*" stated that the glial cells function as glue to put brain together and they are about 1000 billion. These cells outnumber neurons in 10:1 ratio. Their functions include formation of the blood-brain barrier, transport of nutrients, regulation of Immune system and removing the dead cells. Kempermann, Kuhn, and Gage (1997) mentioned a new discovery by neuroscientists, which disclosed that brain generated new neurons in the hippocampal dentate gyrus and olfactory system. Many of them that survive become functional. The neurons that become functional were highly correlated with memory, mood and learning. This process would be controlled by every day behavior of the people and enhanced by exercises, low stress, and good nutrition.

Jensen (1998) stated that the normal functioning of neurons involves continuous firing, integrating, and generating information. Each neuron consists of a cell body with dendrites and axon, a string like structure extends to connect to the dendrites of the cell body of other neuron. Axon splits itself into two repeatedly. Each neuron not only receives information but also passes information to other cells. Information always goes in one direction that is from cell body to down the axon to the synapse but not in reverse. Proper myelinated axon conducts electrical impulses at the speed of 120 meters per second or 200 miles per hour. The more connections make the more efficient communication. The number of synaptic reactions arriving from all the dendrites of the cell body will determine the time to fire itself. Dendrites are branch-like extensions that grow outward from cell body when environment is well enriched.

Fan *et al* (2005) studied that the neurons send electrically changed chemicals such as sodium, potassium, and calcium. When the stimulus changes the electric potential below a threshold (about- 55milli volts), the neuron corresponds with electric explosion activity which is fixed in size for each neuron. Otherwise, neuron does not fire following the all-or-none principle. H-channels that were distributed throughout the dendrite membrane supply potassium and sodium ions in and out of the neuron and altered within 10 minutes following a learning event. Restak (1994) observed that according to the change in the potential difference, the axon generates action potential. Therefore, the change in potential difference of dendrites causes stimulation of target neuron. The chemical signals conducted down to cell body of the post-synaptic neuron then cell body changes chemical signal into electric signals.

Jensen (1998) explained that each cell body works as a small electrical battery with the received input. Changes in the voltage influence the power to transmit signals for dendrites. The body of the cell sends electrical discharge to axon and stimulates the release of the stored chemicals into the synaptic gap, which is the space between axon terminals and tip of the dendrites. When the tip of the dendrites receives neurotransmitters (electrical signals changed into chemical signals) and turns them again into electrical impulses. Donald Hebb (1949), Canadian psychologist rightly postulated that the learning occurs when cell needs less input in the second attempt to be activated. When a cell is stimulated electrically, it excites nearby cell repeatedly. A little later, if a weaker stimulus is given to nearby cell, its ability to get excitement will be enhanced. According to Jensen (1998), when synapse is altered, it causes long-term depression (LTD). Then the chances of firing of cell are very less. Quick learning cannot be promoted by trial-and-error method. Therefore, the receiving capacity of a cell can be determined by previous stimulation. It shows that the learned cells change their behavior.

Neuroscience on Periods of Learning Language

Lenneberg (1967) proposed Critical Period Hypothesis (CPH) and contemplated that the critical period for language learning stretches from 2 years of age to puberty. He thought that the language learning was difficult after puberty because lateralization of language functions in the left-hemisphere would be completed by this age based on study on an aphasic patient but the results were not replicated. Penfield proposed CPH based on neurological plasticity and Lenneberg also refined his hypothesis with the emphasis on hemispheric specialization of function but both of them were put under severe criticism on both conceptual and empirical fronts (Genesee, 1988). Wolfe (2010) in her book "*Brain matters: Translating research into classroom practice*" stated that the development of brain begins in about three weeks of gestation. The growth rate of neuron cells will be approximately 2,50,000 per minute. Simultaneously new dendrites will grow to make synapses. The new connections will be made not only prior to birth but also continuous in the months following birth. Chugni (1998a) studied the PET scans and understood the growth rate of synapses after observing the metabolic rate of glucose consumption in child's brain that was equal to its parent brain's consumption. Kluger (2008) observed that when the child was two years old there were 40,000 synapses for every second which was identified from the fact that every neuron in child's brain had about 15,000 dendrites where as they were only 6000-10,000 in adult brain.

Wolfe (2010) stated that after two years, infrequently used connections will be cut off and only frequently used connection will remain in the process of pruning. In the process of pruning, the connections of the language sounds they hear every day will be strengthened. This process enables the child to perceive the words and their represented meaning and finally speak the language they hear every day. During this period, the brain size will become double due to the growth in new connections, additional glial cells, and strong myelin. Nelson (2006) studied that emotional growth suffers when the child is deprived of forming emotional bond with parents and others. It was studied that the young children who were reared up in deprived conditions found delayed in emotional, social, and cognitive skills. Chugani (1998b) studied that increased consumption of glucose led to increased growth of neural connections, which shows the growth of learning from birth to the age of four. After this period, the rate of growth in connections remains constant for the next six years.

Diamond, Hopson, and Diamond (1998) noticed that the growth of synapses at adolescence goes back to the level at the age of two and stays at the same level throughout the life of a person. The size of the brain becomes triple by the tremendous activity of making synapses at high speed by the age of four to five years. The growth of the size of brain will be stopped as it matches the size of adults' brain by 11 or 12 years of the child. Wolfe (2010) reported that during the period of 6 to 11 or 12 years, some interesting changes will occur in brain's cortex due to the process of pruning. During these middle years, children acquire most conspicuous cognitive ability to learn languages. Striking growth rate can be seen in the temporal and parietal lobes that are specialized in language and comprehending spatial relations. As this growth rate falls sharply after the age of twelve, foreign languages can be acquired before adolescence easily.

Neuroscience on Right or Left Hemisphere Dominance in Learning a Language

According to Genesee (1988), neuropsychological research tries to establish the relation between brain and acquisition of two or more languages. Early scientific research in this field was based on clinical examinations of aphasics that showed the language impairment with the brain damage or disease. Kolb and Whishaw (1980) considered Dax who was the first one to establish the widely accepted point on left-hemisphere dominance in learning language. Subsequent research recognized the "Broca area" in the frontal regions of the left hemisphere, which may be responsible for speech, and the "Werniche area" between the posterior temporal regions of the left-hemisphere, which may be responsible for understanding. In the course of time, the technological advancement in neuropsychological and electro-psychological techniques allowed the researchers to examine the normal individuals instead of aphasic patients.

Carroll (1980) found much left-hemispheric involvement when second language is learned formally where as Genesee *et al*. (1978) found much right-hemispheric involvement when second language is learned informally. Genesee (1988) opined that neurological processes that are involved in language learning might not be the same as those involved in using second language for communicative purposes. Rogers, Tenhouten, Kaplan, and Gardiner (1977) and Scott, Hynd, Hunt, and Weed (1979) found the little evidence to show greater right-hemispheric involvement for processing Hopi and Navajo than English. Since interpretation of Rogers *et al*. (1977) was equivocal and the same results were not replicated in the subsequent studies, it was hypothesized that the languages that activate different modes of thought or different types of script may engage left and right-hemispheres differently.

Scovel (1982) considered that the application of basic research findings to educational practice is risky but Seliger (1982) considered it advantageous for better educational practice. Genesee (1988) stated that the neuropsychological research is double fascinating, one of them is interesting in its own right another is revealing some important truths about all brains of the monolingual and bilingual alike. He concluded that the challenges of the research studies put against poorly substantiated beliefs and promote innovative and improved educational approaches.

Neuroscience on the critical Period of Second Language Acquisition (SLA)

Hartley and Swanson (1986) and Ostrosky, Ardila, Rosselli, Lopez-Arango and Uriel-Mendoza (1998) presented neuropsychological studies which showed that the first three years of schooling cause a lot of change in children's brain whereas illiterates mature later possibly as a result of later working memory maturation. Gaillard *et al*. (2000) investigated to know the differences between the children and adults on the way of patterning and found that children had similar activation patterns to adults pertaining to temporal and frontal regions of the brain, but increased the activation in inferior occipital and anterior superior temporal areas. Nakada, Fujii, and Kwee (2001) conducted fMRI research to know impact of the first language on learning second language. Five out of ten Japanese volunteers were educated in English and five out of ten Native American volunteers had the same educational degree as their Japanese speaking counter parts. The study found that the cognitive processes for reading in second language were similar to those employed for the first language. It was taken up to hypothesize that the second language represents the cognitive extension of the first language. The same results were replicated in the study of Tan *et al*. (2003) and Kevelman and Petitto (2002) studied that the exposure to two languages prior to age of five, developed both the languages optimally. They also examined that the exposure to new languages after this period, which caused to achieve fundamental grammatical knowledge in second language within one year provided the multiple exposures to the second language contexts beyond the formal schooling were given. Therefore, it is concluded that the neural systems of second language were shaped by the first language.

Some studies on the time of exposure to L2 provided important insights into the matters relating to the age at which learning second language was optimally developed. Petitto, Baker, Baird, Kovelman and Norton (2004) conducted neurocognitive research on visual perception, speech recognition as well as native and non-native phonetic perception in infants using Near Infrared Spectroscopy (NIRS) and found that the activation of classical language areas for both bilingual and mono-lingual babies. Abutalebi, Stefano, and Perani (2005) mentioned the fMRI study, which also showed the difference in activation of the regions of the brain on learning two languages by the subjects before 5 years old and adults in later life. The study concluded that the processing of language was declined if the learning of a new language was after puberty. Booth *et al*. (2000) studied that both adults and children used the left frontal cortex when engaged in silent reading and the fMRI scans of the children showed increased activation patterns when compared to adults during the task. Mechelli *et al*. (2004) studied that the density of the gray matter in the left inferior parietal cortex and the degree of structural organization in this region was modulated by the acquired proficiency in second language.

Kail (1984) studied that the ability to remember is better as the children grow older and it develops their rehearsing capabilities. He further stated that instead of constraining with the age, they should be taught using strategies like whispering and creating a mental image. As the children do not transfer strategies to the new situation, teacher has to make the children understand 'why' and 'when' a particular strategy should be used.

Neuroscience on Learning L2 Vocabulary

Dollaghan (1987) noticed that children of 2-8 years old were able to remember the words they heard once, two weeks earlier through the process called fast mapping, which enabled them to infer the connection between new word and referent to comprehend a new word after a single exposure and to recall some nonlinguistic information that associated with the referent. Pollatsek and Rayner (1990) assumed that the brain through activities that correlate with neural activation might increase the reader's potential to identify letters and words in the sequence of a sentence to comprehend them. Phelps, Hyder, Blamire, and Shulman (1997) conducted fMRI scans research and traced verbal fluency that was associated with increased metabolic activity in the prefrontal cortex. It was observed that when the subjects were engaged in three tasks such as 'repeating the words they heard', 'saying opposite of the word', or 'saying a word starting with the given letter' the activation of verbal fluency networks were seen in the left prefrontal cortex region. Tomasello (1999) studied that the babies will attach the label to the object that interests them and observed that the children learn the words best when they already have the object in mind. When adult supplies the label after rather than before the child looks at the object, the child comprehends the label more accurately.

Wimmer, Landerl and Frith (1999) studied that the speed of reading increased with suitable comprehension when the automatic pathway was activated. It was studied that more frequently used words are recognized faster and errors were smothered over to be un-noticed. Children could read common words fluently and accurately by the end of the grade one when they were taught using sound-letter correspondences. Paulesu *et al*. (2000) compared adult readers of Italian which had consistent orthography with adult readers of English which had inconsistent orthography and found that Italian readers, whose left superior temporal regions that were connected with phonological processing were activated greatly, were faster in reading words and non-words than English readers, whose posterior inferior temporal gyrus and anterior inferior frontal gyrus that were associated with word retrieval during reading, were activated greatly. Duncan and Seymour's (2000) longitudinal studies consistently found that children need to know 80% or more the letter-sounds before the word reading and decoding can take off (Dr. Philip Seymour, personal communication, November 2005). OECD-CERI (2002) stated that the reader must analyze and utter the word correctly several times before neural pathways are activated and then exact neural model of the specific word is formed by reflecting on its spelling, pronunciation, and meaning permanently stored in the Occipito-temporal system, which makes reading automatic.

Jobard, Crivello and Tzourio-Mazoyer (2003) carried out a meta-analysis to provide an objective picture of neuroimaging studies on cerebral structures involved in word reading. This study was carried within the framework of the dual route model of reading and concluded that the activations of different regions of the brain conformed the suitability of dual route framework to account for activations observed in non-phonological subjects when they read. It was found that the first step that involved accessing a word was common to both word and non-word stimuli was related to phonological processing. Therefore, it could be hypothesized that the phonological processing is mandatory, early, and fast. It was found that much practice is necessary in pairing sounds consistently with the group of letters then only instant word recognition pathway will be activated that further results in fluency.

Aron, Gluck, and Poldrack (2004) reported a study on fMRI scans which showed increased metabolic activity in the front part of the frontal lobe region of brain while the subjects were engaged in phonological naming. The region was most metabolically active in certain phonological awareness activities like retrieving phonological codes from long-term storage. Irregularities of English pose more problems to children, so children must learn the lists of frequent words in early grades. It was estimated that English medium children require 2.5 or more years of literacy learning to master the recognition of familiar words (Seymour, Aro and Erskine, 2003).

Connor, Morrison and Katch (2005) stated that the children with high initial vocabulary scores had better reading scores with implicit and independent teaching. Abadzi (2006) in his well-known book "*Efficient learning for the poor: Insights from the frontier of cognitive neuroscience*" mentioned a study, which identified two slower pathways that involved in word articulation and analysis (in the left parieto-temporal area and in inferior frontal gyrus, near Broca's speech center). Novice readers used these pathways to link the letters to sounds and decode words. The speech area generates a tendency to sound out sub-vocally in order to decode it. They make conscious decision about letters and read small amounts of text. Church *et al*. (2008) further continued with fMRI scan study on reading high frequency word learning and repetition tasks with the children whose age group was between 7 to10 and the adults whose age group was 18 to 32. The study found similar activity across age groups indicating that both of them used overlapping mechanism while processing high frequency words, but found age group differences. The study noticed decreased activity in the angular and supramarginal gyrus regions of brains of adults, which were hypothesized to play role in phonology when compared to activation of those regions in the brains of children. The results were consistent with decreasing reliance on phonological processing based on age.

Therefore, the studies showed that the brain of children is very active to recognize and manipulate the letters, sounds and forming strong neural pathways for easy learning prospects when compared to the brain of adults. The proper design that confines with the findings of neuroscience research studies may give fruitful teaching and learning L2 vocabulary in the context of English language teaching and learning as second language.

CONCLUSION

The paper showed the vitality of acquiring L2 vocabulary before learning other skills of English language. The advent of technology of 21st century paved the way to understand not only the learning behavior of neurons in human brain but also activation certain neural pathways in the process of retrieving the stored data. The educational neuroscience prepared a platform to develop the brain-friendly strategies in the second language learning classrooms. This paper discussed neuroscience research on learning, learning a language, dominance of particular hemispheres in learning a language besides unfolding neurobiology regarding the critical period of second language acquisition. The paper presented the studies on various scans to show the crucial role of L2 vocabulary along with sounds to accelerate the reading of the beginners. The paper concluded with the appeal to the educators to understand educational neuroscience for developing best-fit strategies for their beloved students.

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