DEVELOPMENT OF INTELLIGENT METHOD FOR DIFFERENTIAL DIAGNOSIS OF SPECIFIC LANGUAGE IMPAIRMENT

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*Abstrac*t- **This paper presents a soft computing model for differential diagnosis of Specific Language Impairment (SLI). SLI is a language disorder that, in many cases, cannot be easily diagnosed by the specialists. This difficulty necessitates the development of a methodology, which will contribute to the differential diagnosis of SLI and will help and support the speech therapist in the diagnostic process. The methodology-tool used is based on Fuzzy Cognitive Maps. The development of the model was based on proven and published knowledge from the literature and then it was successfully tested on four different clinical cases. The results obtained point to its final integration in the future and to its valid contribution as a model of differential diagnosis of SLI.**
***Keywords* - Fuzzy Cognitive Maps, differential diagnosis**

I. INTRODUCTION

Despite the numerous studies that have been conducted since the first half of the 19th century [1], Specific Language Impairment (SLI) remains a language disorder that cannot be easily diagnosed because it has similar characteristics to other disorders. Research has shown that almost 160 factors can be taken into account in the diagnosis of SLI [2] and there is no widely accepted method of identifying children with SLI [3]. This implies that the differential diagnosis of SLI with respect to other disorders, which have similar characteristics, is a very difficult procedure. Therefore, it is necessary to develop a model of differential diagnosis of SLI, which will aid the specialist in the diagnosis and suggest to him/her a possible diagnosis.

Speech assessment is a complicated procedure since it should include a complete history of each patient, diagnostic tests to examine all of the aspects of speech, language and communication in general, as well as a detailed observation of the patient over a long period of time. However, in many cases there are similar symptoms that correspond to a group of disorders. Thus, the differential diagnosis has to determine which is the most probable disorder and this is a much more complicated procedure.

In the first phase of this study, SLI and two other communication disorders were examined, dyslexia and autism. Findings in the literature have shown that both dyslexia and autism are disorders, whose diagnoses often have been confused with the diagnosis of SLI [4],[5],[1],[6],[7]. Particularly, the data has initially lead to the assumption that SLI cases are confused either with severe cases of dyslexia or with mild cases of autism.

The proposed differential diagnosis method is based on Fuzzy Cognitive Maps (FCMs), a soft computing methodology for making decisions that follows the method of human reasoning and decision-making. The differential diagnosis system is a complex system. FCMs use a symbolic representation for the description and modeling of complex systems [8],[9],[10],[11],[12] and decision making systems [13]. They utilize concepts that represent qualitative and quantitative data to illustrate the different aspects of the model and behavior of the system. The interaction of the concepts shows the dynamics of the system [14].

The next section describes the disorders and their main causative factors and symptoms, which are taken into account in this differential diagnosis model. The third section describes Fuzzy Cognitive Maps, the method for developing the differential diagnosis model of SLI with respect to dyslexia and autism. The fourth section discusses the results of the successful implementation of the model in four known clinical cases. Finally, the fifth section contains the conclusions and presents the future directions.

II. DISORDERS AND FACTORS

SLI is a significant disorder of spoken language ability that is not accompanied by mental retardation, frank neurological damage or hearing impairment. Children with SLI face a wide variety of problems both on language and cognitive levels. It must, also, be mentioned that SLI is congenital and it is not a result of some disease or a psychological trauma [1].

Dyslexia constitutes a disorder of children that appears as a difficulty in the acquisition of reading ability, despite their mental abilities, the adequate school training or the positive social environment [15], [16]. Dyslexia is a disorder of written and not of spoken language, although it is possible for a dyslexic child to have limitations in some aspects of spoken language as well [17]. Such a child is very likely to learn how to read with adequate training, but will always remain dyslexic. The problems besides reading that dyslexics face usually concern writing and spelling, as well as some other academic abilities in certain cases [16].

Autism is a developmental disorder and pathologically it is defined as an interruption or regression at a premature level of a person's development [18]. The main idea in autism is the impaired or limited relation that exists between the autistic person and its environment [19]. It constitutes mostly a severe social weakness rather than a frank language disorder. The three basic terms that can give the picture, up to a significant point, of an autistic person are: social withdrawal, repetitiveness and lack of communication [20].

Some basic factors that appear in all three disorders with different frequency and severity in most cases were included in this study. The considered factors are either causative

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Abstract

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factors or symptoms of the disorders. The factors within each disorder were taken into consideration in a comparative way in the development of the model. The significance of each factor as a diagnostic criterion is defined with the following fuzzy variables: a) Very-very important, b) very important, c) important, d) medium, e) not very important, and f) minimally important. These criteria were converted to fuzzy weights for this Fuzzy Cognitive Map Differential Diagnosis Model, which are shown in Table I.

III. SLI Differential Diagnosis Model

A. Fuzzy Cognitive Maps

Fuzzy Cognitive Maps (FCM) are a soft computing tool that is a result of the synergy of Fuzzy Logic and Neural Network methodologies and is based on the exploitation of the integrated experience of expert-scientists [9]. The graphical illustration of a FCM is a signed, weighted graph with feedback that consists of nodes and weighted arcs. Nodes of the graph are the concepts that correspond to variables, states, factors and other characteristics incorporated in the model, which describe the behavior of the system. Directed, signed and weighted arcs, which represent the causal relationships that exist between the concepts, interconnect the FCM concepts. Each concept represents a characteristic, state or variable of the system; concepts stand for events, actions, goals, values, and/or trends of the system being modeled as an FCM. Each concept is characterized by a numeric value that represents a quantitative measure of the concept's presence in the model. A high numeric value indicates the strong presence of a concept. The numeric value results from the transformation of the real value of the system's variable, for which this concept stands, to the interval [0,1]. Values in the graph are fuzzy, so weights of the arcs are described with linguist values that can be defuzzified and transformed into [-1,1].

Between concepts, there are three possible types of causal relationships that express the type of influence of one concept on the others. The weight of an interconnection, denoted by W_{ij}, for the arc from concept C_i to concept C_j, can be positive, ($W_{ij}>0$), which means that an increase in the value of concept C_i leads to the increase of the value of concept C_j, and a decrease in the value of concept C_i leads to the decrease of the value of concept C_j. Or there is negative causality ($W_{ij}<0$), which means that an increase in the value of concept C_i leads to the decrease of the value of concept C_j and vice versa. When, there is no relationship from concept C_i to concept C_j, then ($W_{ij}=0$) [14].

When the Fuzzy Cognitive Map starts to model the system, concepts take their initial values and then the system is simulated. At each step, the value of each concept is determined by the influence of the interconnected concepts on the corresponding weights:

$$A_i^{t+1} = f\left(\sum_{\substack{j=1 \\ j\neq i}}^{n} W_{ji} A_j\right) \qquad (1)$$

where C_i^{t+1} is the value of concept C_i at step t+1, A_j is the value of the interconnected concept C_j at step t, and W_{ij} is the weighted arc from C_j to C_i and $\boldsymbol{f}$ is a threshold function.

The major advantage of fuzzy cognitive maps is that they can handle even incomplete or conflicting information. This is very important in the diagnosis of language/communication disorders because frequently important information may [21]: i) be missing, ii) be unreliable, iii) be vague or conflicting, and/or iv) be difficult to integrate with other information.

B. Description of the Differential Diagnosis Model

In our case, the proposed Fuzzy Cognitive Map depicted in Figure 1, consists of two different types of concepts. The three central concepts (disorder concepts) correspond to the three disorders that are studied in the current differential diagnosis model: specific language impairment, dyslexia and autism.

TABLE I
QUALITATIVE CONNECTION BETWEEN FACTOR-CONCEPTS AND DISORDER-CONCEPTS

Factor- Concepts	**Disorder-Concepts**		
	A. SLI	**B. Dyslexia**	**C. Autism**
1. *Reduced Lexical Abilities*	+ VERY-VERY HIGH	+ MEDIUM to HIGH	+VERY-VERY HIGH
2. *Problems in Syntax*	+ VERY-VERY HIGH	+ MEDIUM to HIGH	+ VERY HIGH
3. *Problems in Grammatical Morphology*	+ VERY-VERY HIGH	+ MEDIUM to HIGH	+ VERY HIGH
4. *Impaired or Limited Phonological development*	+ HIGH	+VERY-VERY HIGH	+ MEDIUM
5. *Impaired Use of Pragmatics*	+ MEDIUM to HIGH	NONE *	+VERY-VERY HIGH
6. *Reading Difficulties*	+ MEDIUM to HIGH	+VERY-VERY HIGH	- HIGH
7. *Echolalia*	+ VERY LOW	NONE	+VERY-VERY HIGH
8. *Reduced Ability of Verbal Language Comprehension*	+ MEDIUM	+ LOW	+VERY-VERY HIGH
9. *Difference between Verbal and Nonverbal IQ*	+VERY-VERY HIGH	+VERY-VERY HIGH	+ MEDIUM to HIGH
10. *Heredity*	+ MEDIUM to HIGH	+ HIGH to VERY HIGH	+ HIGH
11. *Impaired Sociability*	+ MEDIUM to HIGH	+ MEDIUM	+VERY-VERY HIGH
12. *Impaired Mobility*	+ MEDIUM	CASE DEPENDENT	+VERY-VERY HIGH
13. *Attention Distraction*	+ MEDIUM	+ MEDIUM to HIGH	+VERY-VERY HIGH
14. *Reduced Arithmetic Ability*	+ MEDIUM to HIGH	CASE DEPENDENT	CASE DEPENDENT
15. *Limited Use of Symbolic Play*	+ MEDIUM	NONE *	+VERY-VERY HIGH

*Inadequate or conflicting research information has been found for the factor.

The second types of concepts, factor-concepts, are symptoms and cause factors to the disorder concepts, and they are considered as measurements that can determine the result of the diagnosis. The direction of interconnections between the concepts is shown in Figure 1 by the arrowed arcs. This shows in a simple way which concept influences another concept. However, due to limited space and in order to make the figure simpler, the sign and weights of the connections are not illustrated in Figure 1. These are described and can be determined from Table I. Table I describes the existing relationship between factor-concepts and disorder concepts. This relationship may be a positive or negative dependence between factors and disorders, while the degree of the relationship is described by a linguistic value. A positive connection (+) implies that the given factor increases the probability of diagnosis of the connected disorder. Lack of connection between a factor and a disorder suggests that no influence of that factor on the disorder has been found, yet. A negative (-) connection between the factor and the disorder implies that the existence of the given factor must lead to reduction of the probability of diagnosing the particular disorder.

Apart from describing the direction of causality between two concepts and the sign of causality, the degree of cause and effect between two concepts must be determined, since, we do not expect that all factors have the same weight for a given disorder, nor the same weight for each disorder. Each expert describes the degree of influence for each interconnection using a linguistic variable. Thus, each expert of the group of experts suggests a linguistic weight for each interconnection, so a set of linguistic weights for each interconnection is assigned. This set of weights for each interconnection is integrated, using a sum combination method and then the defuzzification method of Center of Area (CoA) [22], [23] is used and a numerical weight for this interconnection is produced, which belongs to the interval [-1,1].

However, the real strength of Fuzzy Cognitive Maps is their ability to describe systems where there are feedback relationships and relationships between the factor concepts. Interrelations between factors concepts have also been found and are shown in Fig. 1 and have a fuzzy a weight of +low.

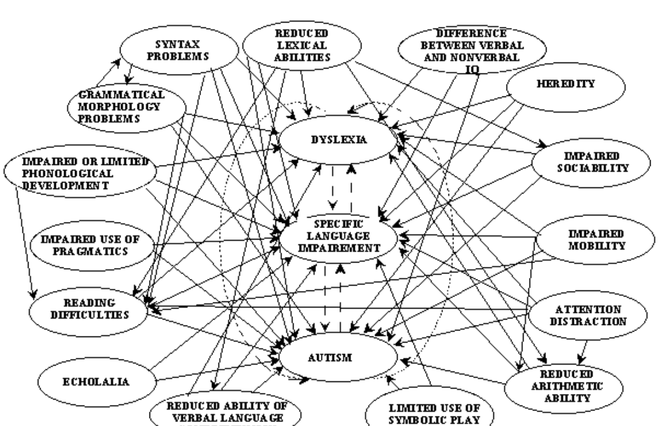

Fig. 1. FCM Differential Diagnosis Model of SLI from Dyslexia and Autism

The proposed Fuzzy Cognitive Map of Figure 1 has also connections (arcs) between the disorder concepts. These are not cause-effect connections but they are inhibitory connections that ensure the competition between the disorder nodes so that only one of them may dominate and be considered the correct diagnosis with the highest probability.

IV. DISCUSSION

After the construction of the above differential diagnosis model, four case studies from the literature were investigated, (two on SLI [7], [24], one on Dyslexia [25] and one on autism [26]), in order to confirm its effectiveness. The value of occurrence of each factor in each case study was denoted with similar fuzzy degrees which were defuzzified into the following initial vectors (1x18) for each one of the 4 cases, respectively:

A_0=[0 0 0 0.9 0.9 0.8 0 0 0 0 0 0.65 0.65 0.5 0 0 0 0]
A_0=[0 0 0 0.8 0.9 0.9 0 0 0 0 0 0.65 0 0 0 0 0 0]
A_0=[0 0 0 0.58 0.8 0.8 0.8 0 0.9 0 0 0.65 0 0 0.5 0 0.5 0]
A_0=[0 0 0 0 0 0 0 0 0 0.9 0.9 0 0 0.9 0.8 0.8 0 0]

For the cases that the initial value of a concept-factor is 0, it denotes that either there was no information available on the given factor or that the given symptom did not exist.

Figure 2 contains plots of the values of the output nodes, SLI, Dyslexia, and Autism as a function of the number of repetitions for each case. Each node converges to a final value and the node with the maximum value is the most probable diagnosis based on the model. In all four cases, even though the information was incomplete, the result given by the model agreed with the published diagnosis. That is in all four cases**, the correct diagnosis was concluded: SLI, SLI, Dyslexia, and Autism, respectively** (Fig. 2). Only in the case of dyslexia the maximum valued-final diagnosis, even though correct, differed by a relatively small amount from the second (which was SLI) for the reason that it is a severe case of dyslexia. As was originally hypothesized and is shown below, severe cases of dyslexia are often confused with SLI.

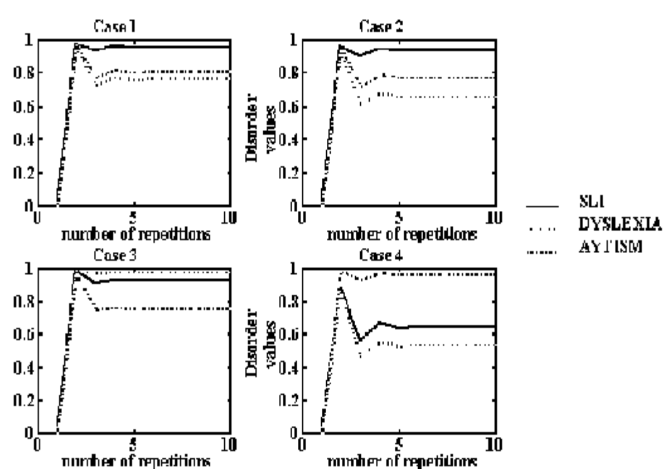

Fig. 2. Results of four clinical cases

V. Conclusions and Future Directions

The major goal of this research was to describe a new approach to the differential diagnosis of SLI from dyslexia and autism based on FCMs, since it had been found that SLI cases were confused either with severe cases of dyslexia or with mild cases of autism. To a high degree this goal was achieved since the reported trials fully verified the effectiveness of the model.

In this first phase of the research, published results from the literature were used as "experts" and these were combined using the Center of Area Method to design the Differential diagnosis FCM.

We hope that this method when completed will be complementary to other diagnostic methods and will be used to assist the speech pathologist. The reason FCMs were chosen as the design methodology is because they can be easily interpreted, since they clearly show the relationships between the different concepts and, at the same time, it is relatively easy to add or remove concepts, whenever necessary.

The ultimate goal of this effort is to develop a sufficient estimation model that can reliably assist the speech pathologist in cases of language and communication disorders that are difficult to discern. Even though this effort is in its initial stage, we hope that when successfully completed it will contribute to the field of differential diagnosis in speech and language pathology.

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