RESEARCH ARTICLE

QUANTIFIED ANALYSIS AND EVALUATION OF HIGHLY SPECIALIZED NEURONS' ROLE IN DEVELOPING READING BRAIN (NEURAL NETWORKS APPROACH)

Hassan M. H. Mustafa

Computer Engineering Department, Faculty of Engineering, Al-Baha University, Al-Baha, Kingdom of Saudi Arabia

Manuscript Info	Abstract

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. Consequently, implemented realistic models have diverse structural paradigms, in consequence with natural characterized features of brain functioning assigned for modeling.

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 correspond 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.

1. INTRODUCTION

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 learning processes' performance .Therefore, it is worthy to refer to WHITE HOUSE REPORT(U.S.A.) in 1989; therein, it has been announced that decade (1990-2000) named as Decade of the brain[1].

Due to rapid and excessive progress in information and computer technological and social changes relevant to application at fields of the learning, cognitive, and neurobiology sciences[2]. Overwhelming majority of neuroscientists have adopted the concept suggests that huge number of neurons besides their interconnections constituting the central nervous system and synaptic connectivity performing behavioral learning in mammals such as: cats, dogs, ants, and rats [3], besides quantitative

learning creativity analysis in human brain [4]. Interestingly, the synaptic connectivity patterns among artificial neurons has implication on learning ability and creativity [5]. Also, it is noticeable that extremely composite biological structure of human brain results in everyday behavioral learning brain functions[6]. Accordingly, adopted neural networks' models correspond closely to biological neuronal systems functionally as well as structurally [7][8][9]. It is observable that language processing in human brain, affected by highly specialized neurons' role in accordance with neuron mechanism of human languages [10][11] [12][13].

The presented piece of research is specifically inspired by adopted approach for optimal solving of children's critical issue for improving performance for their learning process *"how to read?"*.This approach has been motivated by the great debate's findings of children reading issue as presented at [14]. Where a group of researchers at fields of psychology and linguistic have been continuously cooperating in searching for optimal methodology which are supported by field results. Nevertheless, during last decade, phonics methodology is replaced –at many schools in U.S. by other guided reading methods performed by literature based activities [15]. Recently, obtained promising field results as given by [16], which have been supported the optimality of phonics methodology in solving the children issue "how to read?" [17][18].

Furthermore, this paper is supported and inspired by what revealed by National Institutes of Health (NIH) in U.S. that children in elementary school, may be qualified to learn "basic building blocks" of cognition and that after about 11 years of age, children take these building blocks and use them [19][20]. Herein, this work presents an emphasis on How ensembles of highly specialized neurons could be dynamically involved in performing the cognitive function of acquisition and developing of vocabulary words' size during early reading brain phase [21].Accordingly, analysis and evaluation of vocabulary deficits considered as one of factors leading to a reading disability[21][22][23]. More specifically, this paper is motivated by the effect of parenting on word acquisition and mother's speech effect on infant vocabulary [21].

The rest of this paper is organized as follows. At the next second section, a brief review is introduced about biological function of the basic building block of brain (a single neuron). It's presented as schematic structure of a single neuron, along with the mathematical modeling of its function. The algorithmic supervised learning steps of ANN modeling are given at the third section, for vocabulary words' acquisition via infant brain. At the fourth section simulation results are presented. Finally, some interesting conclusions are introduced along with future research work at the last fifth section.

2. LEARNERS' BRAIN FUNCTION

Referring to the White House report about the Decade of the brain [1], neural network theorists as well as neurobiologists have focused their attention on making a contribution to investigate systematically biological neural systems (such as the brain), functions. There is a strong belief that making such contribution could be accomplished by adopting recent direction of interdisciplinary research work, via combining ANN [S] with neuroscience. Consequently, by construction of biologically inspired artificial neural models it might have become possible to shed light on behavioral principles and functions concerned biological neural systems. By some details about brain based learning, it is tightly coupled to brain function as follows:

1) Learning: is the ability to modify behavior in response to stored experience (inside brain synaptic connections).

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.
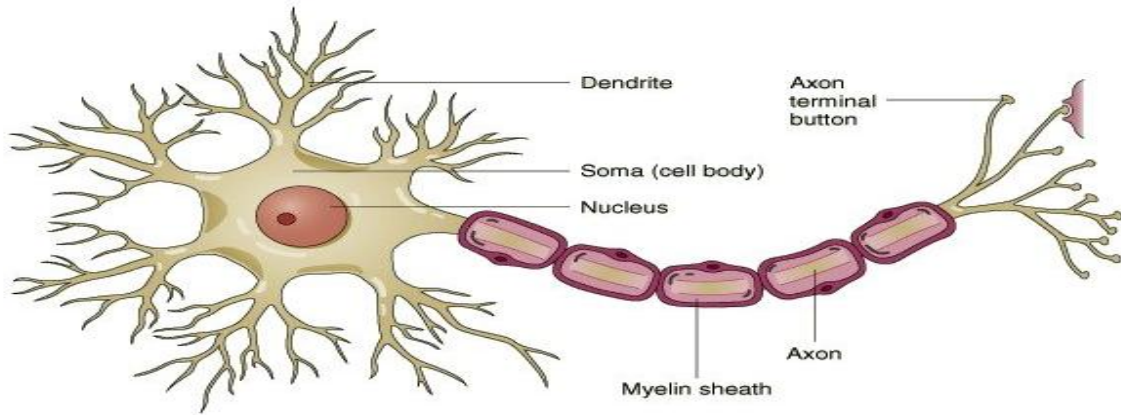
2.1 Single neuron function

At Figure 1, an illustrative schematic drawing is shown for the basic structure of a single biological neuron. In brief , a typical biological neuron composed of three basic components{a cell body(soma), dendrites, and an axon Dendrites}. All are characterized by their thin structures that arise from the cell body, often extending for hundreds of micrometers and branching multiple times, "dendritic tree". An axon is a special cellular extension that arises from the cell body at a site called the axon hillock. The soma frequently gives rise to multiple dendrites, but never to more than one axon, although the axon may branch to approximately (10^4) times before its termination in a form of synaptic connectivity pattern inputs to other neurons . Inside learner's brain structure, patterns of synaptic connectivity among vast number of neurons relies upon information processing conducted through communication between neuronal axonal outputs to synapses. It is given at Figure 1, an illustrative schematic drawing is shown for the basic structure of a single biological neuron. This neuron presents the basic building block of learner's brain structure. Accordingly, performance improvement of many

building blocks (neurons) conducts inevitably a significant enhancement of global brain based learning function. Thus, enhancement of children's intelligence (learning and memory) could be attained via enhancement of neuronal activation (response) function. The following subsection presents a detailed mathematical formulation of a single neuron function.

Figure 1 : A simplified schematic structure a single biological neuron (adapted from [24]).

2.2 Mathematical formulation of a single neuron function

By Referring to T.Kohenen's work [25], the output neuronal response signal observed to be developed following what so called membrane triggering time dependent equation. This equation is classified as a complex non-linear partial deferential. Its solution works to provide us with the physical description of a single cell (neuron) membrane activity. However, considering its simplified formula, which equation may contain about 24 process variable and 15 non-linear parameters. Following some more simplification of any neuron cell arguments, that differential equation describing electrical neural activity has been suggested, as follows:

$$\frac{dz_i}{dt} = \sum_{j=1}^{n} f(y_{ij}) - j(z_i) \qquad (1)$$

Where, y_{ij} represents the activity at the input (j) of neuron (i) , $f(y_{ij})$ indicates the effect of input on membrane potential,
$j(z_i)$ is nonlinear loss term combining leakage signals, saturation effects occurring at membrane in addition to the dead time till observing output activity signal.
The steady state solution of the above simplified differential equation (1), proved to be presented as transfer functions. Assuming, the linearity of synaptic control effect, the output response signal is given by the equation:

$$Z_i = \phi\left(\sum_{j=1}^{n} w_{ij} y_{ij} - \theta_i\right) \qquad (2)$$

Where, ϕ is the activation function having two saturation limits. That ϕ may be linear above a threshold and zero below or linear within a range but flat above.
θ_i is the threshold (offset) parameter , and w_{ij} synaptic weight coupling between two neuron *(i)* and *(j)*.
Considering realistic nonlinearity of neuron's signal activation function *(ϕ_i), it* has been recommended specifically to obey +ive behavioral segment of tangent sigmoid function. It is presented for any arbitrary neuron by the following equation :

$$Y(v) = (1 - e^{-\lambda v}) / (1 + e^{-\lambda v}) \qquad (3)$$

Where

$$V = \sum_{i=1}^{m} w_i x_i - \theta$$

λ ...... is the gain factor value , θ...... is the threshold value, and m......is the number of synaptic inputs (from other neurons) to assigned neuron.

By referring, to the weight dynamics described by the famous Hebbian learning rule [26][27], the adaptation process for synaptic interconnections is given by the following modified equation:

$$\frac{d\omega_{ij}}{dt} = \eta z_i y_{ij} - a(z_i)\omega_{ij} \tag{4}$$

Where, the first right term corresponds to the unmodified learning (Hebb's rule) and η is the a positive constant representing learning rate value. The second term represents active forgetting; a (z_i) is a scalar function of the output response (z_i). The adaptation equation of the single stage model is as follows.

$$w_{ij}^{.} = -a w_{ij} + \eta z_i y_{ij} \tag{5}$$

Where, the values of η , z_i and y_{ij} are assumed all to be non-negative quantities. The constant of proportionality η is less than one represents learning rate value, However, a is a constant factor indicates forgetting of learnt output; (it is also a less than one),[28].

3. Mother's learning reflective algorithm

This section gives an illustration of a simplified macro level flowchart describing briefly algorithmic steps using Artificial Neural Networks modeling of infant's brain performing vocabulary words' acquisition (Figure 1). That shown figure presents realistic simulation learning program using Artificial Neural Networks following equation (3) in the above section. Furthermore, the effect of increased neurons' number at suggested ANN model considered the output after the following parametric relations deduced from equation (3):

$$V = net - \Theta \quad , \; net = \sum_{i=1}^{m} w_i x_i \quad \Theta = 0, \quad V = \sum_{i=1}^{m} w_i x_i \, , \quad Y(net) = (1 - e^{-\lambda(net)})/(1 + e^{-\lambda(net)})$$

After running this program, three graphical output results are plotted as quantitative analysis and evaluation of responsive reflective actions for vocabulary words' acquisition. That is by measuring quantitatively both of infant's brain performance and mother's speech level. Noting that obtained plotted results are shown at (Figures 3,4, and 6) , at the next fourth section.
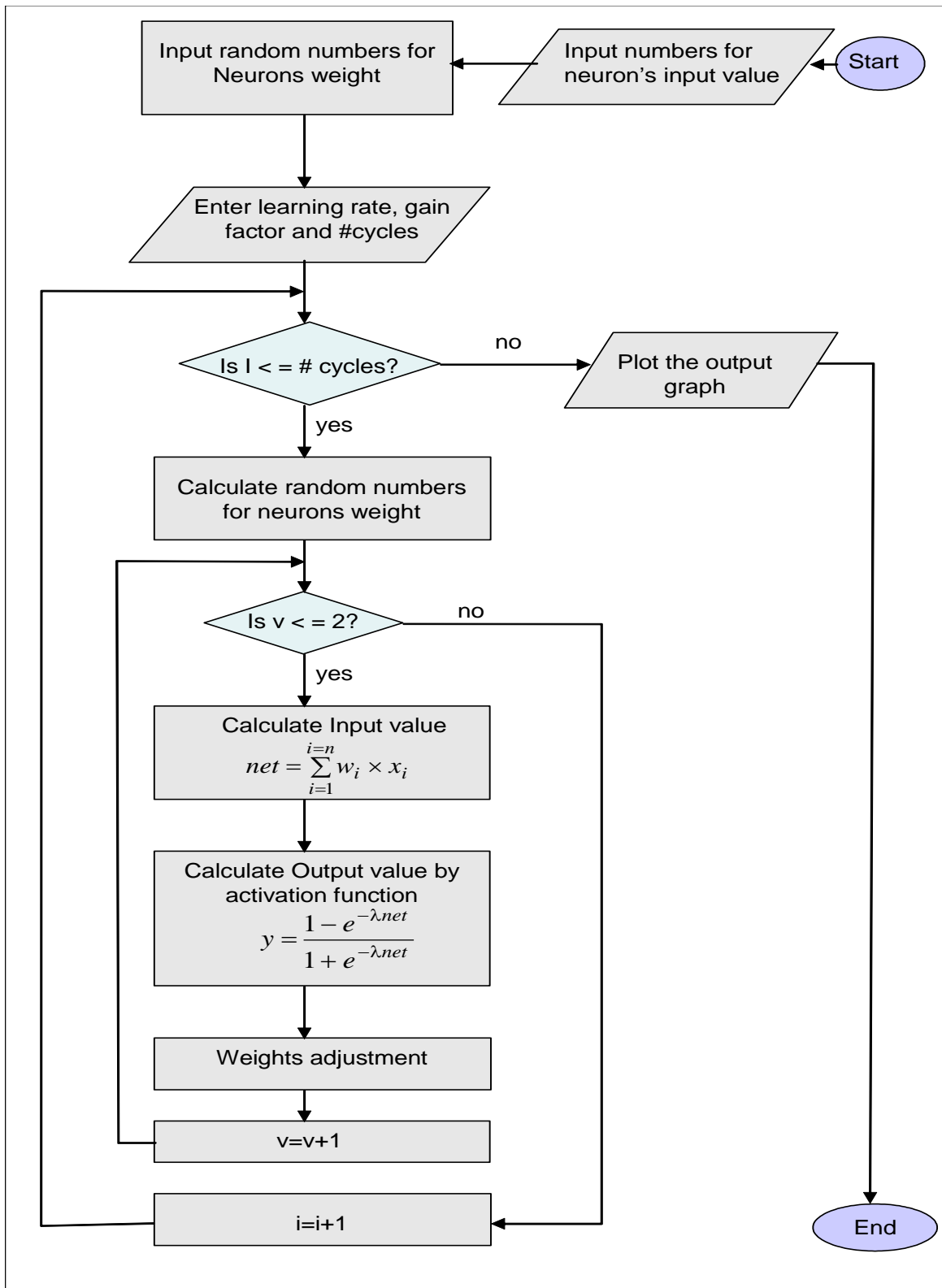
Figure 2 : A simplified macro level flowchart describing algorithmic steps using Artificial Neural Networks modeling.

4. SIMULATION RESULTS

4.1 Responsiveness realistic simulation

This subsection introduces graphically obtained results after running of suggested ANN model program given its algorithmic steps in the above. The two actual high and low responsive graphs shown at Figure 3; are analogously simulated at Figure. 4 by two values of gain factor $\lambda 3 = 2$, $\lambda 1 = 0.5$ respectively**.** Furthermore, at that figure, the curve given by the value $\lambda 2 = 1$ simulates some virtual intermediate responsiveness value between high and low shown at Figure 3. Briefly, the values of gain factors represents the individual differences of infant's brain performance.
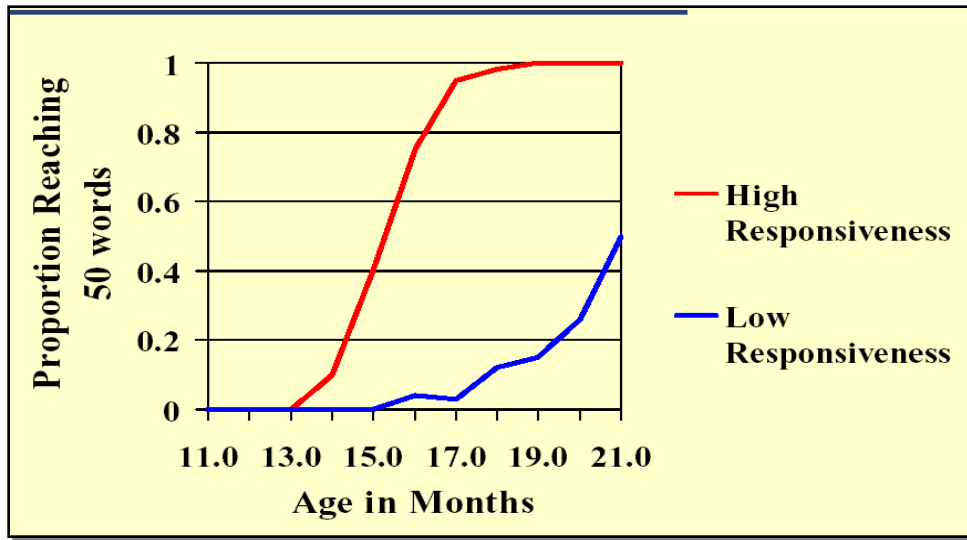

Figure 3: Word acquisition performance of infant's brain while increasing age in months. # Neurons increases by infant's age, adapted from [21]
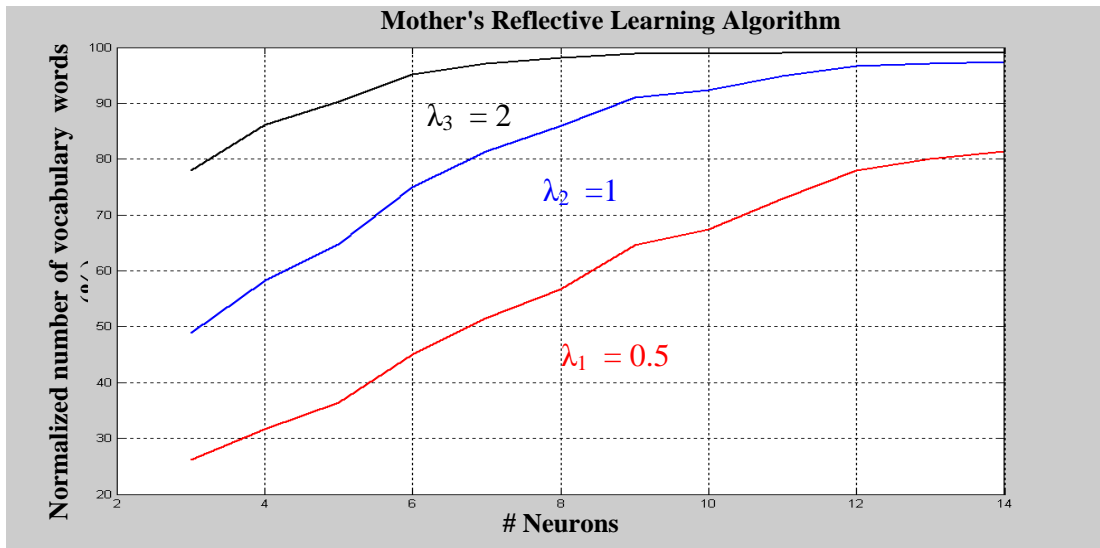

Figure 4:   Graphical simulation results obtained for reached vocabulary number of words' versus different gain factor values (λ_1, λ_2, and λ_3)=(0.5, 1,and 2) ; while # Neurons increases.

4.1.1 Generalized mathematical formulation for different values of gain factors

This subsection introduces the equation of dynamical synaptic plasticity associated to individual different values of gain factors(indicated by λ parameter). This parameter value causes changing of normalized number of vocabulary words versus normalized number of neurons. It is presented by the following equation:.

$$y(n)= (1-\exp(-\lambda i(n-1)))/ (1+\exp(-\lambda i(n-1))) \qquad (6)$$

where λ_i represents one of gain factors (slopes) for hyperbolic tangent activation function, and (n) is the normalized neurons' number (1-10).
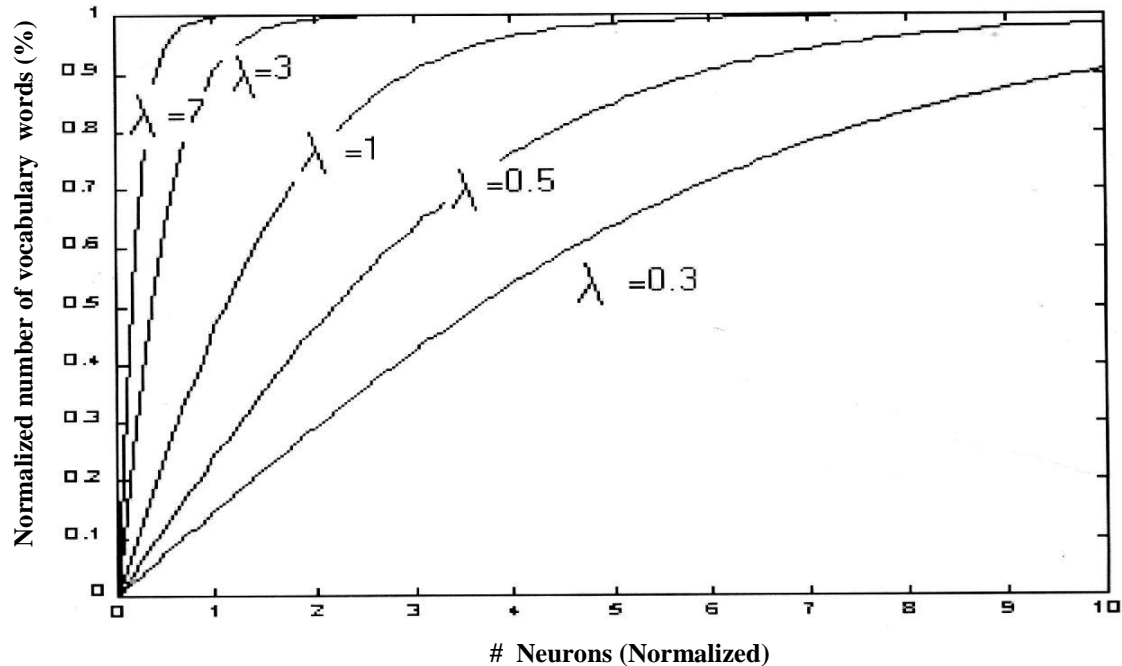

Figure : 5 Graphical representation of learning performance of model with different gain factor values (λ) versus # Neurons.

4.2   Mother's speech level simulation

Interestingly, learning rate values adopted to simulate realistically mother's reflective Learning process follows her speech levels(high, Medium ,and Low). Therefore, the three levels of mother's speech have been analogously considered as leaning rate values(0.3,0.1,and 0.01) respectively. That is illustrated at Figure 6 considering the increased neuron's number during development at early infancy(1-26 months) measuring acquired normalized words vocabulary in accordance with learning rate values.
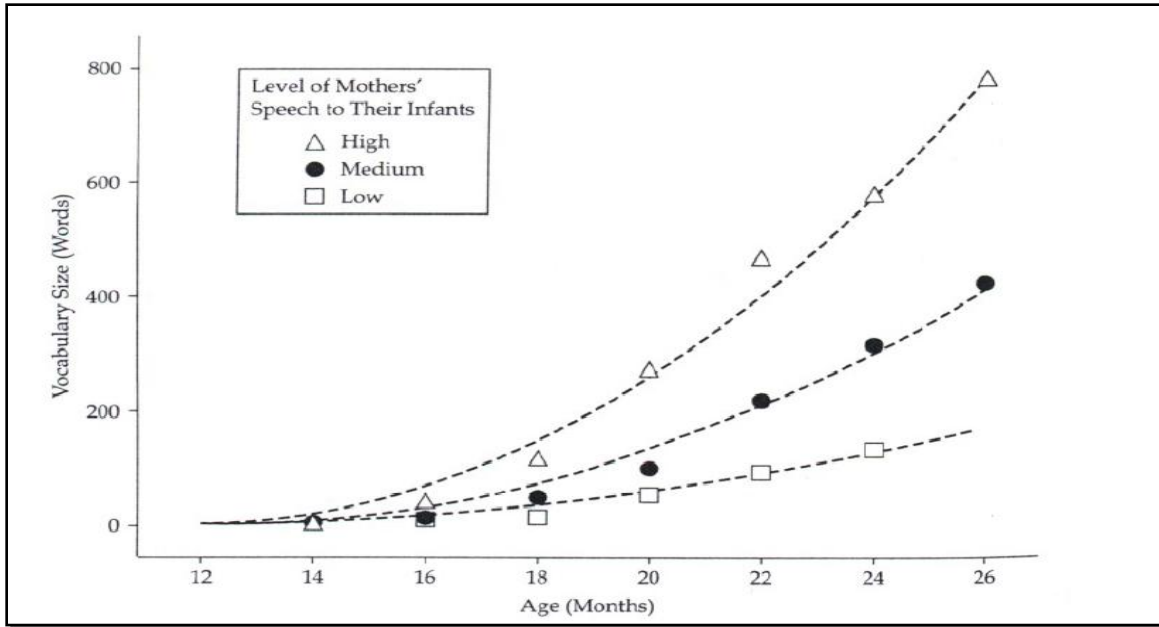
Figure 6:   Effect of mother's speech level on acquired Infant' Vocabulary words, adapted from [21]
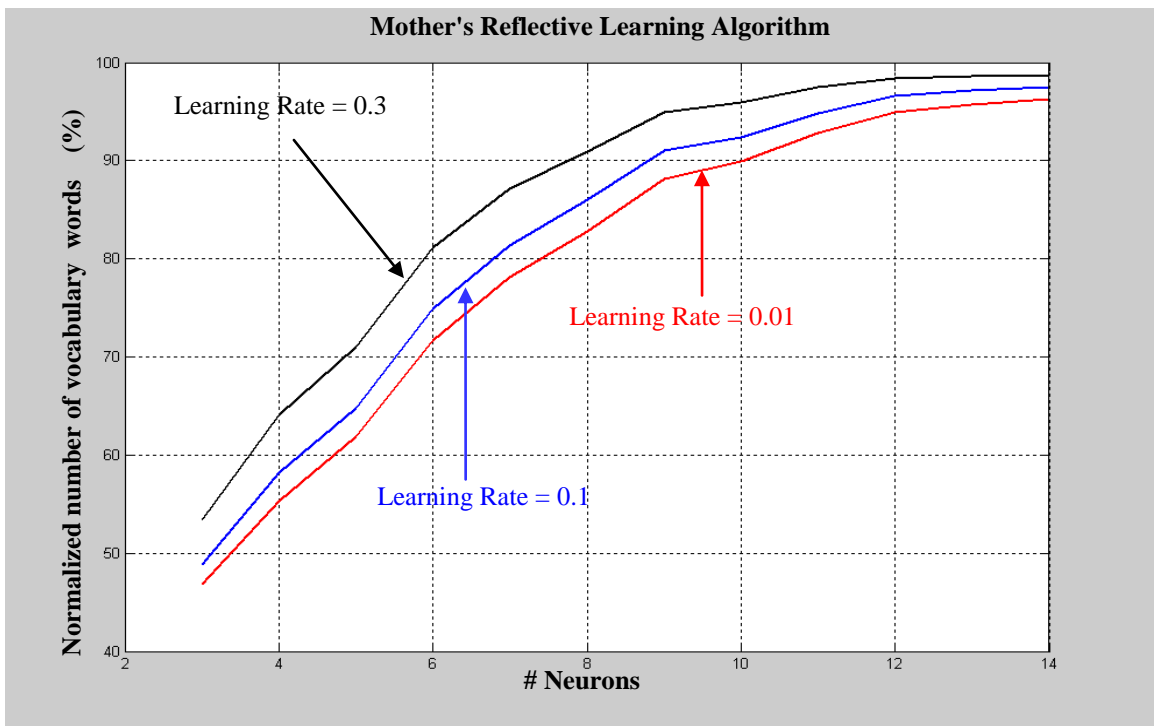

Figure 7 : Illustrate simulated outcome learning performance versus # Neurons For different learning rate values (0.3,0,1,0.01) corresponding to three levels of mother's speech (high, medium, and low) to their infants respectively.

5. CONCLUSIONS AND FUTURE WORK

This work concerned with an interestingly challenging learning issue *"how reading should be taugh*t?" [6][14][15][16]. That's an interdisciplinary issue 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

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language function. It proposes an intelligent classification technique based on ANN modeling to identify 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 [21]. 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 [6]. 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 [29]. Also, the analysis and evaluation of cognitive behavioral phenomena associated with learning creativity [4][30][31], improvement of learning performance quality [32][29], and learning styles[33][34][35],……etc. using realistic Artificial Neural Networks' modeling.

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