Toward a Framework for Augmenting Speech Language Rehabilitation Using Brain Computer Interface

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***Abstract*-To date, the application of brain computer interface (BCI) technology in rehabilitation represents one of the most challenging matters in the BCI filed. With the aim of developing a specific BCI system for speech language rehabilitation, this paper describes framework of a novel BCI system designed for clinical settings in speech language rehabilitation. It presents an overview of the technology involved, the applied context and the system design approach.**

I. Introduction

In recent years, Brain computer interfaces (BCIs) have been increasingly designed for assisting, enhancing or augmenting human mental activity or sensory-motor functions. BCIs were created to bring back lost sensory function, transmit sensory information to the brain or stimulate the brain by artificially generating electrical signals. Most BCI systems rely on the recordings of electrical activity along the scalp with electroencephalography (EEG) [1].

Over the past 15 years, the number of BCI research groups around the world, peer-reviewed journal articles, conference abstracts, and attendance at relevant conferences are indicators of the rapid growth of this field. With dozens of companies and research groups actively participating in the development of BCIs and related technologies, collaboration, a common terminology, and a clear roadmap have become important topics. Researcher and scientists across disciplines such as clinical neurology and neurosurgery, rehabilitation engineering, neurobiology, engineering, psychology, computer science, mathematics, and medical physicist, and biomedical engineering developed number of BCI systems target different applications.

The concept of BCIs was first triggered in 1924 by a German neurologist named Hans Berger. Dr. Berger was the first to record human brain activity by means of an electroencephalography (EEG). He analyzed EEG traces and identified oscillatory activity in the brain. He discovered the alpha wave (8–12 Hz) and called it Berger's wave. Berger's first recording device was very rudimentary. He used silver wires under the scalps of his patients. Later on, he used a more sophisticated measuring devices such as the Siemens double-coil recording galvanometer, which displayed electric voltages as small as one ten thousandth of a volt [2].

In 1946, an electrode device that can be controlled wirelessly by FM radio named Stimoceiver was invented by a neurosurgeon at Yale University named Dr. Jose Delgado. This device has been tested on the brain of a bull. By pressing different buttons on the machine Dr. Delgado was able to make the bull charge and change direction [3].

In 1964, another neurophysiologist named Dr. Grey Walter connected electrodes directly to the motor areas of a patient's brain and performed experiments to test stimulations that made the thumb of a subject move. Dr. Walter produced his own versions of Berger's machine with improved capabilities, which allowed it to detect a variety of brain wave types ranging from the high speed alpha waves to the slow delta waves observed during sleep [3, 4].

Research on BCI systems began in the 1970s at the University of California Los Angeles (UCLA) (Vidal, 1973; 1977). The author gave in his papers the expression "Brain Computer Interface" which is the term currently used in literature [5].

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The recent proliferation of non-invasive EEG-based BCI has been stated due to the portability, ease of use and relative safety compared to imaging techniques currently used in research facilities and hospitals. Advances in these techniques have facilitated the observation of activities or abnormalities within the human brain, without invasive neurosurgery. Moreover, BCI has been shown to be effective in providing insight in to brain activity of a patient in clinical context [6].

In this paper we propose a novel Brain Computer Interface BCI system designed for clinical settings in speech language rehabilitation where we use EEG-based BCI in the context of clinical settings for speech pathology.

II. BCI IN SPEECH LANGUAGE REHABILITATION

Speech sound disorder is a communication disorder characterized by persistent difficulties in producing speech sounds. It can involve phonological problems which are difficulties producing particular sounds or strings of sounds. Speech sound disorder is diagnosed and evaluated by a speech pathologist and treated by taking Speech-language pathology (SLP). Speech-language pathologists use SLP for improvement or cure of communication disorders, including speech, language, and swallowing disorders [7].

Although magnetic resonance imaging (MRI) is effective in diagnosing speech sound disorder and it produces very high-resolution images of brain activity, it is impractical to be used as part of a permanent or semi-permanent BCI. EEG-based BCI technologies can provide practitioners with points of reference for certain brain functions to a good degree of accuracy that can be comparable to MRI images MRI [8, 9].

Our proposed system aims to use EEG-based BCI in the context of clinical settings for speech pathology. It is designed to measure brain activity to provide a detailed recording of the temporal dynamics of brain activity related to language. This kind of study may provide important clues about the mechanisms that allow the speech language therapy processing to be more effective.

The system is designed to provide an intuitive interface for exploring rich datasets of brain visualizations, activity and quantitative measures. These insights aim to assist professionals in uncovering the mechanisms underlying information processing by applying electrophysiological, imaging, and computational approaches of conscious thoughts and intent, emotions, facial expressions and attention processes and its implications for speech and language disorders.

The design approach of the system examines novel engineering implementations of BCIs in the context of speech language pathology. Fig.1 illustrates the context diagram of our system. In line with this, the proposed work is directed along the following main lines:

1. Proposing framework of EEG system to solve the forward problem with speech language pathology.
2. Implementing novel BCI solutions for clinical settings in speech language rehabilitation (e.g. Case *A*, *B*, and *C*) and assessing its usability.
3. Validating the framework with a series of cases having speech sound disorders in speech language rehabilitation.

Our system planned to provide an observation and assessment tool which can recording and monitoring the brain activity and providing a required information that revealed if the language and speech evolved over time. There is potential for BCI application to enhance speech therapy session by providing insight and visualization of brain activity during the session and post session analysis. Using our system with series of cases having speech sound disorders in speech language rehabilitation such as the following:

2.1Agenesis of the corpus callosum

Agenesis of the corpus callosum (ACC or AgCC) is a rare birth defect in which there is a complete or partial absence of the corpus callosum. It occurs when the corpus callosum, the band of white matter connecting the two hemispheres in the brain, fails to develop normally. In this case, the child either has complete agenesis, meaning a complete absence of the corpus Callosum, or partial agenesis meaning that part of the corpus Callosum developed Speech therapy is one of the possible rehabilitative interventions. It helps to improve child's language and reading/writing skills; different techniques are used, according to the specific deficits and skills of the subject [10].

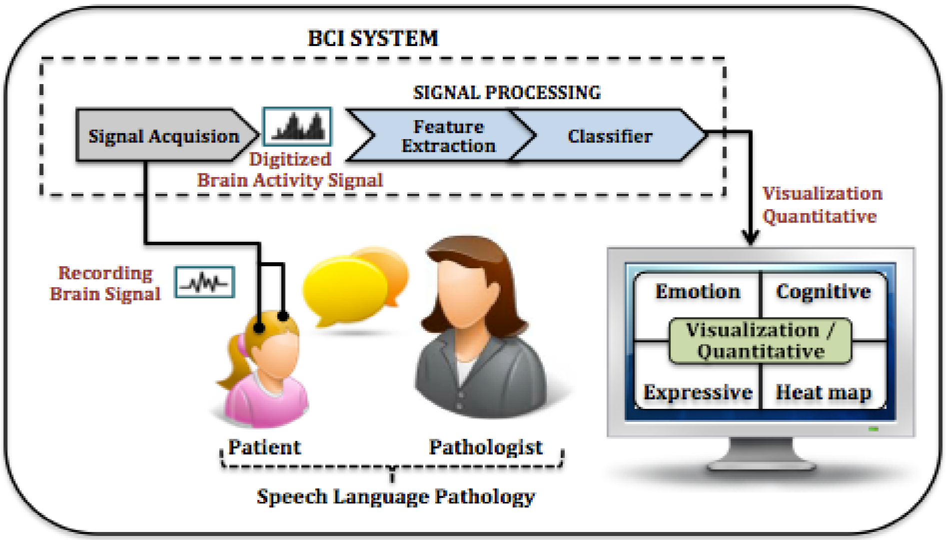

Figure 1: Context diagram for BCI system in speech language therapy session: during speech rehabilitation session, the patient is wearing EEG headset where the electrodes detect electrical signals from brain activity which are recorded on the machine. The brain signals are amplified and digitized. The machine then extracts relevant signal characteristics. This detailed recording of the temporal dynamics of brain activity related to language provide important clues about the mechanisms that allow the speech language therapy processing to be more effective.

2.2 Stuttering

Stuttering (or Disfluencies) is a speech disorder in which the flow of speech is disrupted by involuntary repetitions and prolongations of sounds, syllables, words or phrases as well as involuntary silent pauses or blocks in which the person who stutters is unable to produce sounds. SLPs work to help people who stutter lessen the impact or severity of disfluency when it occurs. The goal is not so much to eliminate disruptions in fluency-which many people find difficult to do-but to minimize their impact upon communication when they do occur. People may be taught to identify how they react to or cope with breaks in speech fluency. They learn other reactions that will lead to fluent speech and effective communication. As people become better at managing fluency in therapy, they practice the newly learned skills in real-life situations [11].

2.3Lisp

Lisps are speech disorders in which individuals are unable to produce a specific speech sound or sounds. Many children lisp naturally as they learn to speak and produce specific sounds and it is common for children to grow out of a slight lisp. Lisp assessments are generally carried out by speech and language pathologists. During an assessment the individual's mouth may be examined and the individual's language and speech abilities will be observed and investigated. It may be that children who have trouble producing certain sounds actually have another speech disorder that may be diagnosed at this time [12].

CONCLUSION

The diagnosis and assessment of patients with Speech sound disorder present challenges for speech language pathologist. There is potential for BCI application to enhance speech therapy session by providing insight and visualization of brain activity during the session and post session analysis.

REFERENCES

[1] Wolpaw, J. R., Birbaumer, N., McFarland, D. J., Pfurtscheller, G., & Vaughan, T. M. (2002). Brain–computer interfaces for communication and control. Clinical neurophysiology, 113(6), 767-791.

[2] Bladin, P. F. (2006). W. Grey Walter, pioneer in the electroencephalogram, robotics, cybernetics, artificial intelligence. Journal of clinical neuroscience, 13(2), 170-177.

[3] Popescu, F., Blankertz, B., & Müller, K. R. (2008). Computational challenges for noninvasive brain computer interfaces. IEEE Intelligent Systems, 23(3), 78-79.

[4] Anupama, H., Cauvery, N., & Lingaraju, G. (2012). Brain computer interface and its types-a study. Int. J. Adv. Eng. Technol (IJAET), 3(2), 739-745.

[5] Al-ani, T., & Trad, D. (2010). Signal Processing and Classification Approaches for Brain-computer Interface. Intelligent and Biosensors, Edited by Vernon S. Somerset, 25-66.

[6] Brumberg, J. S., Nieto-Castanon, A., Kennedy, P. R., & Guenther, F. H. (2010). Brain–computer interfaces for speech communication. Speech communication, 52(4), 367-379.

[7] American Speech-Language-Hearing Association. (1993). Definitions of communication disorders and variations.

[8] Andreasen, N. C. (1979). Thought, language, and communication disorders: I. Clinical assessment, definition of terms, and evaluation of their reliability. Archives of general Psychiatry, 36(12), 1315-1321.

[9] Caramazza, A., Basili, A. G., Koller, J. J., & Berndt, R. S. (1981). An investigation of repetition and language processing in a case of conduction aphasia. Brain and language, 14(2), 235-271.

[10] KUMAR, Y. KIRAN. "Diagnosis of agenesis of the corpus callosum problem by using the fusion technique." Int J Res Rev Appl Sci 1.2 (2009): 87-95.

[11] Chang, S-E., Kenney, MK., Loucks, T., & Ludlow, C. (2009). Brain activation abnormalities during speech and non-speech in stuttering speakers. NeuroImage, 46(1), 201-212.

[12] Dodd, Barbara. Differential diagnosis and treatment of children with speech disorder. John Wiley & Sons, 2013.