On Quantified Analysis and Evaluation for Development of Early Infants' Reading Brain Process (Artificial Neural Networks' Approach)

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Abstract- **This research work specifically adopts an interdisciplinary discipline incorporating Computational Neural Networks, Cognitive Neuronal Mechanism, Neuroscience, and Psycholinguistics. which originated from the challenging performance evaluation of reading native languages' vocabulary at the early infancy started by the first few / months /years of the infant's life. In other words, such learning of vocabulary language is motivated and originated directly by the effect of mother's speech interactive dialogue with her toddler. The first few months of life are so important for brain development because neural connections in the infant brain are emerging in the context of warm, predictable, and responsive social interactions between the parent and infant. Briefly, it concentrates on a very interesting and challenging issue tightly associated to quantitative learning performance of vocabulary evaluation at early infancy of human brain, while that affected with mother's speech. Therefore, due to IN addition to the environmental teaching / learning motivated by developing preliminary phase of reading brain in a significant way. The Presented ANN models have been closely corresponded to performance of these neurons for various learning rate values simulating the effect of interactive vocabulary learning observed via the dialogue of young children with their mothers. More specifically; presented models concerned with their important neurons' role played in carrying out cognitive brain function's learning outcomes. In this context, herein introduced work illustrates via ANN[s] simulation results: How ensembles of highly specialized neurons could be dynamically involved in performing the cognitive function of recognizing words' vocabulary during early infancy development of human reading brain.**

Keywords- **Artificial neural network modelling, preliminary reading brain evaluation, words' acquisition, babies' vocabulary reading activities**

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I. INTRODUCTION

While the field of neuroscience is still growing rapidly, we already have a lot of good information that can help us to understand our children's their early brain development. This article introduces quantification of learning acquisition of reading process. That may be useful for parents to find better understanding and raising their infant's brain within the first few / months / years of toddlers' life [1]. More precisely young children, learn their mother tongue rapidly and effortlessly, from babbling started at 6 months of age to full sentences by the age of 3 years. [2] Language has been the subject of academic fascination for centuries, and the ability to communicate abstract notions through speech and writing allows humans to interact in ways that would not otherwise be possible. *Non-invasive, safe functional brain measurements have now been proven feasible for use with children starting at birth [3].* While the mechanisms of language processing have been studied extensively with behavioural and non-invasive neuroimaging methods, much about how the brain encodes language remains unknown. *Women's elevated Stress, Anxiety, and Depression during pregnancy were associated with altered key features in fetal brain development, resulting in decreased cognitive for the offspring's cognitive development in a toddler at 18 months of age. [* to provide a lot of great information for parents on baby developmental milestones as well as activities for babies and activities for toddlers. As such, the development of a child's brain is of particular interest to us, since an astonishing amount of human brain development takes place during a short period of time during child development. These early years are a critical period in your human development and specifically your child's development as your child learns an incredible number of skills and amount of information that they'll need to function throughout the rest of their lives. The field of learning sciences is represented by a growing community conceiving knowledge associated with educational system performance as well as assessment of technology-mediated learning processes. Accordingly, evolutionary interdisciplinary trends have been adopted by educationalists, neurobiologists, psychologists, as well as computer engineering researchers. Furthermore, during last decade of last century, educationalists have adopted recent Computer generation namely as natural intelligence as well as Information technology in order to reach systematic analysis and evaluation of reading brain process performance. It is well known that, human brain is one of the most magnificent and mysterious wonders of creation, it is an incredible organ that continues to intrigue scientists and layman alike due to its fact of capability in performing human intelligence, interpretation of senses, learning ability, and controller of movement [1]. The brain is known to be deeply heterogeneous at all scales, but it is still not known whether this heterogeneity plays an important functional role or if it is just a byproduct of noisy developmental processes and contingent evolutionary history. Interestingly, Heterogeneity improves generalization: speech learning across time scales Sensory signals such as speech and motion can be recognized across a range of speeds by humans and animals. We tested the role of heterogeneity in learning a circuit that can function across a wide range of speeds. [5] Neurological researchers have recently revealed their findings about increasingly common and sophisticated role of the sixth computer (natural intelligence) generation namely, Artificial neural networks (ANNs). This computer generation is relevantly applicable to implement realistic learning models originated from interdisciplinary discipline incorporating neuroscience, education, and cognitive sciences. It noticed that field of learning sciences is mainly conceiving knowledge associated with educational system performance as well as assessment of technology-mediated learning processes. this piece of research associated with some challenging educational phenomena namely scores of learning ability, robustness, enhancement which are originated and motivated by the OSTP declaration designating the 1990s by to be the "Decade of the Brain”, and by human brain reborn in 2013[6][7]. Due to rapid an excessive progress in information and computer technological and social changes relevant to application at fields of the learning, cognitive, and neurobiology sciences. Due to rapid an excessive progress in information and computer technological and social changes relevant to application at fields of the learning, cognitive, and neurobiology sciences [8]. Consequently, implemented realistic models have diverse structural paradigms, in consequence with natural characterized features of brain functioning assigned for modelling. This paper specifically addressed an interdisciplinary research work problem originated from quantitative evaluation of neuronal mechanism for reading languages' preliminary phases. Briefly, it concentrates on a very interesting and challenging issue tightly associated to quantitative learning performance of vocabulary evaluation at early infancy of human brain, while that affected with mother's speech. Therefore, due to prevailing concept of individual intrinsic characterized properties of highly specialized neurons. Presented ANN models have been closely corresponded to performance of these neurons for developing preliminary phase of reading brain in a significant way. More specifically; presented models concerned with their important neurons' role played in carrying out cognitive brain function's learning outcomes. In this context, herein introduced work illustrates via ANNs simulation results: How ensembles of highly specialized neurons could be dynamically involved in performing the cognitive function of recognizing words' vocabulary during early infancy development of human reading brain. Interestingly, by referring to [9] at the twelfth month onwards, of infant’s life, most infants greatly expand their vocabulary: until the 24 months, the average (American English) infant understands about 300 words. Recently, some interesting research study investigated systematically, the infants' listening preference for emotional prosodies in spoken words and identify their acoustic correlates. That research concentrated special attention for the emotional Speech Processing in 3- to 12-Month-Old Infants considering the effect of harmonic frequency signal to noise ratio on during analyzing toddlers’ account noticed for attentiveness to each emotion [10]. Rather than, this paper concentration on the interesting and challenging issue which tightly associated to quantitative, and qualitative learning performance evaluation. For vocabulary speech of early toddlers, that affected by mother's speech interactive with new borne infant. The relationship between action–language synchrony and the acquisition of verbs considering qualitative and quantitative methods, has been analyzed via coordination of verbs and action in mothers’ input to six-month-old infants and related these maternal strategies to the infants’ later production of verbs [11]. The rest of this paper is organized as follows. At the next second section revising of educational process modeling. Is presented. Some detailed. revising for infants’ brain development is introduced in the third section. At the fourth section simulation results have been given. Finally, the conclusions are shown at the last fifth section

II. REVISING OF EDUCATIONAL PROCESS MODELING

This revising section introduces the conceptual basis of teaching/learning acquisition process and illustrates its realistic interactive modeling via two subsections as follows

A. *Modeling of Interactive Learning Process*

Referring to Figure. 3, it illustrates a general view of a teaching model qualified to perform simulation of two diverse brain learning acquisition. Inputs to the neural network teaching / learning model are provided by mother infant-directed speech / talk, that for mother’s toddlers’ language acquisition (unsupervised learning) [15]. However, correction signal(s) in the case of learning with a teacher given by output response(s) of the model that evaluated by either the environmental conditions (unsupervised learning) or by supervision of a teacher. Furthermore, the teacher plays a role in improving the input data (stimulating learning pattern) by reducing the noise and redundancy of model pattern input. That is in accordance with tutor’s experience while performing either conventional (classical) learning or Computer instruction learning. Consequently, he provides the model with non-redundant cleared data maximizing its signal to noise ratio in according to tutor’s experience [16] [17].

Conversely, in the case of unsupervised/self-organized learning, this is based upon either Hebbian rule [18], or interaction with environment [13] [19]. Both are implicitly formulated mathematically by above equation (7).

B. *Mathematical Formulation of Interactive learning*

The presented model given in Figure 2 simulates simply two diverse learning paradigms. It presents realistically both paradigms: by interactive learning/ teaching process, as well as other self-organized (autonomous) learning. By some details, firstly is concerned with classical supervised by a tutor observed in our classrooms (face to face tutoring). Accordingly, this paradigm proceeds interactively via bidirectional communication process between a teacher and his learners (supervised learning) [18].

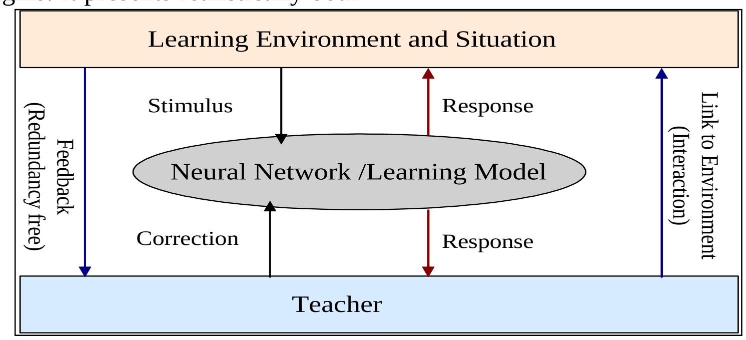

Fig. 1. Illustrates generalized simple block diagram for interactive learning process

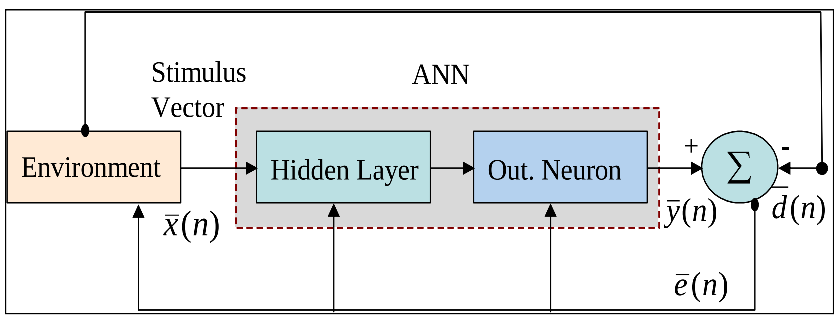

Fig. 2 Generalized ANN block diagram simulating two diverse learning paradigms adapted from [20]

Referring to above Figure 2; the error vector $\bar{e}(n)$ at any time instant (n) observed during learning processes is given by:

$$\bar{e}(n) = \bar{y}(n) - \bar{d}(n) \quad (1)$$

Where $\bar{e}(n)$ …… is the error correcting signal that adaptively controls the learning process,

$\bar{y}(n)$ …… is the output obtained signal from ANN model,

and $\bar{d}(n)$ …… is the desired numeric value(s).

Moreover, the following four equations are deduced to illustrate generalized interactive learning process. These equations are commonly well valid for either guided with a teacher (supervised) or self-learning without a teacher (unsupervised):

Equation (2) considers the scalar product of two vectors the input vector (X) and internal weight vector (W) computed at the time instant (n). It is noticed that both are associated to neuron (k), and each has the same dimension (number of vector's components). The output of this neuron is given by equation (3). Which originated from the hyperbolic tangent function deduced from classical sigmoid function.

Equation (13) computes the error value which controls the guided learning process (supervised with a teacher) and so it does not valid in case of unsupervised (learning without a teacher). Additionally, the synaptic dynamical changes at two subsequent time instances (n) & (n+1) are given by learning law given by equation (14).

$$V_k(n) = X_j(n) W_{kj}^T(n) \quad (2)$$

$$Y_k(n) = \varphi(V_k(n)) = (1 - e^{-\lambda V_k(n)}) / (1 + e^{-\lambda V_k(n)}) \quad (3)$$

$$e_k(n) = |d_k(n) - y_k(n)| \quad (4)$$

$$W_{kj}(n+1) = W_{kj}(n) + \Delta W_{kj}(n) \quad (5)$$

Where *X* is input vector and *W* is the weight vector. φ is the activation function. *Y* is the output. e_k is the error value and d_k is the desired output. Note that $\Delta W_{kj}(n)$ is the dynamical change of weight vector value. Above four equations are commonly applied for both learning paradigms: supervised (interactive learning with a tutor), and unsupervised (learning though student’s self-study). The dynamical changes of weight vector value specifically for supervised phase is given by:

$$\Delta W_{kj}(n) = \eta e_k(n) X_j(n) \tag{6}$$

Where η is the learning rate value during the learning process for both learning paradigms. At this case of supervised learning, instructor shapes child’s behavior by positive/ negative reinforcement Also, Teacher presents the information and then students demonstrate that they understand the material. At the end of this learning paradigm, assessment of students’ achievement is obtained primarily through testing results.

However, for unsupervised paradigm, dynamical change of weight vector value is given by:

$$\Delta W_{kj}(n) = \eta Y_k(n) X_j(n) \tag{7}$$

In equation (16), it is noticed that $\{e_k(n)\}$ given in the supervised learning equation (6) is obviously replaced -when considering- self-organized / unsupervised learning by $\{Y_k(n)\}$ at any arbitrary time instant (n) during the learning process.

III. Revising Children’s Brain Development

While most educators are not trained in neuroscience, of particular interest to educational research are advancing discoveries in learning, the brain and memory. In more details, holistic approach of this issue is originated from the scientific interdisciplinary research areas incorporating fields of neuroscience, psychology and education. All of these research areas Incorporated together referring to two sciences Psycholinguistics and Neurolinguistics The presented piece of research belongs to the critically challenging evaluation process for learning reading of native languages’ vocabulary at the early infancy during the first few / months / years of life.

Neuroscience is the term used to describe the study of the brain and nervous system. It provides new information we can use in early learning services. It sits alongside established theories and cultural approaches as one of several sources that together inform effective practice.

Children’s brain development is influenced by their experiences, so what happens can help or harm their wellbeing. There are some important points to know about the brain and how it influences development, especially in the early years.

In this context, as the toddler’s brain matures, more and more fibers grow and it becomes characterized by increasingly interconnected neural networks. As neural networks form, the child learns both academically and socially. Which are very important to the formation of memories and the connection of new learning to previous learning [21]. More precisely, as children’s neural networks formed, they became capable of learning both academically and socially. Specifically, that learning is defined as “acquiring knowledge or behavioral response from experience” and memory as “the result of the product of learning.” Learning is about acquiring new information and memory is the storage and retrieval of this information [22]. Interestingly, the learning environment plays a significant role in brain development. Accordingly, the importance of matching between learning and memory instruction to a child's maturity level is given through referring to [23], where there is a strong belief that making such contribution could be accomplished by adopting recent interdisciplinary research work direction, via combining ANN^{S} realistic modelling with neuroscience. Therefore, it is interestingly relevant to consider that modelling of the biologically inspired natural neural models it might have become possible to shed lighting on behavioural learning principles and functions concerned mysterious human biological neural systems. By some more details about the learning brain function, it is noticed they have been tightly coupled with the two following mainly sub-functions:

1) Learning: is that ability to modify behavioural brain's response in accordance with the stored experience. That is consequently corresponds to modified synapses’ interconnections (inside brain).

2) Memory: is that ability to restore the modified behavioral information over a period of time. As well as the ability to retrieve spontaneously the modified experienced (learned information) patterns distributed inside brain synaptic connections. In the context of learning in toddler’s brain it has been observed that *All children are born with unique potential to learn and develop Consequently,* the most important point to understand is that all children are capable in developing their mental processes and that their relationships with people, places, and things influence what and how they learn,[25].

A. Computational Modeling of Human Language Processing

Referring to recent analysis of neuroscience modeling for human language processing illustrated comprehensively at [26], a new “reverse engineering” approach to computational modeling in systems neuroscience has transformed our algorithmic understanding of the primate ventral visual stream [27] and holds great promise for other aspects of brain function. This approach has been enabled by a breakthrough in artificial intelligence (AI): the engineering of artificial neural network (ANN) systems that perform core perceptual tasks with unprecedented accuracy, approaching human levels, and that do so use computational machinery that is abstractly similar to biological neurons. In the ventral visual stream, the key AI developments come from deep convolutional neural networks (DCNNs) that perform visual object recognition

https://doi.org/10.17758/URUAE20.AE0323110

from natural images [29]. Here we describe an analogous pattern of results for ANN models of human language, establishing a link between language models, including transformer-based ANN architectures that have revolutionized NLP in AI systems over the last 3 y, and fundamental computations of human language processing as reflected in both neural and behavioral measures. Language processing is known to depend causally on a left-lateralized frontotemporal brain network [30–34].

Finally, until the rise of recent ANNs (e.g., transformer architectures), language models did not have sufficient capacity to solve the full linguistic problem that the brain solves—to form a representation of sentence meaning capable of performing a broad range of real-world language tasks on diverse natural linguistic input. Referring to Figure 5., it illustrates a collection of suggestive results but no clear sense of how close ANN models are to fully explaining language processing in the brain, or what model features are key in enabling models to explain neural and behavioral data.

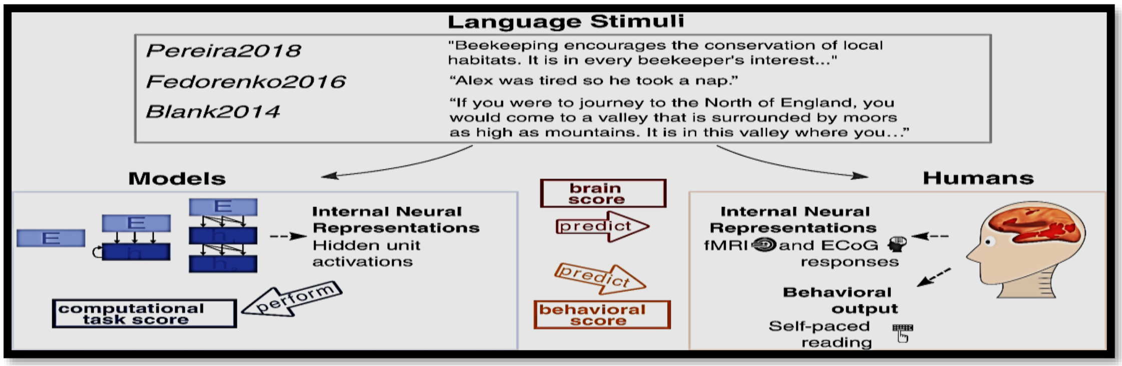

Fig. 3: Comparing ANN models of language processing to human language processing. We tested how well different models predict measurements of human neural activity. Adapted from [26].

B. Learning Rate values:

Before about two decades, referring to [23[, it has been noticed that in healthy children, motor and sensory systems continue to develop during toddlerhood and the preschool years. Auditory and visual skills improve during this time too. Since brain development after birth is influenced by inputs from the environment, and because those inputs are unique to each child, every human brain is unique. Moreover, As the brain matures, more and more fibers grow and the brain becomes increasingly interconnected. These interconnected networks of neurons are very important to the formation of memories and the connection of new learning to previous learning. As neural networks form, the child learns both academically and socially. Conversely, considering prematurely born toddlers, inputs from interactive noisy environmental learning conditions, always respond negatively. Accordingly, these children whose auditory system is not ready when reading instruction is provided will also be delayed in learning to read. More precisely, they are thought to associate the initial noise and clatter around them as painful. Research indicates that a quiet environment allows these children to catch up as their neurons make connections. [24]. Recently, comprehensive investigational systematic study concerned with the toddlers' language learning acquisition experiment. revealed in details at [10]. Which it considers infants' listening preference for emotional prosodies in spoken words and identify their acoustic correlates according to one psycholinguistic experiment revealed that : Forty-six 3- to-12-month-old infants (M_{age} = 7.6 months) completed a central fixation (or look-to-listen) paradigm in which four emotional prosodies (happy, sad, angry, and neutral) were presented. Infants' looking time to the string of words was recorded as a proxy of their listening attention. Five acoustic variables—mean fundamental frequency (F0), word duration, intensity variation, harmonics-to-noise ratio (HNR), and spectral centroid—were also analyzed to account for infants' attentiveness to each emotion.

More recently, a very interesting finding has been announced that in case if Women's elevated Stress, Anxiety, and Depression during pregnancy were associated with altered key features in fetal brain development, resulting in decreased cognitive for the offspring's cognitive development in a toddler at 18 months of age [4]. Accordingly, that psychological disorder features influence negatively the enfants' brain behavior during mother-new born child interactive learning reflected by noisy contamination inside the neuronal synaptic interconnections. In the same context, this period is a phase of greater plasticity, which is the ability that the brain has to change through the numerous connections made between the neurons for each new experience and learning. Noting that toddlers' brain developmental plasticity adapted to environmental experiences. This brain plasticity makes it easier for infants to learn about the world around them, However, this plasticity also makes the brain much more susceptible to negative experiences like parental stress which have similar negative effect as noisy environment. [35].

C. Theory of Toddler’s Brain Cognitive Function

This section considers the cerebral cortex of new borne babies (Ages: Birth to two years). That part of child’s brain that controls voluntary actions. This part of the brain will still be relatively underdeveloped at birth, but it matures rapidly within the first few / months /years of child’s life. [1]. Referring to Jean Piaget's theory of cognitive development given at [26], therein it suggests that children move through four different stages of mental development understanding the nature of intelligence. [36] Piaget’s stages are: Sensorimotor stage: birth to 2 years, Preoperational stage: ages 2 to 7, and Concrete operational stage: ages 7 to 11 Formal operational stage: ages 12 and up. More specifically, this piece of research gives attention to children’s Ages: Birth to 2 Years. Piaget believed that developing object permanence or object constancy, the understanding that objects continue to exist even when they cannot be seen, was an important element at this point of development. By learning that objects are separate and distinct entities and that they have an existence of their own outside of individual perception, children are then able to begin to attach names and words to objects. Considering young children interactive learning with their mothers’ tongue rapidly and effortlessly, from babbling at 6 months of age to full sentences by the age of 3 years, and follow the same developmental path regardless of culture as illustrated at Figure 6. Furthermore, referring to [37], linguists, psychologists and neuroscientists have struggled to explain how children do this, and why it is so regular if the mechanism of acquisition depends on learning and environmental input. This puzzle, coupled with the failure of artificial intelligence approaches to build a computer that learns language, has led to the idea that speech is a deeply encrypted 'code'. Cracking the speech code is child's play for human infants. This figure shows the changes that occur in speech perception and vocabulary words’ production. Referring to typical(natural) biological developing during human infants’ first year of life [37]

IV. Simulation Results

Referring to the introduced results at [38], the obtained findings therein have been in agreement with the given herein. Figures (7,8, and 9) are analogous to the three simulation results at figures (10,11, and 12).

A. Early Language Acquisition

This section presents the concept of Vocabulary words’ Norms by exploring the Size of Productive Vocabulary growth curves for various languages and demographic groups. This analysis shows growth curves for vocabulary size, the number of words that a child produces or understands, for different languages, forms, and measures. For some datasets, it is possible to compare growth curves across different demographic groups (birth order, ethnicity, gender, mother's education). Use a median quantile type to compare demographic groups on a single plot, or other quantile sizes to see separate curves and plots for each group. See below for more details and an important disclaimer about clinical usage.

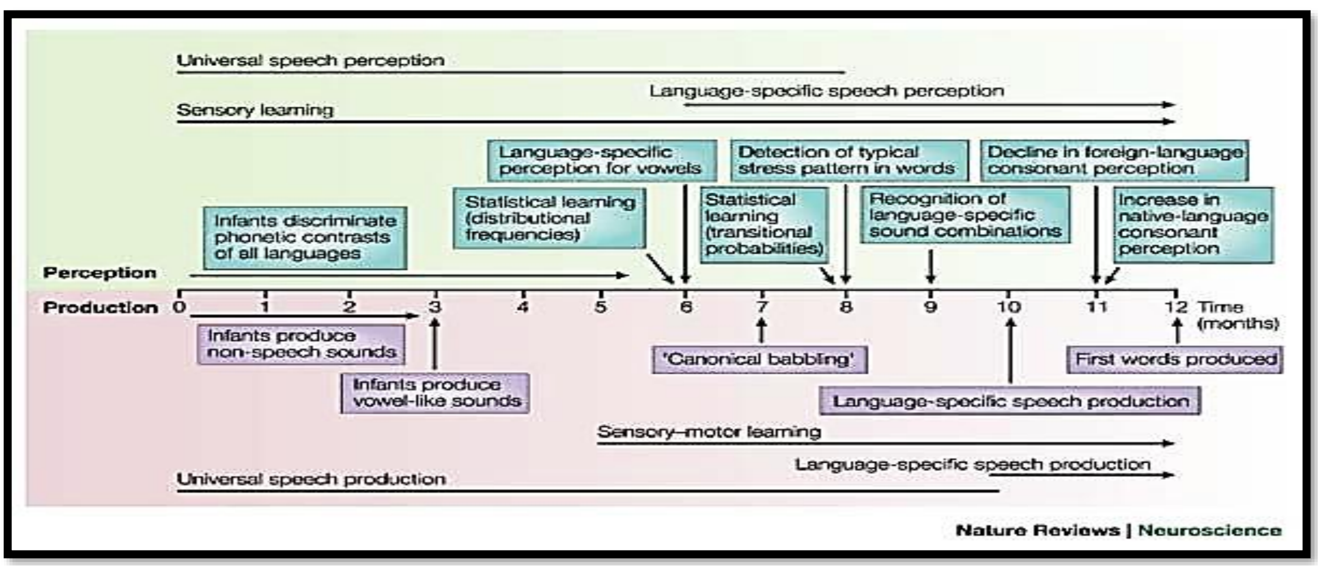

Fig. 4. Illustrates the universal language timeline of speech-perception and speech-production development, Adapted from [37].

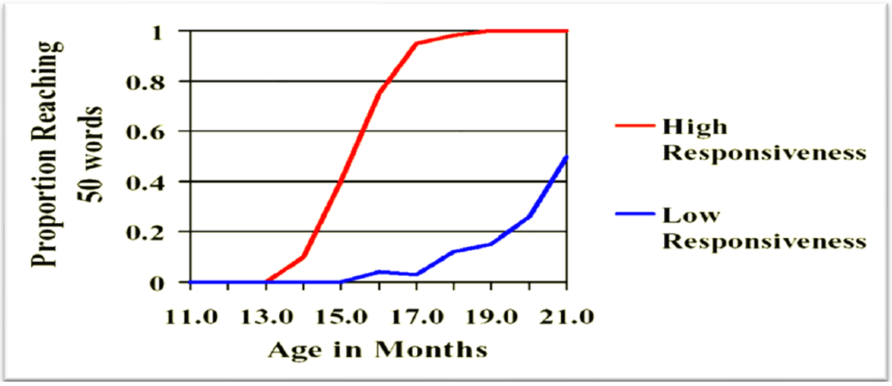

Fig. 5: Word acquisition performance of infant's brain while increasing age in months. # Neurons increases by infant's age, adapted from [39]

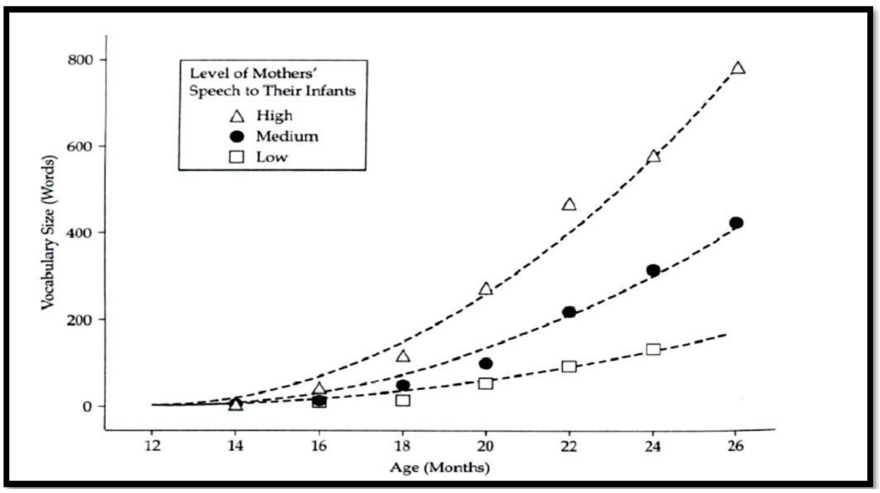

Fig. 6.: Effect of mother's speech level on acquired Infant' Vocabulary words, adapted from [39]

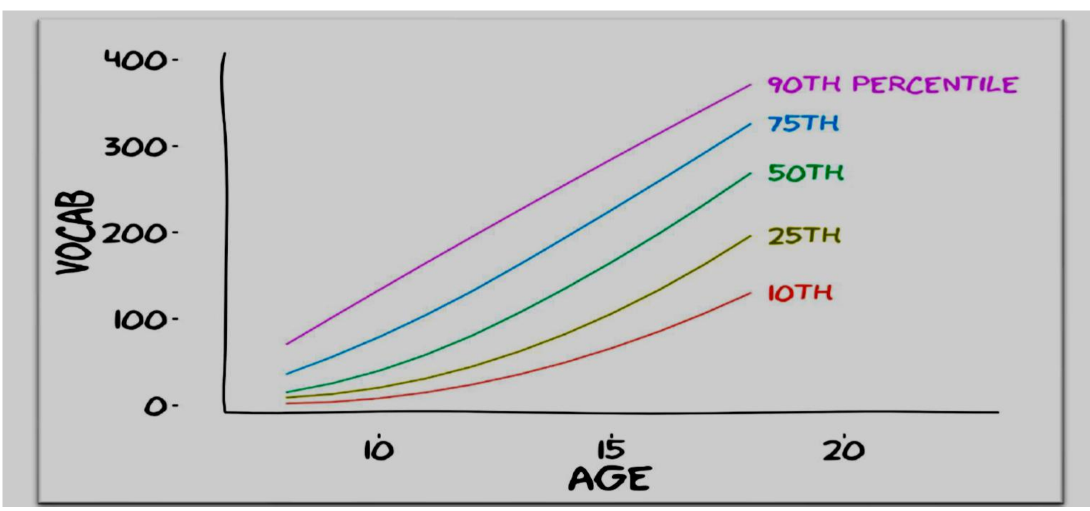

Fig. 7: Illustrates the. raw production scores for English (American) production data. Dots show individual participants, while lines give standardized percentiles, computed via spline-based quantile-regression. Adapted from [40]

B. Neural Network’s Simulation Results

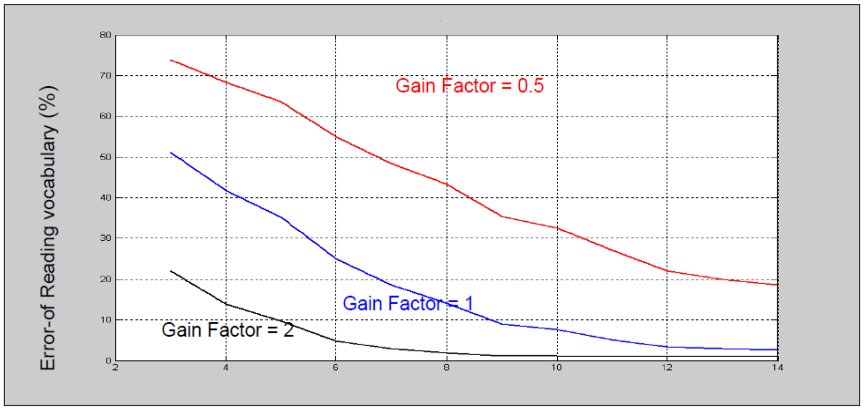

Fig 8:. Illustrate error while learning vocabulary considering the individual differences among toddlers having various gain factor in ANN

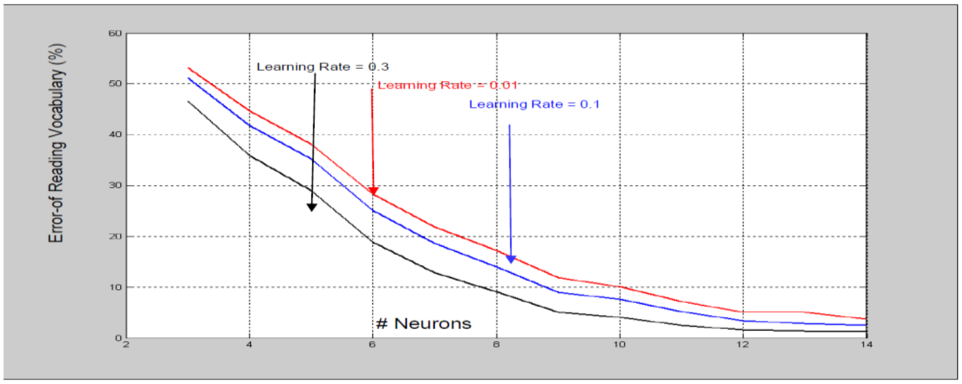

Fig. 9. Illustrates error while learning vocabulary considering different learning rates when #cycles = 300 and gain factor = 1

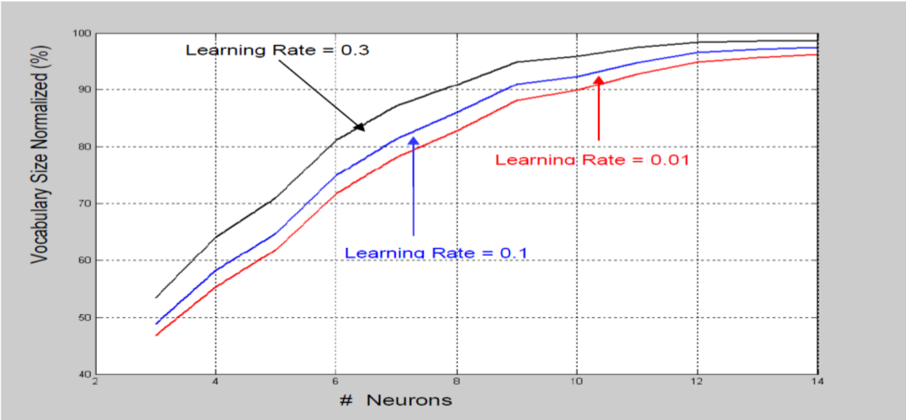

Fig. 10: Illustrates simulated outcome presented as percentage degree of lesson focusing versus # Neurons for different learning rate values η (0.3,0.1, and 0.01).

V. CONCLUSIONS

This work adopted an interdisciplinary and challenging educational issue *"how reading should be taugh*t?" [41][42][43]. That piece of research issue is associated with neuronal coding of speech formant in the infant brain responding to mother's reflective learning algorithm. This paper addressed a rather interdisciplinary preliminary reading issue associated with brain language process during mother's reflective learning algorithm. More specifically, this work concerned with modeling of simple neuronal mechanism in human brain speech **LANGUAGE** function. it proposes an intelligent classification technique based on identification modeling for three categories associated with different mother's level of speech. furthermore, the presented model calcifies individual differences into three categorized levels. in other words, this presented work adopts supervised ANN paradigm based on cognitive associative learning of preliminary reading brain by acquired vocabulary words affected by two factors [29]. by more details, the factor of learning environment effect (mother's speech levels), is realistically simulated by three categorized values of learning rates. however, the effect of other factor (children's individual differences) is simulated via its classification into three various gain factor values. obviously, the natural extension of this work deals with reading brain development. in such dealing, individual intrinsic characteristics of highly specialized neurons (in visual brain area) have direct influence on the correctness of identified images associated with orthographic word-from [31]. interestingly, expected future work of presented paper extension is due to prevailing concept of individual intrinsic characterized properties of highly preliminary reading specialized neurons. therefore, it considers evaluation of highly specialized neurons' response time characterized for infant's acquisition concerned with some fixed number of vocabulary words. furthermore, it is highly recommended to consider more elaborate investigational analysis and evaluations for improvement of learning performance phenomenon. such as improving of teaching mathematical schools' topics [44].

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