Online Decision Support for Speech & Language Pathology Assessment and Rehabilitation of Individuals with Multiple Needs

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Abstract— **Individuals with complex communication problems have multiple needs that frequently cannot be met by speech and language clinicians, but they may require the intervention and consultation of highly specialized professionals. The challenge to provide advance support and consultation to clinicians for such cases has led to the design and development of intelligent decision support tools. This work presents an online decision support system consisting of interactive modules used to perform advanced tasks for speech and language pathology assessment and differential diagnosis, which is also able to provide support for the rehabilitation of individuals. An example case is included.**

Keywords— **Intelligent Decision Support, Fuzzy Cognitive Maps, Assessment, Rehabilitation, Speech and Language Pathology.**

I. INTRODUCTION

Studies investigating the prevalence of speech and language impairments have shown results roughly ranging between 5 and 15% throughout the lifespan of individuals [1-3]. The impairments can be a wide range of developmental or acquired problems related to speech, language, voice, hearing, cognition, and/or swallowing. The continuous expanding need for specialized assessment, diagnosis and rehabilitation tools, in conjunction with the availability of new technologies, their wide spread use and the fact that internet is a communication means for almost anyone in the world, led to the development of online tools to support telehealth activities in speech-language pathology. Various applications of telehealth have been applied based on different types of technology, providing various services to patient and clinicians [4]. On the other hand speech-language pathologists have to evolve face-to-face clinical practices, which require novel, advance and effective telehealth procedures. The adoption of telehealth practices in speech pathology has to take into consideration the specific diagnostic /intervention and patient needs that involve many challenges and opportunities. Most conventional applications are based on hybrid methodologies to provide traditional Speech Language Pathology (SLP) services utilizing computers, web cameras, headsets with an embedded microphone, and requiring Internet [5][6].

The timely and accurate detection and diagnosis of speech/language pathology problems are essential so that appropriate intervention and rehabilitation is implemented. When the problems are multiple and moderate to severe, they are clinically significant due to the repercussions they may have in areas such as communication, cognition, psychopathology, social well-being, and health.

Specific attention is required in the case of a bilingual/multilingual patient, which increases the complexity, especially when the SLP clinician offering services to the patient is monolingual or cannot completely comprehend the language in which the patient and his/her direct environment is fluent.

Furthermore, the critical area of swallow/dysphagia, in which speech pathologists play a crucial role in evaluation and management, is related to survival, quality of life, but, also, a social matter. Recent studies propose telerehabilitation approaches to provide reliable swallow examinations proving that the outcome of diagnosis and decisions made either online or face to face were comparable [7-9].

The individuals that face serious problems in speech, language and dysphagia often have multiple needs, increasing the difficulty of precise detection and diagnosis of their problems. Such individuals require specialized clinical Speech/Language Pathology services. When these individuals find themselves in regions away from large urban clinical centers, they have decreased access to suitable specialists. Moreover, taking into consideration the difficulty and the high cost of continuing education in academic centers for the provision of specialized knowledge, it is becoming increasingly important that the locally available SLP may be supported by experts through telepractice.

This paper introduces and describes an underdevelopment pilot system, the WebDSLogo, aiming to support SLP clinicians. The system consists of the following online tools: a) the intelligent decision support for detection and differential diagnosis of speech/language pathology problems, b) the intelligent decision support for intervention and

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rehabilitation planning, and c) the telepractice specialized support service, as shown in Fig. 1.

This paper discusses the three components that make up the system, primarily focusing on the first two, which constitutes an integrated Decision Support System based on Fuzzy Cognitive Maps. An example case of a bilingual patient with a complex speech language problem is presented.

II. System Description

A. Online Intelligent Decision Support for Detection and Differential Diagnosis of Speech/Language Pathology Problems

This component is based on models that have been designed and developed based on Fuzzy Cognitive Map (FCM) that have used for differential diagnosis systems for various speech and language disorders [10-14]. Correct differential diagnosis is essential so that of appropriate interventions are planned as well as setting of rehabilitation goals and possible means of rehabilitation.

The development of methodologies and software tools for differential diagnosis is modelled to resemble the manner in which human reasoning leads to clinical decision making and so, it mostly relies on the human expert knowledge. Decision making approaches exploiting expert reasoning have been proposed and are accomplished using soft computing and computational intelligence approaches based on Fuzzy Cognitive Maps (FCMs) combined with Case Based Reasoning (CBR) and Genetic Algorithms (GM) [10-15].

The detection and differential diagnosis component supports speech/language problems characterized by high complexity that in general present increased difficulty in detection and differential diagnosis by SLPs with limited experience. Such problems are, for example. Specific Language Impairment [12] and the various Dysarthrias [11]. Increased complexity in detection and diagnosis is also reported when multilingualism and/or comorbidities exist.

Fig. 2 presents the modules and interactions of the Intelligent Decision Support System (IDSS). In the event of a patient presenting added complexity for the aforementioned reasons, the SLP asks for IDSS advice and he/she inserts the data for the patient onto the online system, as is shown in the left part of Fig. 2. These are the data related to the patient's history (personal, medical, educational, family, social/environmental), information on the linguistic history if the patient is bilingual/multilingual (e.g. age of acquisition of L2 [second language], order of L1 [mother/first language] and L2 acquisition, manner of acquisition of L2, similar or different cultural environment, level of using of L1 and L2, linguistic relationship of L1 and L2, time exposed to L1 and L2 environments). In addition to this the SLP also inserts the results of assessment tools and the measurements related to specific problems in various subareas: Phonology, articulation, voice, language abilities (comprehension and production) cognitive functions, motor functions, fluency, hearing and swallow. All this information is processed and integrated by the FCM Decision Support tool and an appropriate diagnosis/detection of problem is provided to the SLP as a second opinion.

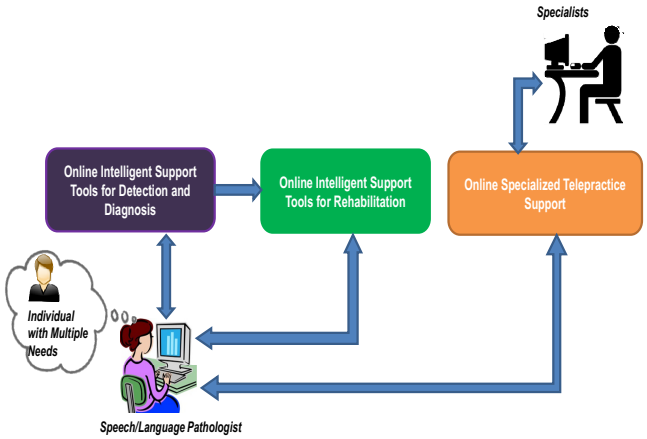

Fig. 1 Block Diagram of components of WebDSLogo

B. Online Intelligent Decision Support Tool for Intervention and Rehabilitation Planning

The online intelligent support tool is also used for planning the appropriate interventions, setting goals and methods for rehabilitation, as is shown on the right side of Fig. 2. Based on the diagnosis module presented on the left part, the intelligent intervention/rehabilitation tool, again using FCM techniques combined with Case Based Reasoning (CBR), proposes where the initial intervention must focus. This tool allows the running of scenarios [16] so that the SLP can investigate the potential effect of an improvement in a particular area where the individual presents a specific problem, e.g. phonology. Via the various scenarios a set of "smart" hierarchy of objectives for the intervention process is suggested and provided.

For example, through the FCM-DSS for Detection and Differential Diagnosis Tool a child patient is diagnosed with a complex language disorder, e.g. SLI. Then, the assessment tool provides the degree of severity of each attribute of the patient's verbal and nonverbal skills, as shown in Table 1.

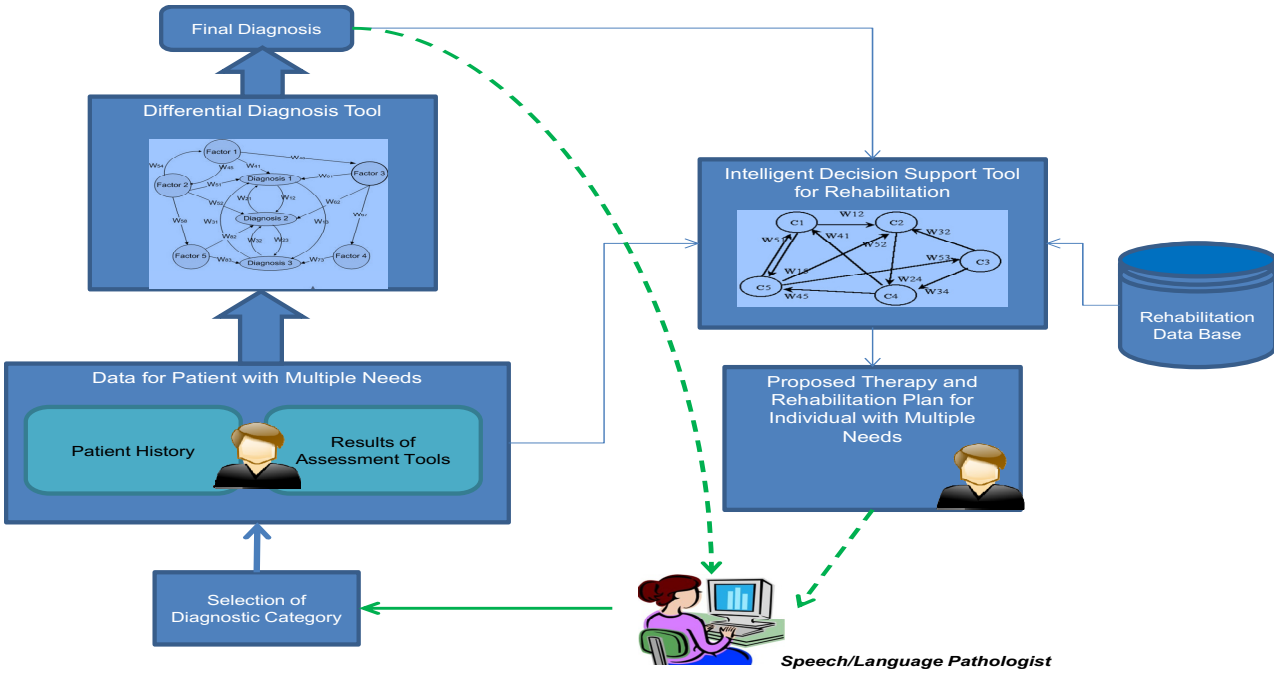

Fig. 2 Intelligent Decision Support Subsystems for diagnosis and intervention/rehabilitation planning

Table 1 Sample Patient Attributes

	Attributes	Degree of Severity
1.	Reduced Lexical Abilities	MEDIUM
2.	Problems in Syntax	HIGH
3.	Problems in Grammatical Morphology	HIGH
4.	Impaired or Limited Phonological Development	VERY HIGH
5.	Impaired Use of Pragmatics	HIGH
6.	Reading Difficulties	VERY HIGH
7.	Echolalia	-
8.	Reduced Ability of Verbal Language Comprehension	MEDIUM
9.	Difference between Verbal – Nonverbal IQ	HIGH
10.	Heredity	MEDIUM
11.	Impaired Sociability	LOW
12.	Impaired Mobility	MEDIUM
13.	Attention Distraction	-
14.	Reduced Arithmetic Ability	MEDIUM
15.	Limited Use of Symbolic Play	-

Given the deficiencies in many areas, and the fact that some of these are interrelated [10] how does an SLP decide on which areas to focus first? This is the time to ask for intervention of the online system support.

The online support subsystem for intervention and rehabilitation planning first runs scenarios based on the patient specific attributes and how each attribute change affects other attributes. The results of scenarios show which attribute changes will have the highest impact and therefore, guide the SLP in making priorities in the intervention planning and setting a rehabilitation course from the available tools.

C. Telepractice Support Subsystem

The online telepractice support (Fig. 3) functions simultaneously and operates in parallel with the other two components so advanced services of diagnosis and intervention can be provided by experts to SLPs that are subscribers to the service. In the pilot phase, this service will be available for cases of multilingualism, augmentative alternative communication technology and swallowing problems. These three areas have been selected since they constitute critical patient areas in Speech Language Pathology on one hand, and on the other hand, they usually presuppose particular specialization and/or advanced knowledge that inexperienced SLPs may not have.

Telecare has been shown to be effective in SLP practice [17]. It is pointed out that the all information will be handled with extremely confidentiality adopting the strict

specifications of personal data handling according to HIPAA (Health Insurance Portability & Accountability Act) as well as the secure Web site –Google drive protocols which support HIPAA compliance.

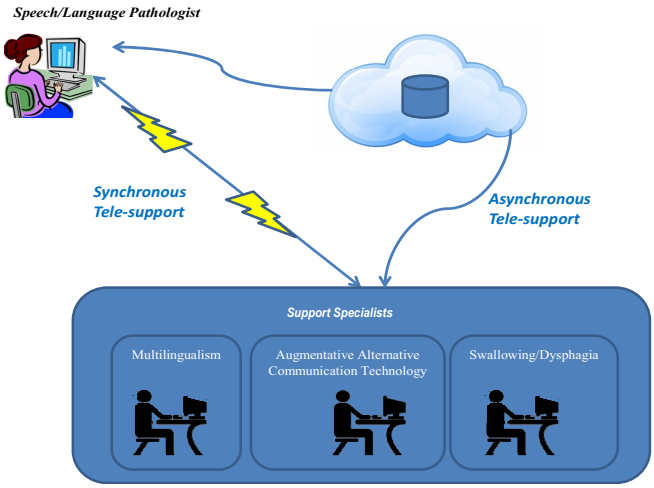

Fig. 3 Synchronous and Asynchronous Support through Telepractice

III. Case Example

An eight year old boy with language difficulties living in a bilingual Albanian/Greek environment is facing severe speech and language difficulties leading to significant academic problems. As a result he is referred to a SLP clinician in his town for assessment. The clinician is inexperienced in bilingual assessment and as a subscriber to the WebDSLogo service she has a teleconsultation with the specialist on bilingual issues (Telepractice Support Subsystem). The specialist guides the SLP clinician to use an Albanian-Greek interpreter and to select bilingual tools on the Online intelligent decision support for detection and differential diagnosis of speech/language pathology problems subsystem.

The child after being assessed in both languages (Greek and Albanian) leads to the results presented in Table I regarding language and non-language factors. The differential diagnosis system provides a Diagnosis of Specific Language Impairment (SLI) for the boy. There are many various accepted definitions of SLI that have evolved as more knowledge of this complex impairment is gained. According to Schwartz [18], SLI is a language impairment that affects the areas of comprehension, production, or both, without any neurological impairment, hearing impairment, general intellectual functioning, and autism diagnosis.

Due to many areas of language deficits that SLI covers, patients with SLI are an inhomogeneous clinical group, and therefore, it is important to have support in deciding the intervention course the SLP clinician will take. After the assessment and diagnosis results, the online intelligent subsystem runs various scenarios and it is found that what would likely provide the most gain would be the starting with intervention for phonological deficits in Greek language (language of instruction in school). The second priority will be grammatical morphology. Addressing these two is expected to have a positive effect towards other area deficits: reading difficulties, syntax, reduced ability of verbal language comprehension, and impaired sociability.

It is important to note the support tool for intervention and rehabilitation planning is not static. This means that as the patient progresses, the IDSS may provide to the SLP clinician an updated rehabilitation plan.

IV. Conclusions

The WebDSLogo is an innovative online service and it is expected to evolve into a particularly useful service, providing SLP clinicians the possibility to interact through a variety of computing devices (desktops, notebooks, tablets, smart phones etc.). It has relatively limited computing requirements from the accessing device since it relies heavily on cloud technology. It is based on the widely accepted soft computing decision support techniques and previously developed Fuzzy Cognitive Map Decision Support Tools and it aspires to be an essential support tool particularly for new SLP clinicians.

Conflict of Interest

The authors declare that they have no conflict of interest.

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