International Conference
ICT for Language Learning

# Quantified Performance Analysis of Highly Specialized Neurons for Development of Reading Brain Function Using Neural Networks' Modeling (Sanger's Rule Approach)

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## Abstract

*This piece of research adopts an interdisciplinary conceptual approach that incorporates Artificial Neural Networks (ANN) with learning, neurological and cognitive sciences. Specifically, it considers modeling of associative memorization to introduce optimal analysis for development of reading brain performance via the role of ensemble Number of highly specialized neurons. By more details, this brain performance realistically simulated using ANNs self-organized modeling paradigm. In other words, presented simulation adopts Sanger's Rule Approach which equivalent to Generalized Hebian Algorithm (GHA). Furthermore, it inspired by functioning of highly specialized biological neurons in reading brain based on the organization the brain's structures/substructures. In accordance with the prevailing concept of individual intrinsic characterized properties of highly specialized neurons. Presented models have been in close correspondence with set of neurons' performance for developing reading brain in a significant way. More specifically, herein, introduced model concerned with their important role played in carrying out cognitive reading brain function's outcomes. Accordingly, the cognitive goal for reading brain is to translate that seen word (orthographic word-from) into a spoken word (phonological word-form). In this context herein, the presented work illustrates via ANN simulation results the following: How a number of highly specialized neurons corresponding to visual brain area contribute to the perceived sight (seen) signal is in direct proportionality with the correctness of identified depicted / printed images. These images represent the orthographic word-from has to be transferred subsequently into a phonological word-form during reading process. Furthermore, individual intrinsic characteristics of such highly specialized neurons (in visual brain area) influence directly on the correctness of identified images associated with orthographic word-from.*

## 1. Introduction

Overwhelming majority of neuroscientists have adopted motivational concept that huge number of neurons besides their synaptic interconnections constituting the central nervous system. And synaptic interconnectivity perform dominant roles for behavioral learning processes in mammals (such as: cats, dogs, ants, and rats), besides learning creativity in humans [1][2]. During last decade, the conceptual human learning is specifically motivated and supported by what has been revealed by National Institutes of Health (NIH) in U.S.A. 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 [3][4]. In the context of learning how to read phenomenon, more interesting findings have been revealed considering ensembles of highly specialized neurons (neural networks) in human. Those neurons play the dominant dynamical role in developing functioning of reading brain specifically while adopting phonics reading methodology [5][6][7][8]. More specifically, neurological researchers have recently revealed findings associated with the increase of commonly sophisticated role of Artificial Neural Networks (ANN$^{s}$). That's for realistic and systematic modeling of interdisciplinary reading brain discipline which integrates neuroscience, education, and cognitive sciences [9]. Therefore, such ANN Modeling processes have been widely varied in accordance with the nature of assigned brain function and/or educational phenomena to be modeled such as children's individual differences. More specifically, this work concerned mainly with the understanding of how reading abilities emerge from preexisting visual perception and language abilities. For example, interpretation of orthography, the written form of language, places unique demands on the brain's visual object-processing systems. Linking orthography (orthographic word-from) with phonology (phonological word-form), the sound structure of language, is the *sine qua non* of reading acquisition [10][11]. Recently, a related research work has been published. That addressed the issue of 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 [12]. 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.[13]. In accordance with briefly above introduced analysis which concerned with modelling characteristics of reading brain function. This work adopts a realistic relevant approach categorized as neural computational model [14][15]. In more detail, it is based on optimal unsupervised learning paradigm originated from the Generalized Hebian Algorithm (GHA) and Sanger's rule [14][15][16][17]. The rest of this paper is organized as follows. At the second next revising of Sanger's rule via some detailed descriptions of sequential principal components analysis is presented. The third section introduces the generalized description of adopted ANN model associated with reading brain function. Simulation results are introduced at the fourth section. Finally, the last fifth section presents some conclusive remarks and discussions.

## 2. Revising of Sanger's Rule

Sanger's rule, also known as sequential principal components analysis, developed by American neurologist Terence Sanger in 1985, is a version of Oja's rule which forces neurons to represent a well-ordered set of principal components of the data set [14].

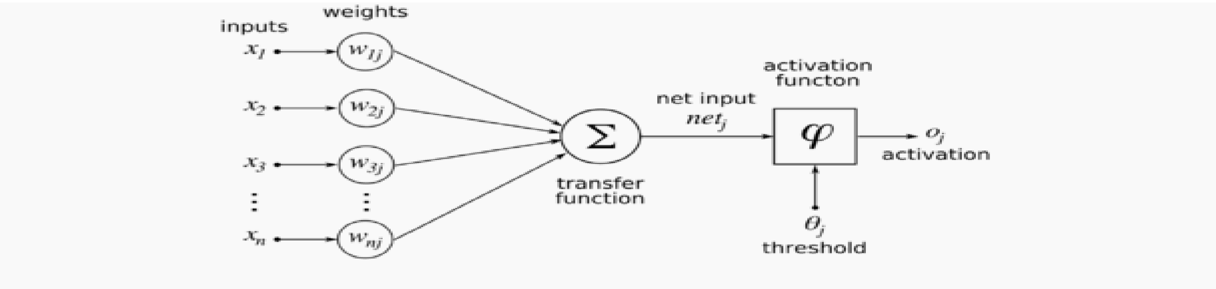


**Figure 1.** Simplified model of neuron (*j*) is the index of the neuron when there is more than one neuron. For a linear neuron, the activation function is not present (or simply the identity functions).

We use a set of linear neurons. Given a set of k-dimensional inputs represented as a column vector $\vec{x} = [x_1, x_2, \cdots, x_k]^T$, and a set of *m* linear neurons with (initially random) synaptic weights from the inputs, represented as a matrix formed by *m* weight column vectors (i.e. a *k* row x *m* column matrix):

$$\mathbf{W} = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1m} \\ w_{21} & w_{22} & \cdots & w_{2m} \\ \vdots & & & \vdots \\ w_{k1} & w_{m2} & \cdots & w_{km} \end{bmatrix}$$

Where $w_{ij}$ is the weight between input *i* and neuron *j*, the output of the set of neurons is defined as follows: $\vec{y} = \mathbf{W}^T \vec{x}$

Sanger's rule gives the update rule which is applied after an input pattern is presented:

$$\Delta w_{ij} = \eta y_j (x_i - \sum_{n=1}^{j} w_{in} y_n)$$

Sanger's rule is simply Oja's rule except that instead of a subtractive contribution from all neurons, the subtractive contribution is only from "previous" neurons. Thus, the first neuron is a purely Oja's rule neuron, and extracts the first principal component. The second neuron, however, is forced to find some other principal component due to the subtractive contribution of the first and second neurons. This leads to a well-ordered set of principal components. The only problem is that while it is true that the entire input set *can* be constructed from one primary principal component, one secondary principal component, and so on, the components themselves are not necessarily *meaningful*. Rather than the entire set, there may only be *subsets* of the input set for which principal components analysis over each subset makes sense. This insight leads to Conditional principal components analysis [15]

## 3. Reading Brain Modeling

### 3.1 Biological Bases for Reading Function

In the context of neurobiology, the strength of response signal is dependent upon the transfer properties of the output motor neuron stimulating salivation gland. The structure of neural model after the original Pavlov's psycho-experimental work is presented at Figure 2 [18]. That presents Hebbian learning rule in its simplified form (single neuronal output), where A, and C represent two sensory neurons (receptors)/ areas and B is nervous subsystem developing output response.
In accordance with reading brain, the output response signal is measured quantitatively by the exactness of pronouncing letter/ word (reading achievement [%]) as presented at next fourth section. That output response signal is dependent upon the transfer properties of the output motor neuron stimulating pronouncing as unconditioned response (UCR) for heard phoneme (sound signal). However, this pronounced output representing phonological word-form for the seen letter/ word is considered as conditioned response (CR) when input stimulus is given by (orthographic word-from).

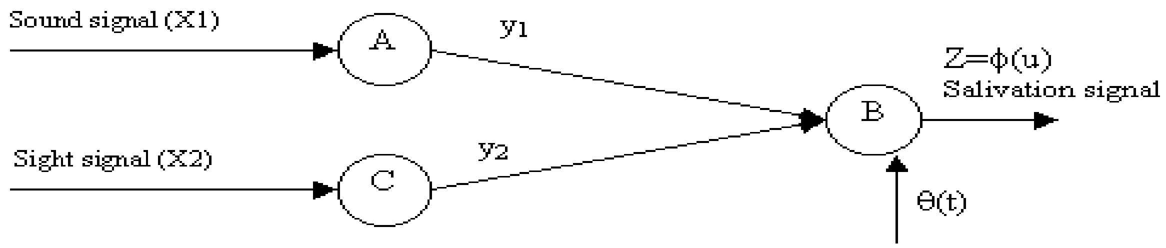


**Fig. 2.** Simplified structure that presenting Hebian learning rule model.

Referring to the two figures Fig.3, Fig.4, Lettered circles A, B, C, and D represent a neuron cell body. Furthermore, lines connecting cell bodies represent interconnectivity synaptic junctions Wij between neuron (i) and neuron (j) .The output signals released out from sensory sound and sight neurons A and C are transferred via two synapses y1 and $y_2$ respectively. Referring to the two figures (Fig.4&Fig.5) shown in below, suggested models obeys that concept as the two inputs $I_1$, $I_2$ represent sound (heard) stimulus which simulates *phonological word-form* and visual (sight) stimulus which simulates *orthographic word-from* respectively. The outputs $O_1$, $O_2$ are representing pronouncing and image recognition processes respectively. In more details, Fig.3 drives an output response reading function (pronouncing) that is represented as $O_2$. However the other output response represented as $O_1$is obtained when input sound is considered as conditioned stimulus which results in visual recognition as condition response of the heard letter/ word is obtained as output $O_1$. Figure 4 is derived from Figure 3 to present directly reading brain function. Interestingly, that figure is straight forward analogous to above Simplified structure that presenting Hebian learning rule model at figure 2.

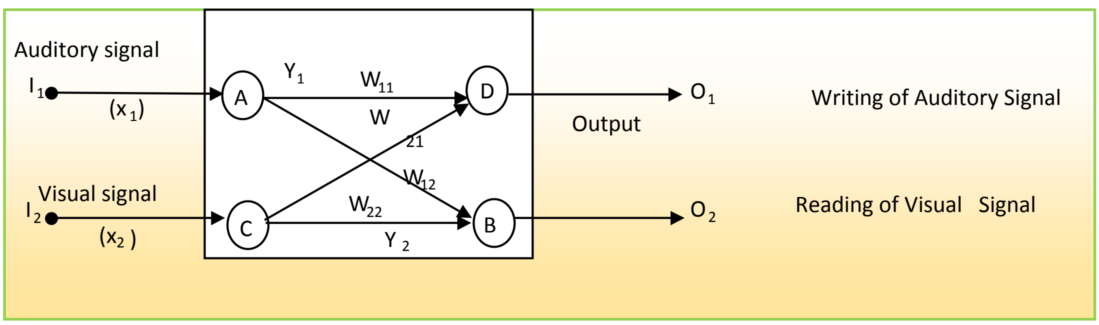


**Fig. 3.** Generalized reading model which predented as pronouncing of some word (s) considering input stimuli and output.

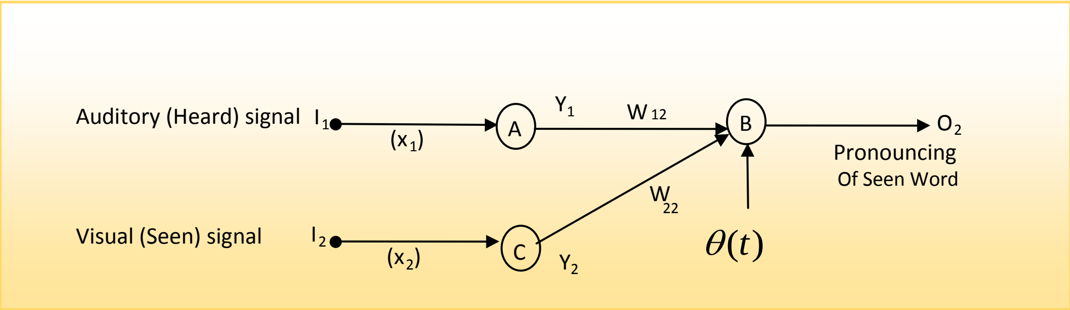


**Fig. 4.** The structure of the first model where reading process is expressed by conditioned response for seen letter/ word (adapted from [19])

## 4. Simulation Results

Figure 5 illustrates Obtained measured human results versus realistic neural network modeling results considering basic images with different images' resolution (number of pixels). Interestingly, the improvement of basic images by increasing number of pixels is straight forward analogous to the increasing of neurons' number illustrated at Fig.6. More precisely, the observed performances measured are clearly improved by the increase of neurons and pixels respectively both Fig. 5 & Fig.6.

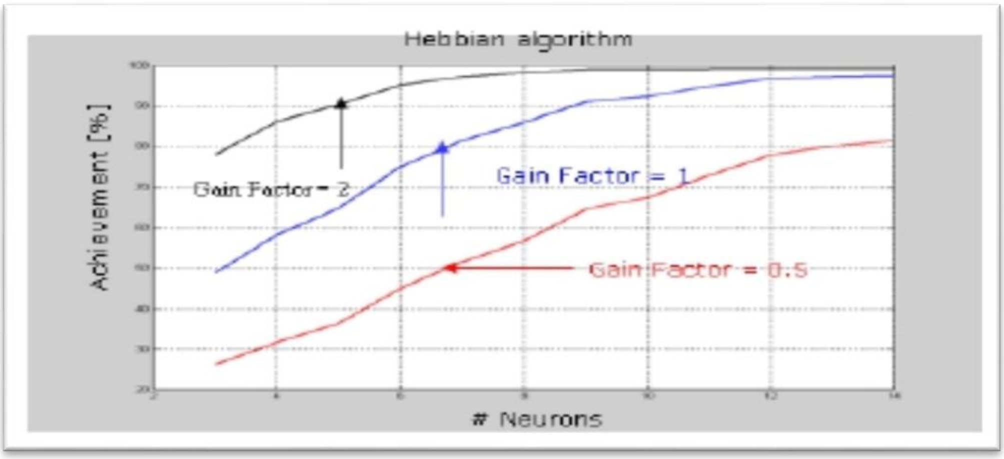


**Fig. 5** Simulation results obtained after running of neural network model compared versus measured human results considering basic images with different images' resolution (number of pixels) {adapted from [20]}

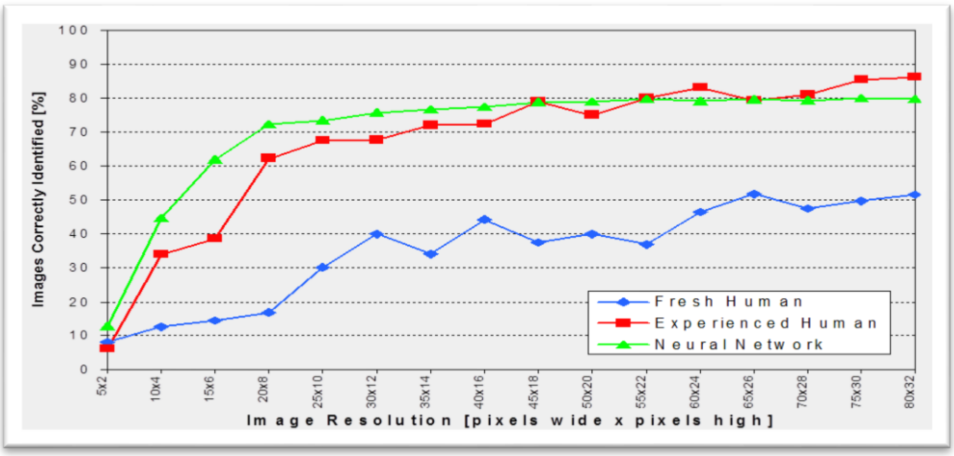


**Fig. 6** Reading performances considering different number of neurons and various gain factors 0.05, 1, and 2, while Learning Rate in Hebbian model has a fixed value: equals to 0.3

## 5. Conclusions

Herein, the introduced study illustrates how a set of highly specialized neurons could be dynamically realistically simulated via ANN modeling. Furthermore, it shows that how a flock of neurons interacts together among themselves as flock's agents in order to perform a specific considered common role of Reading function, via visual and auditory brain substructures' areas. Interesting analogy between the performance of number of highly specified flock of neurons contributing to reading brain function and quality of identified images is clearly straight forward referring to Fig.5 versus Fig.6 respectively. This work motivated by associative memorization based upon pavalovian experimental work as shown at Fig.3. Additionally, it adopts GENERALIZED HEBBIAN ALGORITHM (GHA) equivalently Sanger's Rule Approach. However for future extension of this work it is recommended to adopt Hopfield neural network for associative memorization between seen word (orthographic word-from) and a spoken word (phonological word-form).

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