**Using Brain Computer Interface For Communication In Non-Speaking Autistic (NSA) Population**

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**Background**

*Non-speaking autistic population*

Language is main tool to socialize and express our thoughts while this may not be similar in autistic population as language problem is main specifier for autism diagnosis (*Diagnostic and Statistical Manual of Mental Disorders*, 2013). Even around 25% to 35% of autistic population are not able to speak (Baghdadli et al., 2018; Rose et al., 2016; Wodka et al., 2013).

“Non-speaking doesn't mean non-thinking,” mentioned by a non-speaking poet (Grodin & McDonough, 2021). Autistic population should be supported to communicate their desires, thoughts and feelings. They also need a sense of belonging to society and social inclusion, but feeling isolated could affect their mental health and trigger suicidal ideas (Mitchell et al., 2021) and a higher rate of self-injury behaviors in non-speaking autistic population (Richards et al., 2012).however, a recent review reports that there is few studies for teaching verbal communication to non-speaking autistic population (Koegel et al., 2020).

*Disadvantage of current AAC*

A meta-analysis by comparing different types of AAC applications (e.g., Picture Exchange (PE), Picture Exchange Communication Systems (PECS), Speech Generating Devices (SGD)), reported that autistic population prefer using technology for speaking and communicating (Aydin & Diken, 2020). However, current AAC for non-speaking autistic population are not always equitably accessible in term of learnability, availability, affordability (Baxter et al., 2012; Elsahar et al., 2019; Moorcroft et al., 2019) and also need training in theoretical and practical experiences for teachers (Baxter et al., 2012; Moorcroft et al., 2019). Further, motor skills problems in autistic population can limit the use of some AAC application, such as manual sign apps (Aydin & Diken, 2020).

*BCI and its application*

There have been growing interests in using brain-interface technology (BCI) based on electroencephalogram (EEG) for a variety of conditions such as autism, ageing, physical disabilities (Hossain & Doulah, 2020).

The classic applications of using BCI is to detect the pattern of task imagery. Researchers report that motor imagery signals can be detected using EEG signals to help people with disabilities including autism, physical disabilities, ageing adults (Hossain & Doulah, 2020) and a variety of outcomes, including rehabilitation (e.g., therapies to regain physical abilities), diagnosis (e.g., autism, coma), recreation (e.g., gaming, art), assistive technology (e.g., communication, mobility) (Zander et al., 2010).

*Benefit of BCI*

EEG based BCI can help interventional and diagnostic possibilities… BCI is easy to use and does not need physical or verbal respond…

*BCI application in autism*

BCI for autism population has been used to detect sound/music preferences for autistic children (Cibrian et al., 2018) and the music aligned with autistic child’s mood for using in therapy (Niu et al., 2022), to explore mental stress during arithmetic tasks (Sundaresan A et al., 2021), anxiety state (Penchina et al., 2020), emotional state (distress vs non-distress), engagement level in task, mental workload (Eldeeb et al., 2021; Fan et al., 2018; Val-Calvo et al., 2017), interest to tasks in autistic children by monitoring the level of attention (Ravindranathan et al., 2020), to classify joint attention (de Arancibia et al., 2020; M. G. Ezabadi & M. H. Moradi, 2021; Simoes et al., 2020), neurofeedback training to improve social skills (Teo et al., 2021), through a BCI video game to improve attention (Mercado et al., 2021), and to teach driving to autistic adolescents (Fan et al., 2018), improve joint social attention (Amaral et al., 2017; Bittencourt-Villalpando & Maurits, 2020; Castelo-Branco, 2019) and to teach interpreting emotional facial expressions and social skills (White et al., 2016). Overall, EEG-based BCI with an accurate algorithm using machine learning (ML) could be influential in leading us to understand and help autism (M. G. Ezabadi & M. H. Moradi, 2021). There is a variety of signal sources for using AAC including touch/breath activated, imaging, mechanical methods, and BCI methods for non-autistic population (Elsahar et al., 2019), however there is no evidence of using BCI for speech in NSAP or generally, to AAC devices for autism.

**Aim**

BCI can benefit autistic population including NSAP by facilitating communication between their internal world and external world, their peers, family members, friends, non-autistic population and via social media. It does not need training or using motor skills (Elsahar et al., 2019). Based on our literature review exploring autism and BCI keywords in multiple databases, we did not find any study working on verbal communication in NSAP. Only a recent review refers to the point of lack of BCI study for assisting speech in NSAP (Williams & Gilbert, 2020), however, there are studies have explored verbal communication in other population (J. van Kokswijk & M. Van Hulle, 2010; Khachatryan et al., 2015, 2016, 2018; Mora-Cortes et al., 2014; Wittevrongel et al., 2018) that could be enlightening for our journey by applying the principles for autism population. Therefore, our aim is to use BCI for NSAP to translate their brain signals to words and pictures, displayed on phone/computer monitor.

*Need for further research [to explain multi-department team]*

The use of BCI, which requires a interdisciplinary cooperation of researchers (with expertise in rehabilitation science, psychologist, clinicians, engineering, machine learning, signal processing) to improve its applicability and convenience as well as benefits for clients (Niu et al., 2022).

**Method**

*Participants*. We will recruit participants (N= , age = ) from autism communities and organizations. They may speak minimally or not be able to speak. For minimally speaking participants, word counts will be reported based on the guideline in a systematic review paper (Koegel et al., 2020).

*Study Protocol*. Participants receive multimodal auditory and visual stimulus simultaneously including a picture and playing the name of the picture via a rhythmic-expressed/articulated/pronounced audio. The preferences of autistic population in terms of pictorial and musical/rhythmic features are considered... Also, in language processing features, evidence recently state rhythmic feature in communication underlies inference, generation and prediction of morphemes, words and phrases without prior knowledge (Meyer et al., 2020). The studies report “Rhythmic auditory cueing” can be effective for rehabilitation practices (Hardy & LaGasse, 2013), referring to neurologic music therapy (Thaut, 2007) that uses rhythmic activities to improve cognitive, sensory and motor functions (Hardy & LaGasse, 2013) …. a rhythmic element in stimuli can improve the accuracy of pattern recognition of signals …...

*Stimulus Feedback*.

*EEG acquisition*. We will use a mobile/portable EEG-based BCI to extract brain signals of non-speaking autistic participants when they are looking at pictures and hearing the name of the picture (multimodal approach). Then, the algorithm will be classified using ML techniques.

There are difficulties in training BCI for Autistic individuals (Kashihara, 2014). However, to control errors, there are a variety of approaches. For instance, a combination of Event Related Desynchronization (ERD)-based active BCI with gaze control, a hybrid BCI, may resolve the midas touch problem. And then, a passive BCI based on human error processing, bringing new forms of automated adaptation in BCI (Zander et al., 2010). Further, using multimodal components (e.g., audio-visual) improves the accuracy in using BCI for speech compared to use one modal (Brumberg et al., 2018).

*BCI-P300 Paradigm*

“The stimulus presentation paradigm with the BCI-P300 is in many ways suitable for studies where the detection of EEG reaction characteristics for particular classes of stimuli and the predictive capacity of the EEG in terms of assigning one or another stimulus to particular classes are important.” (Ganin et al., 2018).

*Measures*

Vineland Adaptive Behavior Scales (VABS)-Third edition (Cicchetti et al., 2013; Sparrow, 2011). This standardized semi-structured interview measures personal and social skills, receptive and expressive communication utterance and motor skills for all ages.

**Data analytic plan**

We use Deep Neural Networks (DNNs) for BCI data classification was adapted for language modelling (Kostas et al., 2021) to generate automatic speech recognition. A study (Kostas et al., 2021) refers to a wav2vec 2.0 framework (Baevski et al., 2020), used for a self-supervised speech recognition through “encoding speech audio via a multi-layer convolutional neural network and then masking spans of the resulting latent speech representations, these then can be fed to a transformer network to build representations capturing information from the entire sequence” (Kostas et al., 2021).

*Performance analysis*.

*EEG analysis*.

*Offline and online preprocessing*.

*BCI Decoder*.

*Performance Analysis*.

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