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

**Background**

One of the important diagnostic criteria 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. “All people have a basic human right to have the resources and supports necessary to communicate their desires, thoughts, & feelings 6. However, there are few studies for teaching specifically verbal communication to the non-speaking autistic population based on a recent review 7. 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 8 and self-injury behaviors, especially in the non-speaking autistic population 9.

Augmented and Alternative Communication (AAC) is a substitute option for the non-speaking autistic population to communicate. A meta-analysis 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 10. Further, SGD and PECS were rated as effective in helping autistic people to have basic communication 10. These applications are not always equitably accessible in terms of learnability 11–13. To use of AAC devices effectively requires training for autistic individuals and extensive theoretical and practical experiences for teachers 11,13.

Further, there are limitations in the use of AAC applications for those who have multiple disabilities and/or motor skills problems 10,14,15.

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. The AAC-BCI has been suggested as a beneficial approach for those with significant or multiple disabilities such as Rett syndrome 15 as it has short training times and a simple control task. Further, by direct translation of the brain signals to audio/visual output (or in other words—by direct, natural, neural control of assistive technologies 17), the limitations of traditional AAC devices such as the misattribution of motor movement of the participants 16, can be resolved 17.

There has been growing interest in using electroencephalogram (EEG)- based BCI for a variety of conditions, e.g., autism, aging, and physical disabilities 18 and a variety of outcomes, e.g., rehabilitation (e.g., therapies to regain physical abilities), diagnosis (e.g., coma), recreation (e.g., gaming, art), assistive technology (e.g., communication, mobility) 19. Researchers state that EEG-based BCI with an accurate algorithm using machine learning (ML) could be influential in leading us to understand and help people with autism better 20. Further, BCI is easy to use and does not need training or using motor skills on part of the participants 12. The evidence indicates using a steady-state visually evoked potentials (SSVEP) paradigm in BCI can help an efficient, accurate communication 21. SSVEP can be applied to a variety of populations and conducted in a short time, without needing an overt response, with a high signal-to-noise ratio (SNR) and high information transfer rate (ITR) 21,22.

Based on our brief literature review (from 2015 to 2022), BCI studies in the autism field can be classified into two main categories, i.e., identification and training purposes. For example, BCI can identify sound/music preferences 23 and the music aligned with autistic children’s mood for therapy purposes 24, mental stress during arithmetic tasks 25, anxiety state 26, emotional state (distress vs non-distress), engagement level in a task, and mental workload 27–29, interest to tasks by monitoring the level of attention of autistic children 30, and social joint attention of autistic children 20,31,32. Training-purposed BCIs for those with autism improve attention using a BCI-based video game 33, social skills using neurofeedback training 34, social joint attention 35–37, learning to interpret emotional facial expressions and social skills 38 and learning to drive for autistic adolescents 28.

Current studies indicate that using BCI can be useful and feasible in the autism population to improve social skills and teach specific tasks. However, there is no evidence of using BCI to expand AAC or improve communication for autistic people, consistent with the result of a recent review 39. There are a variety of AAC-BCI used with other populations 12,40–46 and established literature on AAC for those with cognitive and literacy problems45 that could be enlightening for our project by adapting their principles and knowledge 45 to the autistic population.

An EEG-based BCI is popular to use because it is a non-invasive, safe, and more affordable technique compared to other devices and can facilitate accurate communication 17. *We aim to explore the use of an EEG-based BCI in AAC (12 pictures in this study) for Non-Speaking Autistic population.* We will study the feasibility of BCI+AAC 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 with pictorial-AAC conditions” and “AAC without BCI condition”.  Further, if the results of this project will be promising, the possibility of BCI-AAC will be considered for those with significant disabilities and multiple disabilities (e.g., autism with significant intellectual disabilities, those with intellectual and physical disabilities, such as Rett syndrome).

**Aim**

We aim to explore the application of BCI-AAC for autistic individuals. We aim to detect brain signal patterns using an SSVEP-based BCI in response to visual stimuli (12 pictures) in the non-speaking autistic population. Further, we aim to translate the recognized brain signal patterns from participants into audio presented in a phone app or computer.

**Method**

*Participants*. We will recruit participants (N= 15, age = 12 -18) 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 7. 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. The participants will have normal vision or corrected normal vision. Photosensitivity assessment will be checked before enrolment in the study with visual light sensitivity questionnaire-8 (VLSQ-8). 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 ID will be excluded.

*Measures.* Vineland Adaptive Behavior Scales (VABS)-Third edition 47,48. This standardized semi-structured interview measures personal and social skills, receptive and expressive communication utterances, and motor skills for all ages. Further, before each conduction, the comprehension of participants from each experiment picture will be checked by asking them to point out each picture by telling the name of the picture. *Social Communication Questionnaire (SCQ)*49 will be administered for autism scores and Literacy skills (reading ability) will be assessed via   *Early Reading Screening Instrument* 50 which includes knowledge of letters, the concept of words, and word recognition to be sure that participants have some degree of literacy.

*Study Protocol*. *Task design and BCI modality:* AAC combined with SSVEP-based BCI will be chosen because the SSVEP paradigm can be applied to a variety of populations, it does not need an overt response, and can be conducted in a short time with no need for subject training. This paradigm also benefits from high SNR and high ITR. A total of 12 pictures (i.e., AAC) will be selected for the task. In each trial, 4 pictures will randomly be presented on an LCD monitor in front of the subject and 4 LEDs placed in the top left (1), top right (2), down left (3), and down right (4), of the monitor. LEDs flicker with 8, 10, 12, and 15 Hz respectively. Subjects try to select the output command (i.e., one of 4 pictures on the monitor) by paying attention to a sound that defines the number of the picture along with a visual cue (i.e., an arrow pointing at the picture). Each session includes 120 trials and each picture will be presented 10 times. Each trial time is equal to 7 seconds including 5 seconds picture presentation followed by a 2-second rest black/white screen (the total duration of each session will be 14 minutes). Overall, 3 sessions will be presented by inserting about a 5-minute break between sessions. The schematic task design and presentation are shown in Figure 1.

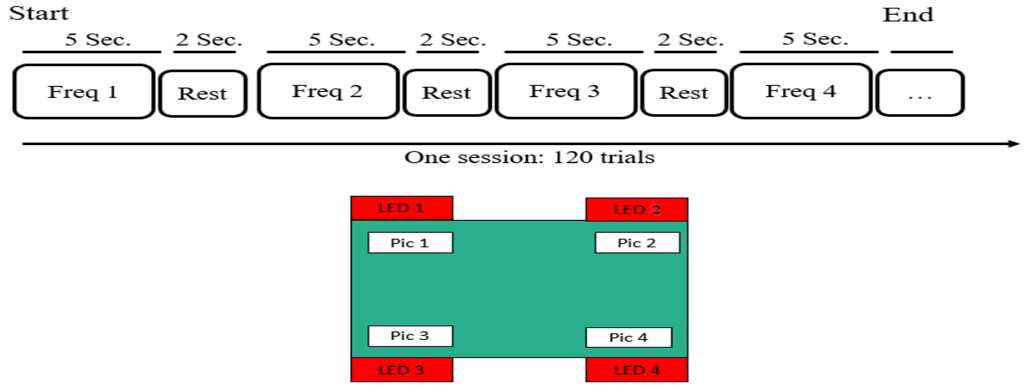


Figure 1: Schematic presentation of task.

*Data acquisition*: Eight channels of EEG signals will be acquired using a 10-20 standard system. Electrodes will be placed in occipital and parietal areas. The right ear and Fpz are dedicated to reference and ground electrodes respectively. Online notch (50 Hz) and bandpass filters (2-100 Hz) will be used. The frequency sampling frequency in this study is 512 Hz. The location of EEG electrodes is depicted in Figure 2. Synchronization pulses/trigger signals should be recorded simultaneously with EEG signals.

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| Figure 2: The location of EEG electrodes. | Figure 3: General block diagram of the experimental setup and data analysis. |

*Data analysis*. Firstly, EEG data will be preprocessed with a baseline correction and offline appropriate bandpass filters. Then the data of each trial will be extracted using triggers/ synchronization pulses. After the preprocessing, extracted signals of each trial will be analyzed with time, frequency, and time-frequency analysis. Informative features for each analysis will be used in the input table of machine learning methods. Machine learning methods (e.g., SVM, Decision tree, etc.) classify the signals and determine the output command. A general block diagram of the experimental setup and data analysis is illustrated in Figure 3.

*Performance analysis*. Two well-known criteria will be measured for validation of the analysis. Accuracy (Acc) defines the fraction of corrected trials for all trials.

(Eq.1)

Information transfer rate (ITR).  A general evaluation metric devised for BCI systems determines the amount of information that is conveyed by a system's output.

Where:

ITR= information transferred in bits per trial,

N= number of targets,

P= classification accuracy. It is calculated by dividing the number of correct command classifications by the total number of classified commands.

***Other requirements for application***

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

Considering the interdisciplinary nature of the 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 experience in the interdisciplinary area of 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 surveys 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.*

The use of BCI requires interdisciplinary cooperation of researchers (with expertise in rehabilitation science, psychologist, clinicians, engineering, machine learning, and signal processing) to improve its applicability and convenience as well as benefits for clients 24. The proposed project needs some facilities including testing rooms and EEG facilities and assistance. For this purpose, MIDB can be an appropriate place where the project can take place. The current project brings experts from different fields to improve life outcomes and quality of life by facilitating communication for autistic youth and young adults.

*Updated CV*

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

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*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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