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Measuring and monitoring emotional changes in children who stutter

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ABSTRACT

The assessment of clients with speech disorders presents challenges for speech-language pathologists. For example, having a reliable way of measuring the severity of the case, determining which remedial program is aligned with a patient's needs, and measuring of treatment processes. There is potential for brain-computer interface (BCI) applications to enhance speech therapy sessions by providing objective insights and real-time visualization of brain activity during the sessions. This paper presents a study on emotional state detection during speech pathology. The goal of this study is to investigate affective–motivational brain responses to stimuli in children who stutter. To this end, we conducted an experiment that involved recording frontal electroencephalography (EEG) activity from fifteen children with stuttering whilst they looked at visual stimuli. The contribution of our study is to provide a comprehensive background and a framework for emotional state detection experiments as assessment and monitoring tool in speech pathology. It mainly discusses the feasibility and potential benefits of applying EEG-based emotion detection in speech-language therapy contexts of use. The findings of our research indicate that emotional recognition using non-invasive EEG-based BCI system is sufficient to differentiate between affective states of individuals in treatment contexts.

1. Introduction

Emotion is an affective state encouraged by a specific event, object, or surrounding. It is an integral component of many aspects of an individual's life such as learning, decision making, motivational priorities, and communication. The link between motivation and emotion has been described by physiology theories of emotion [1–3]. For example, emotions like frustration and boredom can lower motivation and, thus, affect the ability to learn. On the other hand, excitement and meditation can increase motivation, which increases the interest to learn and practice [3].

Emotion measurement and assessment methods can be subjective and/or objective affective measures. Subjective measures use different self-report instruments such as questionnaires, adjective checklists, and pictorial tools to represent any set of emotions, and can be used to measure mixed emotions. However, self-report techniques do not provide objective measurements, where they measure only conscious emotions and they cannot capture the real-time dynamics of the experience. Objective measures, on the other hand, can be obtained without the user's assistance. They use physiological cues derived from the physiology theories of emotion. Instruments that measure blood pressure responses, skin responses, pupillary responses, brain waves, and heart responses are all used as objective measures methods. Moreover, hybrid methods combining both subjective and objective methods have been used to increase the accuracy and reliability of emotional states [4–6].

Accurate diagnosis and assessment of clients with speech disorders often present challenges for Speech-Language Pathologists (SLP); since subjective responses from clients during therapy sessions are influenced by mental affective states. Inferences drawn from objective techniques are a promising approach to address the variation of subjective assessments or variability in assessments across therapies [5]. BCI systems provide objective measures for the clinical, remedial and rehabilitation contexts. They are designed to measure brain activity and provide a detailed recording of brain dynamics related to communication disorders [6]. Thus, we were motivated by the belief or hypothesis that there is potential for this EEG-based BCI application to enhance speech therapy sessions by providing insights and visualizations of the affective state of the brain during the therapy session.

In order to craft an approach that will effectively augment the

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speech-language pathology diagnosis using objective measures of brain activities, our BCI system (Emo-in-Speech) is designed to integrate BCIs in clinical settings for assessing and diagnosing speech-language pathologies. Using wireless EEG headsets to extract brain signals, preprocessing, feature extraction/selection and machine learning classification, our approach develops a novel non-invasive passive BCI system that aids speech-language pathologists in objectively assessing and diagnosing speech disorders.

Emo-in-Speech is designed to be used in clinical settings with different use cases in speech and language pathology. One use case involves using the BCI system in a series of test cases with people who stutter (PWS), in which the flow of speech is interrupted by repetitions (st-st-stuttering), prolonging sounds and/or syllables (ssssstuttering), and abnormal stoppages (ST—stuttering) or blockades of sounds and/or syllables [10]. We focus specifically on children who stutter (CWS). Within this context, there are many theories about why children stutter and the factors behind it. Also, the emotional state of the client changes in different ways (e.g. visible frustration when the client is trying to communicate, or exhibiting signs of being tense during speech). Furthermore, avoidance behaviors such as fear and anxiety may happen with the CWS [7]. In our experiment, data were collected from 15 children who stutter and analyzed to identify what affective states were present during a speech therapy session. Visual stimuli were presented to evoke specific targeted emotional states such as excitement, meditation, boredom, and frustration. Power spectral density and frontal asymmetry features were extracted using frequency domain analysis methods. Deep neural network classifier was used to distinguish between the target affective states. In addition, participants' subjective ratings and speech pathologists' observation rating were obtained.

The contributions of this study include: (i) A framework that categorizes various ways in which BCI can improve and augment speech and language pathology. This framework suggests a methodology for augmenting speech and language therapy with BCI systems. The idea of this methodology is to start with real-time feedback of affective states and subsequently combine the objective metrics with the subjective assessments of speech and language progress metrics. (ii) Novel settings for BCI feature extraction and classification for emotion detection using EEG-based technologies that are aligned with speech therapy requirements. Specifically, we introduced new techniques for embedding BCI in clinical settings by augmenting the subjective assessments with real-time feeds of affective states of clients. Therefore, Emo-in-Speech system can be considered as a novel therapeutic\assessment tool for emotion detection in CWS by using an EEG headset to record the brain signals and detect the subjects' affective state during a therapy session.

This paper is organized as follows: In Section 2, a brief stuttering background is presented. Section 3 discusses some related work. In Section 4, we describe the BCI system's analysis and design process. Section 5 describes the materials and methods used to conduct our experiment. Experimental results and discussion are described in Section 5. Finally, we conclude in Section 6 with a summary of contributions and future work.

2. Stuttering background

Stuttering is a complex communication disorder having affective, behavioural, and cognitive components [8], besides psychological and social effects [1,9]. Stuttering is a multi-factorial communication disorder interrupting the forward flow production of speech by repetitions, prolongations, abnormal stoppages, or blockades of sounds and syllables [10]. These interruptions could be a major factor contributing to difficulties facing PWS.

However, the definition of stuttering continues to regularly develop, in line with both scientists' theories and abilities to better determine the nature of the disorder and to measure its various aspects [11]. In Ref. [12], Wingate (1964) suggests that stuttering may occur owing to the fact that the peripheral speech mechanism is uncoordinated. However, most scientists who define stuttering consider at least three verbal behaviour descriptions, all of which strongly connect with the disorder: repetitions, prolongations, and cessations.

PWS face difficulty in establishing and maintaining fluent speech, particularly when presented with cognitively demanding tasks [2]. Although exogenous factors are certainly of importance to our understanding of the association of emotion and childhood stuttering, others have recently begun to consider whether CWS more actively process exogenous or environmental emotional stress and whether such processing (e.g., temperamental vulnerability) may be associated with their stuttering [13]. One percent of all adults suffer from developmental stuttering, which is defined as stuttering that develops during childhood without obvious neurological origin [14]. Stuttering has negative emotional, psychological and social consequences in children. Quality of life is reduced when stuttering persists [14].

3. Related work

Speech and language therapies are designed to assess, treat and follow up the person who suffers from communication disorders. The evaluation procedure for an individual with speech-language disorder requires a wide variety of diagnostic tools, processes and a coterie of professionals such as neurologists, psychologists, speech-language therapists and other medical experts [9]. Within the last two decades, a variety of research has studied (and are still studying) a potential benefit of information technology in speech therapy sessions [15–19]. In Ref. [20], Cotton (2008) investigated the effectiveness of information technology when integrated into speech therapy sessions with children with disabilities. Cotton observed children with learning disabilities, hearing impairment, speech-language disorders, and emotionally disturbed children and found that they benefited from information technology integration to augment therapy sessions. He proved that the use of computers can greatly improve achievement in learning and therapy.

Currently, it is a widely held notion that computer-based speech therapy systems (CBST) and tools are essential in the speech-language evaluation. These CBST systems are either rehabilitative or monitoring systems. Rehabilitative computer software systems consist of a series of thematic exercises and interactive didactic games which transforms audio-visual classical materials into a wide range of electronic clinical material from which inferences can be drawn [19]. Monitoring CBST systems focus on measurement and assessment. This system gives an SLP a handle to observe and interpret graphical inflection of words, natural and distorted vocalization of sentences, changes in speech rhythm and fluency, continuous phonation, co-articulation of phonemes, respectively. Some CBST systems perform complex evaluations and diagnosis of clients with speech disorders and provide reasonable decisions about the speech status. On the other hand, other CBST systems offer just visual displays and helpful information. This later CBST system leaves the interpretation of data to the speech-language pathologist [19].

Nevertheless, one reported drawback of CBST is the inability of these systems to detect how the emotional state of human subjects might lead to inadequate behavioral responses [18]. Moreover, many researchers have reported that the emotional state of a subject plays a key role in both classical speech therapy and CBST. This is particularly crucial if subjects are children. If the emotional state of a subject in neither taken into account nor explained, a half-blind result will be the ultimate output. This affects the validity of the entire assessment process [18,19]. Therefore, it is important to automatically detect the emotional state of participants during therapy sessions. Emotion recognition could be done from the text, speech, facial expression, and physiological responses such as pulse, skin conductivity/temperature, and EEG. For example, in Ref. [18], researchers have developed emotion recognition as an extension of their CBST system. They detect emotional states by using speech flow as an information channel.

Built on finding from our systematic review in Ref. [6], There is an