A Neural Network model of generalization problem in autistic brains

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***Abstract*—Previously, we hypothesized that over-fitting occurs in the brain networks of the patients with autism. In this study, we implement this idea in an artificial neural network (ANN). A set of tasks, named configural grouping tests, used by Mottron and colleagues in 2003, were picked out to be applied on a typical ANN which we designed. The visual stimuli were fed as the input; over time, the output error was monitored to evaluate the generalization capability of the network. The ANN training results of 6 letters were represented and the over-fitting was observed in all of them. In the learning process, before over-fitting (over learning) occurrence, testing error diagram decreases with decay in training error which indicates that ANN was trained well. This condition simulates the behavior of a healthy person. By continuing the learning process, testing error begins to increase and over-fitting occurs in the ANN, i.e. the generalization capability of the network decreases which simulates the behavior of an autistic brain. Based on these results, we suggest that ANN approach is an efficient tool for understanding some neurological conditions as autism.**

Keywords—Autism; Artificial Neural Network; Over-fitting; Generalization; Brain network

I. Introduction

Autism Spectrum Disorder (ASD), sometimes indicated as Pervasive Developmental Disorder (PDD) [1], refers to a wide range of neurodevelopmental disabilities, including Classic Autism, Asperger syndrome, and Atypical Autism [2]. These abnormalities mostly start before the age of 3 and hinder the patients' capabilities throughout their lifetime [3].

The main symptoms of ASD are problematic communicative interactions and repetitive stereotyped patterns in behavior [3]. Weak Central Coherence (WCC) theory showed that the patients with autism focus on details rather than general structures [4]. Further investigations noted their inability to generalize their experiences [5].

Previously, we hypothesized that the reduced generalization feature of people with autism can be viewed from the perspective of artificial neural networks (ANNs). ANNs are simplified models of human neurons. Learning rules are used to construct the pattern of connections between the neurons and give the network its ability to compute different functions. One problem in neural network training is "over-fitting", i.e. the error on the training set becomes very small, but the error with applying new input to the network is large. In other words, the network has learned the training examples, but it is not able to generalize and find the true answer in new situations. . We hypothesized previously that the generalization problem of autistic brain network is to some extent similar to over-fitting in ANNs [6]. In this study, we implement this idea in an ANN in order to evaluate our hypothesis.

Cohen [7] used the ANN approach and concluded that a network with too many connections shows high discrimination and low generalization –a model of autistic brain- beside, too few connections network shows low discrimination and high generalization –a model of retardation. It was shown that conception of semantic correlation ability in the patients with autism decreased [8,9]. For solve this problem. McClelland [9] suggested a model for hyperspecificity in autism using neural nets. They proposed a change in some parameters in autistic brain with using of some conjunctive codes in the brain of patients, the same in the ANNs.

Mottron and coworkers tested a group of fragmented tasks on autistic children to show their generalization inability [10]. We applied this test to a typical ANN model, and monitored the network's outputs in both normal and over-learned (over-fitting) conditions over time. The mentioned tasks consisted of two groups of alphabetical symbols both in integrated and fragmented forms. These symbols were fed to the ANN as pictorial inputs. The output error is defined as failure in recognizing the fragmented symbols as their integrated forms. We assessed the ANN generalization ability before and after over-fitting. Finally, we discuss the advantages of ANN approach in understanding the behavior of patients with autism, and in introducing novel learning procedures for these patients.

II. Model

A. ANNs

An artificial neural network (ANN) is inspired from biological neural networks. A typical ANN is made up of a number of layers, each of which is composed of artificial neurons, being in connection with one another based on the needed network architecture, modeled by predetermined mathematical relationships. There are three main groups of layers in a network: the input layer (obtaining inputs from outside environment), the middle layers known as hidden layers (obtaining inputs from other layers based on the structural design of the network's internal connections), and the output layer which produces the final output of the whole network. ANNs are applied in a wide range of fields including: data classification, function approximation, pattern recognition, and computational modeling of biological neural systems; among which, the last application is specifically aimed to use mathematical models in order to help better understand the mechanisms underlying neural learning and other similar procedures. The mentioned abilities are achieved via training the networks based on a particular learning algorithm which refines the parameters of the internal mathematical connections between neurons and leads the outputs towards the desired qualities through the learning process [11-14].

B. Over-fitting Phenomenon in ANNs

One of the main properties of an artificial neural network is its capability in generalization. In a situation which the learning steps increase significantly or the network structure becomes too complex for being applied on the available quantities of the input data, the ability of the network to minimize the test error (the difference between desired state and outputs corresponding to a new test input) gradually decreases. This condition, named over-fitting (over-learning), decreases the network ability to make correct decisions for new inputs. In this situation, the network is focused on the individual cases and the generalization is restricted [14, 15].

C. Simulation

In this study, we used a set of tasks, named configural grouping tests, which introduced by Mottron and colleagues in 2003 [10]. In this task, Mottron et al. challenged the capability of autistic participants in recognizing large structures through using the combination of small fragments. In this study we applied this task on a typical ANN, and assess its capability in imitating an autism-like behavior in the case of generalizing its outputs to new cases.

In fact, while healthy subjects are expected to identify both forms as one, and in other words, generalize the fragmented picture to the integrated picture, most patients with autism fail to accomplish the intended generalization, as they tend to intensively focus on the elementary fragments of the visual stimuli. In this work we designed a typical artificial neural network, whose number of input nodes and hidden layers were selected upon the features of its input visual matrices. The visual stimuli were fed as the input and the output error was monitored over time to check whether the network behavior was able to model the generalizing behavior of the network.

We used the neural network toolbox from Matlab 7.8 software to construct a network. Since we want to use a simple network, we construct an artificial neural network with one hidden layer containing three neurons. A schematic of our network is illustrated in Fig. 1. The number of neurons in the input and output layer is the same as the length of input data, i.e. equal to 19. The input data is a 31 by 19 matrix. The rows of input matrix were fed to the network sequentially. Fig. 2 shows the visual input matrices fed to the implemented ANN in training and testing steps. In addition, the corresponding images of input (integrated letter) and output (fragmented letter) are depicted in Fig.2.

III. REults

Fig.3 depicts six diagrams in each of them the solid line indicates the output error of the network in the training condition, while it is learning the integrated letter. The internal parameters of the mathematical interconnections between neurons are being updated by every single learning epoch. Simultaneously, the dotted line represents the error produced at the output of the same network, while the testing set (fragmented matrix) is fed as the input of the network and the error between the ANN outputs and the desired output (integrated letter) is calculated. In this way, the capability of network in generalizing that the testing set to the training set, could be assessed. According to Fig.3, in all of the six runs for training six letters, the training diagram follows a decreasing pattern, while the testing diagram starts with a decreasing trend followed by an increasing trend as the number of epochs increase (highlighted by arrows). That means an over-fitting phenomena occurred. Although this is an expected effect in such classification tasks, the point is that we want just to show over-fitting phenomena in a typical ANN with configural grouping tasks, which introduced by Mottron et al. [10].

IV. Discussion

In our previous study, we presented the idea of over-fitting occurrence in the brain network of patients with autism that is similar to this phenomenon in the artificial neural networks (ANNs). In other words, we hypothesized that autistic brains which suffer from inability of generalization are similar to an artificial neural network which is over fitted and can't generalize what is learned to new inputs.

In this study, we modeled the disordered generalization of patients with autism with artificial neural networks in over-learning state. For this purpose, we implemented the experiment which was used by Mottron et al. in patients with autism. In their study, they showed the autistic disability in generalization in configural task. According to their experiment, we selected six alphabet letters in the integrated and fragmented forms, represented by two groups of digital matrices, as the training and testing inputs for our designed ANN, respectively. We run this test to examine if the network is capable of generalizing the learned (trained) set of data to the testing set.

The ANN training results of 6 letters were represented and the over-fitting was observed in all of them. In the learning process, before over-fitting (over learning) occurs, testing error diagram decrease with decreasing of training error and ANN was trained well (fragmented letter was determined as integrated letter). However, because of focus on details, testing error begin to increase and ANN doesn't determine the testing input (fragmented letter) as the training input (integrated letter) i.e. over-fitting occurred.

According to Fig. 3, in all of the six runs for training six letters, testing diagram is beginning to increase at the point indicated by arrow. This turning point in the testing diagram defines the onset of the phenomenon "over-learning" (over-fitting). The increasing error shows that the generalization capability decreased.

The outcomes showed an overall increase in the learning quality of the target ANN before the over-learning condition (modeling the recognizing behavior of a healthy person), followed by a gradual decrease in the accuracy of the generalization capability of the network after the onset of over-learning (modeling the recognizing behavior of a patient with autism). The outcomes were consistent with the results presented by Mottron and colleagues comparing generalization skills in healthy and autistic participants in response to fragmented and integrated visual stimulation patterns.

We suggest that using ANN approach is an efficient tool for analyzing some neurological conditions as autism. Paying attention to the concept of over-fitting may lead to design efficient behavioral therapies in autism. Surely, more clinical experiences are needed to propose such novel therapeutic maneuvers.

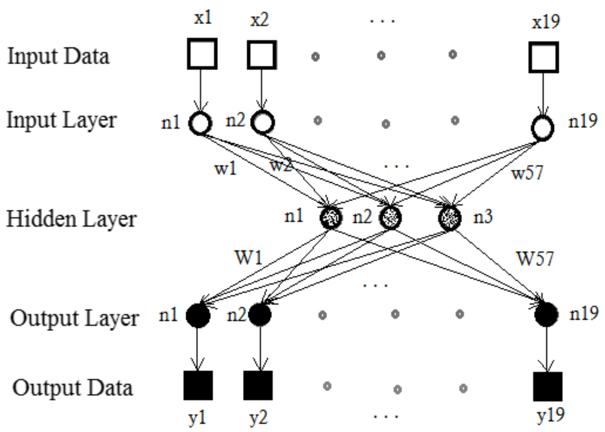

Fig. 1. *The internal structure of our ANN.*

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[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 ;
 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 ;
 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 ;
 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 ;
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 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 ;
 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 ;
 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 ;
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0];
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(a)

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[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 ;
 0 1 1 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 0 ;
 0 1 1 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 0 ;
 0 1 1 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 0 ;
 0 1 1 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 0 ;
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 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 ;
 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 ;
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0];
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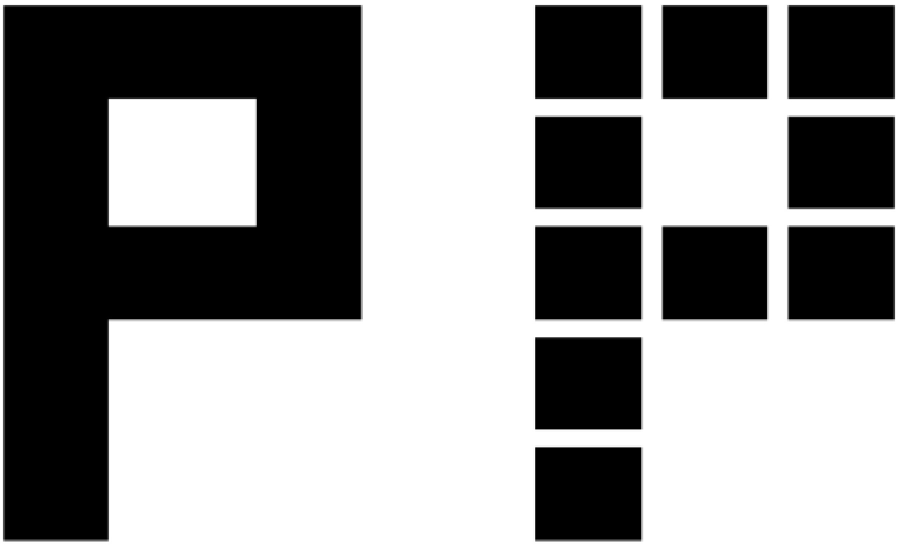
(b)



(c) (d)

Fig. 2. *The visual stimuli fed to the ANN as digital matrices for letter ‘P’. The picture (a) is the training input data, representing the integrated letter, and the picture (b) is the testing input data, representing the same letter in its fragmented form. The picture (c) is the image of the integrated letter whose matrix is shown in the picture (a). And the picture (d) is the image of the fragmented letter whose matrix is shown in the picture (b). The aim is to examine if the network is capable of generalizing its learning to new cases and is able to identify the testing set the same as the trained set of data.*

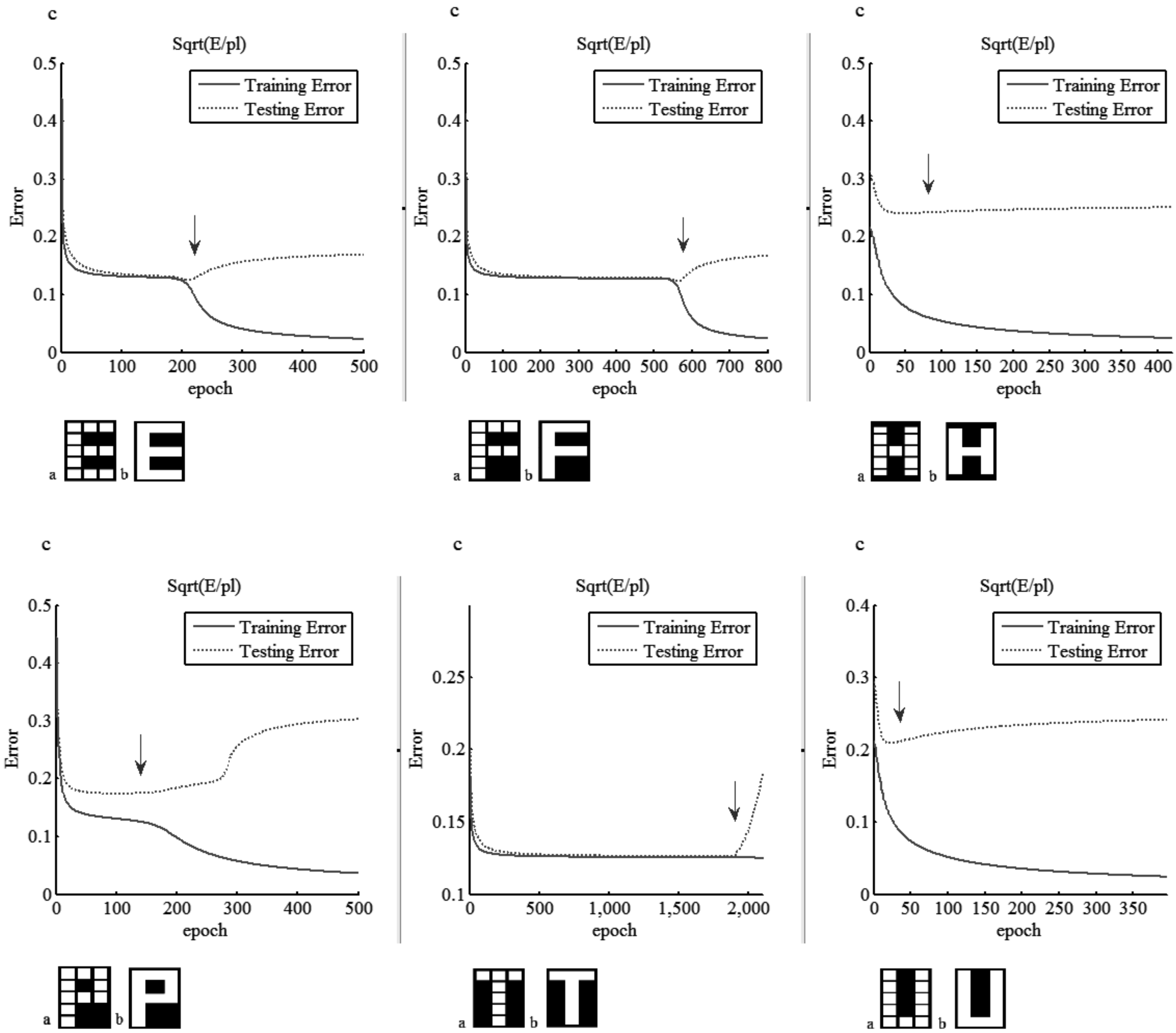


Fig. 3. *a: The fragmented letter (testing input) is shown, b: The integrated letter (training input) is shown, c: Training error diagram versus the number of training epochs (solid line) and testing error diagram versus the number of training epochs (dotted line) are depicted. The highlighted arrow shows the beginning of over-fitting in testing data.*

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