**A Feasibility Study: Application Of Brain-Computer Interface In Augmentative And Alternative Communication For Non-Speaking Autistic Population**

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**Background**

*Non-speaking autistic population*

The main specifier for autism diagnosis is communication problems 1. Around 25% to 35% of the autistic population are not able to speak 2–4, however, “Non-Speaking doesn't mean Non-Thinking,” as mentioned in a poem by a non-speaking child 5. The autistic population should be supported to communicate their desires, thoughts, and feelings. However, there are few studies for teaching verbal communication to the non-speaking autistic population based on a recent review 6. Autistic people need a sense of belonging to society and social inclusion, but feeling isolated could affect their mental health and trigger a variety of emotional problems such as suicidal ideas 7 and self-injury behaviors, especially in the non-speaking autistic population 8.

*AAC*

Augmented and Alternative Communication (AAC) is a substitute option for the non-speaking autistic population to communicate. 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 the autistic population prefers using technology-based AAC for communicating 9. Further, SGD and PECS were rated effective in helping autistic people to have basic communication 9. Though these devices are not always equitably accessible in terms of learnability 10–12. The use of AAC devices needs training for autistic individuals and extensive theoretical and practical experiences for teachers 10,12.

Further, there are limitations in the use of AAC applications in those who have multiple disabilities and/or motor skills problems 9. Adding eye-tracking module to AAC also does not resolve the physical and communication barriers. For instance, researchers taught eye gaze to participants with Rett syndrome (previously categorized under the autism spectrum) as a selection for AAC. However, they reported that it was challenging because the participant did not have the motor movements to make other types of communication selections; and also challenging to disentangle what was the participant having difficulty understanding what they were communicating vs. what was having a hard time using the eye gaze device (so holding the gaze long enough to satisfy the dwell time) 13.

Considering the potential of AAC, we aim to expand its modalities for the autistic population by adding brain-interface technology (BCI). BCI can translate brain signals into identifiable words, or/and audiovisual output. BCI does not need training for either the users or caregivers. Further, by direct translation of the brain signals to audio/visual output (or in other words—by direct, natural, neural control of assistive technologies 14), the limitations of traditional AAC devices such as the misattribution of intents of the participants 13, can be resolved 14.

*BCI and its application*

There has been growing interest in using BCI based on electroencephalogram (EEG) for a variety of conditions such as autism, aging, and physical disabilities 15. The classic application 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, aging adults 15, 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) 16. BCI is easy to use and does not need training or using motor skills 11. Researchers state that EEG-based BCI with an accurate algorithm using machine learning (ML) could be influential in leading us to understand autism better 17.

*BCI application in autism*

Based on our brief literature review (from 2015 to 2022), BCI studies in the autism field can be classified into two main classes, i.e., identification and rehabilitation purposes. For example, BCI can identify sound/music preferences 18 and the music aligned with autistic children’s mood for therapy purposes 19, mental stress during arithmetic tasks 20, anxiety state 21, emotional state (distress vs non-distress), engagement level in a task, and mental workload 22–24, interest to tasks by monitoring the level of attention of autistic children 25, and social joint attention of autistic children 17,26,27. Rehabilitation-purposed BCIs for autism improve attention using a BCI-based video game 28, social skills using neurofeedback training 29, social joint attention 30–32, learning to interpret emotional facial expressions and social skills 33 and learning driving to autistic adolescents 23.

Current studies indicate that using BCI can be useful and feasible in the autism population to improve social skills and teach some tasks. However, there is no evidence of using BCI in communication or AAC for autism, consistent with the result of a recent review 34, and less work on pictorial AAC-BCI, which is more suitable for those who have limited literacy skills or those developing literacy 35 There are a variety of AAC-BCI in other populations 11,35–41 and established literature on AAC for those with cognitive and literacy problems35 that could be enlightening for our journey by adapting their principles and knowledge 35 to the autism population.

An EEG-based BCI is popular because it is non-invasive, safe, and more affordable compared to other devices and can facilitate accurate communication 14. *We aim to explore the use of an EEG-based BCI in AAC for the Non-Speaking Autistic population. We will study the feasibility of AAC+BCI in autistic individuals* who already use AAC successfully. Because they will not have difficulty with the motor responses and we can explore their comprehension across different modalities. *Further, we can compare the results of using BCI for AAC conditions with AAC without BCI.*

**Aim**

We aim to explore the application of BCI-AAC for autistic individuals in this proposed project. We aim to detect brain signal patterns using an EEG-based BCI in response to visual stimuli in the NSA population. Further, we aim to translate the recognized brain signal patterns from participants into audio presented in a phone app or computer. In the future, we aim to use BCI-AAC for those with significant disabilities and multiple disabilities (e.g., cognitive and physical disabilities).

**Method**

*Participants*. We will recruit participants (N= 15, age = 12 -40) from autism communities and organizations. They may speak minimally or not be able to speak. For minimally speaking participants, word counts will be assessed based on the guideline to define the level of speech 6. Inclusion criteria: participants should have a formal diagnosis of either autism or unspecified neurodevelopmental disability. Those with mild intellectual disabilities (ID) and without ID will be included. Further, participants should already use AAC. Exclusion criteria: participants who do not have the mentioned formal diagnoses, those with epilepsy history, those who have metallic cranial implants, and those with moderate or most significant intellectual disabilities will be excluded.

*Study Protocol*.

…

*EEG acquisition*.

*SSVEP Paradigm*. Studies indicate that this paradigm can be applied to a variety of populations, it does not need an overt response and can be conducted in a short time 42.

SSVEP will be evaluated based on ITR, assessed in bits per minute, and the accuracy of classification 43,44.

*Measures*

Vineland Adaptive Behavior Scales (VABS)-Third edition 45,46. This standardized semi-structured interview measures personal and social skills, receptive and expressive communication utterances, and motor skills for all ages.

Checking the understanding of the participants from each card... Each participant before the experiment will be asked to point at a card by telling the name of the picture on the card. This is to be sure that participants recognize what is shown on each card.

**Data analytic plan**

Recently, Deep Neural Networks (DNNs) for BCI data classification were adapted for language modeling 47 to generate automatic speech recognition47, using a wav2vec 2.0 framework 48, for 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” 47. We will use this approach to recognize brain signal patterns in reacting to audio-visual stimuli.

*Performance analysis*.

*EEG analysis*.

*Preprocessing*.

*BCI Decoder*.

The algorithm will be detected and classified using Deep Neural Networks (DNNs) techniques.

*Performance Analysis*.

Other requirements for application

*Which MIDB cores will be utilized to facilitate the research? (½ page)*

Considering the interdisciplinary nature of proposed project, we will collaborate across multiple departments/centers at MIDB as follows. Jessica Simacek, with extensive knowledge in autism and interdisciplinary research areas, the director of “*TeleOutreach Core (TOC)*” core and Jed Elison, with extensive experiences in interdisciplinary area in brain imaging and autism, the director of “*The Measurement and Human Phenotyping Core (MHPC)*” contribute to this project. TOC and MHPC will facilitate this project by providing the related knowledge and skills on autism, brain science as well as equipment (e.g., EEG), data acquisition (EEG data) and testing rooms (to conduct survey and experiments).

*Applications should provide a statement of how the work fits the mission of the MIDB (½ page) and confirm whether the study will take place at MIDB.*

*Updated CV*

*Letter of endorsement from proposed mentor(s)-1 page.*

*Detailed budget and budget justification with timeline*

*Please include information regarding the project’s IRB/IACUC status.*

The IRB application for the proposed project will be started once the proposal will be granted.

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*[to explain multi-department team]*

The use of BCI, which requires an 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 19.