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SPECIAL COMMUNICATION

Critical Issues Using Brain-Computer Interfaces for Augmentative and Alternative Communication

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Abstract

Brain-computer interfaces (BCIs) may potentially be of significant practical value to patients in advanced stages of amyotrophic lateral sclerosis and locked-in syndrome for whom conventional augmentative and alternative communication (AAC) systems, which require some measure of consistent voluntary muscle control, are not satisfactory options. However, BCIs have primarily been used for communication in laboratory research settings. This article discusses 4 critical issues that should be addressed as BCIs are translated out of laboratory settings to become fully functional BCI/AAC systems that may be implemented clinically. These issues include (1) identification of primary, secondary, and tertiary system features; (2) integrating BCI/AAC systems in the World Health Organization's *International Classification of Functioning, Disability and Health* framework; (3) implementing language-based assessment and intervention; and (4) performance measurement. A clinical demonstration project is presented as an example of research beginning to address these critical issues.

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Augmentative and alternative communication (AAC) is a field of endeavor dedicated to providing effective and efficient interventions, strategies, and technology to help individuals whose natural speech is not functional to participate in their daily activities.[1] The most effective AAC interventions supplement or replace speech production, or both, with strategies and technology that offer characteristics of a natural language; for example, the AAC system allows for spontaneous, novel utterance generation.[2] Spontaneous novel utterance generation allows a person to formulate sentences and say anything at any time,[3] and thus achieve interactive communication. Communication generated using AAC systems can be measured using traditional measures of language performance to gauge overall effectiveness in addition to measures of achieved functional outcomes. Additionally, AAC system features can be selected and manipulated to improve the communication performance of the AAC speaker or system.

Brain-computer interfaces (BCIs) may potentially be of significant practical value to patients in advanced stages of amyotrophic lateral sclerosis (ALS) and locked-in syndrome for whom conventional AAC systems, which require some measure of consistent voluntary muscle control, are not satisfactory options. In these individuals, brain signals (eg, P300 potentials) might be good alternatives to channel as a noninvasive approach for accessing assistive technologies. However, measuring the effectiveness of BCIs to support communication becomes an expectation as BCIs mature into fully functional BCI/AAC systems.[4] As translational research efforts move BCIs out of laboratory settings to be recommended by speech-language pathologists as viable BCI/AAC systems, quantitative language and communication metrics will become critical for making informed decisions about effectiveness and value. BCI research and development and clinical AAC practice benefit from the use of clearly defined or standardized measures for comparing performance between and within AAC speakers and systems.

The purpose of this article is to introduce 4 critical issues that the BCI field should be accountable for addressing as BCI systems mature into BCI/AAC systems that may be implemented

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clinically. These issues include (1) identification of primary, secondary, and tertiary features of BCI/AAC systems; (2) integrating BCI/AAC systems in the World Health Organization's *International Classification of Functioning, Disability and Health* (ICF) framework[5]; (3) implementing language-based assessment and intervention; and (4) performance measurement. A clinical demonstration project measuring the communication performance of BCI/AAC system speakers[6] is presented as an example of research beginning to address these critical issues.

Critical issues to address

Primary, secondary, and tertiary device features

The first critical issue to address relates to identifying features of BCI/AAC systems. AAC interventions are compared and matched to an individual based on primary, secondary, and tertiary features. These features must be accounted for in fully integrated BCI/AAC systems. Translational research should identify and evaluate the specific features (independent variables) that are controlled and manipulated in attempts to improve performance on desired metrics (dependent variables). Figure 1, which has been modified from previous publications,[2,7] shows features that BCI researchers should be accountable for identifying when using BCIs as AAC systems.[7-9] Primary features, which relate to how language is represented and generated, include language representation methods, access to vocabulary, and methods of utterance generation.

Detailed descriptions of the characteristics of primary features have been published elsewhere.[10,11] Briefly, the 3 main language representation methods include alphabet-based methods, single meaning pictures, and semantic compaction. Even though multiple language representation methods are available to most AAC speakers, BCI research has focused on the alphabet-based methods of spelling and word prediction.[12-14] Two categories of vocabulary words are generally considered—high-frequency, core vocabulary words and contextualized, extended vocabulary words. Methods of utterance generation include spontaneous novel utterance generation and pre-stored sentences. Access to core vocabulary maximizes the potential for spontaneous novel utterance generation and allowing AAC speakers to participate in conversation.[15] These language-based features should be considered a higher priority than technology features.[2,8,10]

BCI/AAC systems in the ICF framework

The second critical issue to address is integrating BCI/AAC systems into the ICF framework. The ICF framework emphasizes the classification and assessment of functioning and disability in everyday activities, and participation for individuals with medical conditions.[16,17] The international AAC community has a diverse group of stakeholders who are multilingual, multicultural,[17] and interdisciplinary. The overall aim of the ICF is to provide a unified and standard framework for the description of health and health-related states.[5] Using the ICF can help establish uniform terminology for description, assessment, and intervention in the AAC field and improve communication between stakeholders, disciplines, and countries.[18-21]

The ICF framework is an interactive classification of health-related domains, including functioning and disability and contextual factors. Three major components are associated with functioning and disability: (1) body functions and structures, (2) activities, and (3) participation. Two contextual factors influence and are influenced by the functioning and disability components: (1) environmental factors and (2) personal factors. Communication skills can be impacted by any of the major ICF components and can be influenced by a range of environmental and personal factors. Communication has been identified as a common thread across several areas of the ICF including Learning and Applying Knowledge, Interpersonal Interactions and Relationships, and Community, Social, and Civic Life.[22]

AAC is vital for helping people with complex communication needs communicate. For example, persons with ALS[23-25] may have lost the ability to speak but still be involved in daily living activities in the home and community. Their level of participation or ability to hold a conversation, relate stories, or make requests may depend on use of an AAC system, which is classified in the ICF as communication devices and techniques.[26] The outcomes achieved using this AAC system are influenced by environmental factors such as communication partner support or a system operator to set up the device. Environmental factors that influence communication outcomes include products and technology for communication, support and relationships, attitudes and services, and systems and policies. Personal factors impacting performance may include motivation and acceptance of the BCI/AAC system. Consequently, a BCI/AAC system has the potential to integrate with all areas of the ICF framework, as shown in figure 2.

Language-based assessment and intervention

Language-based assessment and intervention can be implemented when BCI/AAC systems are considered in the ICF framework. The ICF framework provides a rationale for AAC practice: to improve interactive communication so that an individual's social participation can be increased.[21] This central premise is reflected in the BCI/AAC Language-Based Assessment and Intervention Model.[27] This model (fig 3) reflects priorities of foundational research that are required to transform BCIs into fully functional BCI/AAC systems that may be recommended for intervention. To establish strong language-based intervention, foundational factors focused on language and communication should be addressed and supported with evidence before higher-level factors are addressed. The first element of a strong foundation is the goal of BCI/AAC: the most effective interactive communication possible. As reflected in the ICF model, full interpersonal communication is crucial to enhancing one's potential for education, employment, and independence.

Building on this goal, language models and domains are considered when weighing decisions about primary system features. Particular attention may be given to decisions about language representation methods because different language representation methods correspond to fundamentally different approaches to organizing vocabulary content. Objective and informative measures of language performance should be

List of abbreviations:

AAC	**augmentative and alternative communication**
ALS	**amyotrophic lateral sclerosis**
BCI	**brain-computer interface**
ICF	***International Classification of Functioning, Disability and Health***