Assistive Technology Outcomes and Benefits
Volume 13, Summer 2019, pp.1-20
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Available online: www.atia.org/atob

Considering Augmentative and Alternative Communication Research for Brain-Computer Interface Practice

Kevin M. Pitt, PhD, Jonathan S. Brumberg, PhD, Adrienne R. Pitt, MSP

University of Nebraska-Lincoln
University of Kansas

Corresponding Author
Kevin Pitt, PhD
University of Nebraska-Lincoln
Special Education & Communication Disorders
357 Barkley Memorial Center
Lincoln, NE 68583
Phone: (402) 472-2149
E-mail: kevin.pitt@unl.edu

Abstract

Purpose: Brain-computer interfaces (BCIs) aim to provide access to augmentative and alternative communication (AAC) devices via brain activity alone. However, while BCI technology is expanding in the laboratory setting, there is minimal incorporation into clinical practice. Building upon established AAC research and clinical best practices may aid the clinical translation of BCI practice, allowing advancements in both fields to be fully leveraged.

Method: A multidisciplinary team developed considerations for how BCI products, practice, and policy may build upon existing AAC research, based upon published reports of existing AAC and BCI procedures.

Outcomes/Benefits: Within each consideration, a review of BCI research is provided, along with considerations regarding how BCI procedures may build upon existing AAC methods. The consistent use of clinical/research procedures across disciplines can help facilitate collaborative efforts, engaging a range of individuals within the AAC community in the transition of BCI into clinical practice.

Keywords: brain-computer interface, augmentative and alternative communication, clinical, translation.

Considering Augmentative and Alternative Communication Research for Brain-Computer Interface Practice

Since the early 1970s, research on providing access to augmentative and alternative communication (AAC) devices for those with severe physical impairment has grown dramatically with an expanded reach for considering an increasing number of individuals from diverse cultural and linguistic backgrounds, advocating for AAC acceptance, and utilizing an expanding array of devices for AAC access (Hourcade, Everhart Pilotte, West, & Parette, 2004; Light & McNaughton, 2012). One area of focus is the provision of AAC control via brain-computer interface (BCI) technology, which does not require any overt behavior. BCIs for accessing AAC provide communication device control by recording brain signals associated with attention (e.g., the P300 event-related potential and steady state visually evoked potential) and attempted or imagined motor control (e.g., sensorimotor modulations), via electroencephalography (Brumberg, Pitt, Mantie-Kozlowski, & Burnison, 2018). Unlike conventional AAC access methods such as switch access and eye gaze, the BCI link between an individual's neurological activity and AAC device eliminates the need for a person to possess any form of reliable physical movement to access communication. Therefore, BCI technology has the potential to unlock communication for adults and children with the most advanced physical impairments due to neurological diseases and disorders such as amyotrophic lateral sclerosis (ALS), locked in syndrome, and cerebral palsy (Fager, Beukelman, Fried-Oken, Jakobs, & Baker, 2012).

Initial investigations show individuals with severe physical impairments are positive about the potential applications of BCI techniques (Blain-Moraes, Schaff, Gruis, Huggins & Wren, 2012). For instance, a focus group including eight individuals with ALS revealed that while participants noted barriers to BCI use, such as fatigue and discomfort, they found BCI technology offered freedom, hope, and connection, filling an unmet need in their daily lives (Blain-Moraes et al., 2012). However, even in light of this positive view of BCI technology, and promising results from long-term in-home trials (e.g., Wolpaw et al., 2018; Holz, Botrel, Kaufmann, & Kübler, 2015; Miralles et al., 2015), BCIs are still primarily restricted to laboratory settings, and there is limited interest from AAC professionals and commercial partners (Nijboer, 2015; Chavarriaga, Fried-Oken, Kleih, Lotte, & Scherer, 2017). This limitation is, in part, due to continued problems associated with BCI reliability (e.g., Vansteensel, Kristo, Aarnoutse, & Ramsey, 2017) and set up requirements (e.g., Blain-Moraes et al., 2012, Zickler et al., 2011). However, a general lack of consistency between AAC research and BCI procedures may further impede the effective translation of BCI technology into clinical practice.

The field of AAC as a whole seeks to provide person-centered communication access to individuals with complex communication needs that support an individual's strengths, autonomy, social interactions, activities of daily living, and unique desires, along with their family and caregivers (e.g., Light & McNaughton, 2013; Blackstone, Williams, & Wilkins, 2007). These person-centered frameworks encourage stakeholder involvement in the assessment and intervention process, facilitating communication device success (Pitt & Brumberg, 2018a; Gosnell, Costello, & Shane, 2011; Johnson, Inglebret, Jones, & Ray, 2006). Although the foundation exists for considering BCIs in the context of AAC (e.g., Pitt & Brumberg, 2018a), current BCI practice does not fully utilize existing AAC frameworks. For instance, BCI research primarily focuses on the development of spelling-based devices for adults with acquired neuromotor disorders (see Rezeika et al., 2018 for review), which leaves children, and others with limited literacy, as an understudied and underserved population. In addition, current practices tend to focus on the assessment of one or two BCI devices, instead of across the full range of possible BCI types, which may limit appropriate matching of BCI technology to individual strengths and needs (cf. Pitt & Brumberg, 2018a). As BCI technology continues to mature, incorporation of established AAC research and clinical best practices are needed to ensure advances in both fields are fully leveraged. Using an AAC perspective for BCI research will help development of effective person-centered BCI products, policies, and practices. This manuscript will outline different considerations for future BCI research, which all build upon established clinical AAC practices with the goal of encouraging multidisciplinary collaborations between researchers and professionals from both BCI and AAC and assisting the translation of BCI technology into clinical settings.

Target Audience and Relevance

The topics outlined in this paper aim to inform multidisciplinary AAC professionals about pertinent AAC and BCI developments to encourage a variety of disciplines in both the public and private sectors to engage in the translation of BCIs for AAC access into clinical practice. In addition, BCI researchers can benefit from the following discussion by using AAC perspectives and research outcomes to advance the development and implementation of BCI technology from existing AAC practices.

Methods

A multidisciplinary team including two speech-language pathologists, and one BCI engineer, with combined experience in BCI, AAC, and individuals with complex communication needs identified six major topics of consideration important for BCI products (including access to commercial AAC devices, and supporting children and individuals with impaired or emerging literacy skills), practice (i.e., person-centered assessment, outcomes, and developing engaging and supportive training practices), and policy (i.e., consistency with American Speech-Language Hearing Association (ASHA) policies for AAC practice), based upon published reports of AAC and BCI developments. Within each of the following sections, we first briefly review current BCI advancements, and following, outline different considerations for BCI products, practices and policies to build upon existing AAC methods.

AAC Considerations for the Development of BCI Products and BCI Access to Commercial AAC Devices

To date, the primary focus of BCI development is to provide access to spelling-based communication for adults with acquired neuromotor disorders. A large variety of BCI systems are currently in development, which most commonly rely on brain signals including the P300 event related potential (e.g., Donchin, Spencer & Vijesinghe, 2000), steady state visually evoked potential (e.g., Sutter, 1992) and motor (imagery) modulations of the sensorimotor rhythm (e.g., Blankertz et al., 2006). These target brain-signals are recorded by non-invasive electroencephalography, in which brain activity is recorded on the surface of the scalp using electrodes that are placed in a fabric cap (similar to a swimming cap).

P300 and steady state visually evoked potential-based BCI devices are controlled using selective attention to presented items (Brumberg, Pitt, Mantie-Kozlowski, & Burnison, 2018). P300-based BCI displays often utilize a grid layout containing letters, symbols, and numbers (e.g., Donchin et al., 2000). To make a selection, the individual attends to the target communication item they wish to select, while all items within the grid are randomly flashed. Approximately 300ms after the target stimulus is flashed, a positive voltage is detectable in the electroencephalography recordings in comparison to the other non-target stimuli (Donchin et al., 2000). The BCI algorithm then selects the item that is associated with this P300 event. For steady state visually evoked potential access, the BCI display contains multiple stimuli all flickering at different frequencies (e.g., 5-15Hz). The BCI algorithm is able to identify and select the attended item using posterior scalp recordings, which will have the greatest amplitude (Müller-Putz, Scherer, Brauneis, & Pfurtscheller, 2005) and temporal correlation (Lin, Zhang, Wu, & Gao, 2006) for the attended strobe frequency in comparison to non-attended items. Finally, motor (imagery) devices are controlled via imagined movements (i.e., mental rehearsal of an action without physical execution). Imagery tasks, along with actual or attempted movements, are detectable by the BCI through modulation of the sensorimotor rhythm, which is an electroencephalography signal occurring in the mu (8-12 Hz) and beta (15-25 Hz) frequency bands over sensorimotor scalp locations. Motor (imagery) tasks decrease the power of the sensorimotor rhythm in comparison to rest (Brumberg, Pitt, Mantie-Kozlowski, & Burnison, 2018), leading to BCI output. Modulation of the sensorimotor rhythm can be interpreted by the BCI continuously, such as a left-hand imagery moving an onscreen mouse cursor to the left (e.g., Wolpaw & McFarland, 2004; Brumberg, Pitt & Burnison, 2018), or discretely, such as switch type access (Friedrich et al., 2009; Brumberg, Burnison, & Pitt, 2016; Scherer et al., 2015). A full review of BCI methods including both auditory and visual techniques can be found in Brumberg, Pitt, Mantie-Kozlowski, and Burnison (2018), and Akcakaya et al., (2014).

Most often, BCIs are designed with lab-specific displays, presentation paradigms, and software that may or may not be designed from a person-centered approach, in contrast with commercially available AAC device designs that are based upon a history of person-centered considerations (Romich, 1993). Thus, although early efforts are being made to utilize BCI methods to access commercial AAC paradigms (e.g., Thompson, Gruis & Huggins, 2013; Scherer et al., 2015; Brumberg et al., 2016) and assistive technology software (QualiWorld, QualiLife Inc. Paradiso-Lugano, CH; e.g., Zickler et al., 2011), a heightened focus on utilizing commercially available technology may promote collaborations with commercial partners and manufacturers to help navigate barriers to funding (Ray, 2015).

The BCI development process should incorporate feedback from individuals who may use BCI to ensure BCI technology meets their unique needs (Nijboer, 2015). Currently, studies exploring the specific desires of individuals with complex communication needs are still emerging (e.g., Blain-Moraes et al., 2012; Liberati et al., 2015). For instance, findings by Liberati et al. (2015) reveal that individuals with ALS highly value devices that can adapt to one's changing sensory-cognitive-motor profile and exploit the strongest current communication channel both in the short (e.g., within one day) and long term. The incorporation of commercial AAC technology into BCI development increases device modularity, by allowing individuals to continue accessing their existing AAC device using BCI as a new access method only. Importantly, device continuity across the disease course may also decrease learning demands and the emotional struggle individuals experience when learning a new assistive technology (Liberati et al., 2015) and brings BCI development in line with current AAC practices for establishing multimodal access to commercial communication devices (e.g., eye gaze plus switch; see Fager, 2018 for a review). These considerations in total provide individuals with the freedom to alter their access method throughout the day depending upon their preference, environment, and level of fatigue (Brumberg, Pitt, Mantie-Kozlowski, & Burnison, 2018).

Supporting Children and Individuals with Impaired or Emerging Literacy Skills

The focus of traditional BCI development on adults with acquired neuromotor disorders (e.g., Moghimi, Kushki, Guerguerian, & Chau, 2013) is primarily due to difficulty studying pediatric neurophysiology such as sensory sensitivity, the developing brain, and the limited amount of neurotypical data available (Huggins et al., 2017). However, restricting BCI use to adults limits the potential applications of BCI, especially for those with impaired or emerging literacy skills, and fails to account for the potential impacts of early AAC intervention across a child's lifespan. Incorporating the perspectives of children in BCI research, design, and development is equally as important as adults, as both groups have different communication wants and needs (Light, Page, Curran, & Pitkin, 2007). When asked to design communication supports, children emphasized the importance of device personalization (e.g., colors, shapes, access technique), and incorporated multiple functions beyond speech such as play, artistic expression, social interaction, and companionship to promoting meaningful communication (Light et al., 2007). In addition, effective AAC implementation for children must provide developmentally appropriate access to language and literacy and facilitate participation in educational opportunities (Light & Drager, 2007). Therefore, how to best support children's development and meaningful interactions in their various social and educational environments with both neurotypical peers and those who use AAC is an important consideration for child-centered AAC and BCI success (Ibrahim, Vasalou, & Clarke, 2018).

Current BCI techniques may be adapted for accessing communication utilizing pictorial symbols as a first step toward the provision of BCI access to AAC for children (Brumberg, Pitt, Mantie-Kozlowski, & Burnison, 2018). Though BCI translation in this domain is still in the early stages (e.g., Ahani et al., 2014; Scherer et al., 2015; Brumberg et al., 2016), there is an established history of AAC interface research and development that provides for the cognitive, linguistic, sensory, and communication needs of children. Further, AAC professionals consider an array of factors when designing communication device displays to meet the needs of children who use AAC (Thistle & Wilkinson, 2015), including icon color and contrast (Wilkinson & Jagaroo, 2004), placement and size (Beukelman & Mirenda, 2013), texture and shape (Scally, 2001), and motion (Jagaroo & Wilkinson, 2008).

In addition, commercial AAC devices have historically focused on grid-based graphical layouts (Wilkinson & Jagaroo, 2004), as have many BCIs including the popular P300 speller (e.g., Donchin et al., 2000) in which individual symbols/letters are selected from a decontextualized arrangement. However, AAC research has begun to explore visual scenes as an alternative to grid layouts, which are based on context rich images (e.g., photographs) that depict events, activities, and individuals significant to the person using the AAC device. In this manner, the visual scene environment is used to display items and symbols for selection (e.g., the individual may select their favorite toy from an image of their toy chest) that, once selected, can produce communication output (Dietz, McKelvey, & Beukelman, 2006; Wilkinson, Light, & Drager, 2012). Visual scene displays are currently available in many commercial AAC devices, with studies showing the utility of these displays in supporting both adults and children with complex communication needs (see Wilkinson & Jagaroo, 2004; Wilkinson et al., 2012 for a full review). The concept of utilizing BCI techniques to provide AAC access to visual scene displays is an interesting consideration in BCI development. The contextual nature of visual scene images means items within the scene, by nature, may differ from each other in relation to size, shape, color, and orientation, which all may impact the quality of signals used for BCI control. In addition, how items within the visual scene display are highlighted / selected during scanning (e.g., bold outline, motion) influences visual scene outcomes (McCarthy & Boster, 2017). Similarly, P300 grid stimulus patterns are known to affect P300 signal quality (Akcakaya et al., 2014), and it is possible stimulus presentation using visual scenes will also affect target BCI signals.

It is important to note, however, that design considerations go beyond just the graphical interface. Below, we outline additional feature matching considerations for AAC and BCI assessment in more detail. However, it should be mentioned that special considerations are necessary to decrease a child's learning demands and support his or her developing language, literacy, learning, and growth trajectory, in addition to changing needs, skills, and preferences (Light & Drager, 2007). Congenital motor impairment may further complicate feature matching guidelines due to the possibility of impaired first-person motor imagery skills (recreating the sensations associated with the performance of a physical action; Olsson & Nyberg, 2010), which are important for successful motor imagery-based BCI outcomes (Neuper, Scherer, Reiner, & Pfurtscheller, 2005; Vuckovic, & Osuagwu, 2013). Finally, design aesthetics are an important consideration for both adults (Blain-Moraes et al., 2012; Nijboer, 2015) and children. However, children are more likely to engage in the use of technologies that they find appealing, cool, and bolster their social image (Light & Drager, 2007).

AAC Considerations for BCI Practice

Person-Centered Assessment

Feature matching is the established best practice for AAC intervention and includes individualized assessments, which seek to match an individual to a specific AAC device and page-set based upon factors such as their current and future sensory, motor, cognitive, and linguistic profile, in addition to their environment, communication needs, and levels of support (Pitt & Brumberg, 2018a; Gosnell et al., 2011; Beukelman & Mirenda, 2013). These person-centered procedures allow an individual to trial multiple AAC devices with a variety of access methods, feedback types, and graphical interfaces. This ultimately leads to the selection of an AAC device that best matches each individual's unique strengths and preferences and facilitates AAC success while limiting the potential for device abandonment (Beukelman & Mirenda, 2013). Application of the feature matching framework is important for the transition of BCI into clinical practice (e.g., Hill, Kovacs & Shin, 2015), especially given the range of profiles of adults and children with complex communication needs who may use BCI and the diversity of BCI devices (e.g., Brumberg, Pitt, Mantie-Kozlowski, & Burnison, 2018). Specifically, each BCI method may differently support an individual's unique sensory-cognitive, motor, and motor imagery strengths (Pitt & Brumberg, 2018a), with each individual having a unique BCI preference (Peters, Mooney, Oken, & Fried-Oken, 2016).

Identifying predictors for BCI performance is a growing area of BCI research and is critical for understanding how person-centered factors such as motivation (e.g., Nijboer, Birbaumer, & Kübler, 2010), attention (e.g., Riccio et al., 2013), and motor imagery skills (e.g., Vuckovic, & Osuagwu, 2013) influence BCI success. However, while feature matching-based assessment protocols aiming to inform BCI trials are in early development (Pitt & Brumberg, 2018b), existing research typically focus on predicting performance for only one or two types of BCI rather than across a full range of techniques, as is the case with clinical AAC assessment. The shortcomings of focusing on so few potential BCIs means that individuals who may need BCI for communication may not be matched to the most appropriate device that meets both individual needs and preferences. However, the foundational efforts for BCI assessment have resulted in positive outcomes and point to the need for additional studies investigating how person-centered factors influence BCI performance across a full range of devices, eventually leading to multiple BCI device trials for establishing individual preferences. In addition, as potential stakeholders may not be aware of BCI tools (Vansteensel, et al., 2017), future efforts should explore how BCI fits into existing AAC frameworks in order to lower barriers for speech-language pathologists, and other AAC specialists, to learn and incorporate BCIs into clinical AAC practices. Recognizing that BCI can be considered as an access technique for AAC can help facilitate adoption of BCI approaches into clinical and commercial AAC.

Feature matching also considers display design for determining preference and appropriateness of AAC selections and has specific importance for BCIs. For instance, traditional P300 grid paradigms highlight all items within the graphical display by toggling between grey (or a dark color) and white (e.g., Donchin et al., 2000). However, recent BCI research is also exploring other stimulation patterns such as the use of faces and non-face stimuli for identifying the current communication item (e.g., toggling between the communication item and a human face or shape). However, while non-face stimuli have only been evaluated for use by neurotypical adults (e.g., Kellicut-Jones, & Sellers, 2018), faces may increase BCI outcomes for individuals with ALS (Kaufmann et al., 2013; Geronimo, & Simmons, 2017). Similar to current AAC practice, it is clear these and other interface characteristics such as matrix size and interstimulus interval (e.g., Sellers, Krusienski, McFarland, Vaughan, & Wolpaw, 2006), flash rate (McFarland, Sarnacki, Townsend, Vaughan, & Wolpaw, 2011), symbol size, color (e.g., Salvaris & Sepulveda, 2009), and motion (e.g., Guo, Hong, Gao, & Gao, 2008) should be included into future BCI feature matching procedures, though their specific importance for individual outcomes are still emerging. The role of caregivers is also an important consideration in any feature matching framework, especially for BCI, due to factors associated with BCI set up (e.g., correct placement of electroencephalography cap, application of electrolyte gel) and potentially lengthy training times (Pitt & Brumberg, 2018a). Therefore, efforts to include caregivers in the BCI process is a critical step in the application of BCI in clinical practice (Wolpaw et al., 2018).

Person-Centered Outcomes

To date, BCI research focuses on outcomes relating to speed and accuracy in order to validate the complex algorithms used for translating brain activity into computer control. While initially important for developing reliable BCI systems, a broader focus is now needed on personalized BCI outcomes (Nijboer, 2015). Drawing from conventional AAC research, speed and accuracy are still relevant (e.g., Brumberg, Pitt, Mantie-Kozlowski, & Burnison, 2018), in addition to person-centered AAC outcomes including functional skills (e.g., initiating interactions, repairing communication breakdowns, engaging in social conversations), and quality of life (e.g., their ability to participate in various preferred environments) (Beukelman & Mirenda, 2013; Hill et al., 2015).

The World Health Organization's International Classification of Functioning (ICF) Disability and Health framework, developed by a multidisciplinary and multicultural group of experts, emphasizes daily activities and participation during assessment of an individual's function and disability (Andresen, Fried-Oken, Peters, & Patrick, 2016; Hill et al., 2015; ; Moghimi et al., 2013), and is well suited to AAC assessment (Fried-Oken & Granlund, 2012). However, the use of this framework for BCI is still in the early stages, with recent work by Andresen et al. (2016), aiming to map a range of BCI assessment tools onto the ICF structure. In addition, Andresen and colleagues included individuals with neuromotor disorders in the research team, helping identify important constructs beyond those presented by the ICF, including quality of life, and the function, design, and support of assistive technology. Previous work also examined BCI outcomes in relation to user centered design (effectiveness, efficiency, satisfaction, and use in daily life; Kübler et al., 2014); however, there is currently a lack of standardized procedures for evaluating BCI outcomes, which limits scientific discussion, and understanding individual differences in BCI outcomes (Chavarriaga et al., 2017).

Developing Engaging and Supportive Training Practices

As with traditional AAC techniques, BCI control is a learned skill, and the field is currently investigating a range of paradigms to provide meaningful BCI instruction, feedback, and tasks during BCI training protocols, including virtual reality (Lotte et al., 2012), real-time feedback of brain activity (Hwang, Kwon, & Im, 2009), increasing task complexity (McFarland, Sarnacki, & Wolpaw, 2010), using meaningful auditory and visual feedback (Brumberg, Pitt & Burnison, 2018), along with allowing for free exploration of BCI control strategies (e.g., Neuper, Müller, Kübler, Birbaumer, & Pfurtscheller, 2003), and identifying strategies that may support BCI success such as goal oriented tasks (e.g., imagining reaching for a cup, Vuckovic & Osuagwu, 2013), familiar imagined actions (Pitt & Brumberg 2018b) and novel imagined actions (Halder et al., 2011). See Lotte, Larrue, & Mühl, 2013, and Lotte & Jeunet, 2015, for a full review. However, best practices for BCI learning are still unknown, though there is agreement that traditional BCI training approaches are suboptimal (Jeunet, Jahanpour, & Lotte, 2016; Chavarriaga et al., 2017) and focus too heavily on machine learning rather than the individual (Lotte et al., 2013). In addition, current BCI training paradigms often provide unimodal feedback that is too simplistic for individuals to understand how to improve their performance. For instance, during motor imagery BCI control tasks, individuals may only receive feedback regarding whether task completion was correct/incorrect, or a visual graphic (e.g., bar or cursor) that fluctuates in proportion to the power of the sensorimotor signal used for motor imagery BCI control (Jeunet, et al., 2016; Chavarriaga et al., 2017), both of which are difficult to use for online modification of BCI control. Taken together, these training methods do not fully consider the unique individual, or follow learning principles utilized by other disciplines, which may impede BCI mastery (Lotte, et al., 2013, and Lotte & Jeunet, 2015).

While there are hurdles specifically associated with BCI training due to the nature of individuals' specific neurological and physical impairments, and an inability for communication partners to access the BCI system, existing AAC training approaches may aid development of BCI practices for guiding adults and children toward BCI mastery. AAC instruction is designed to account for the varied abilities, learning preferences, and priorities of individuals with complex communication needs with the aim of meeting the individual's personal goals, strengthening relationships, and furthering societal participation (Blackstone, et al., 2007). Individuals who use AAC may wish to utilize a range of learning supports such as print materials, drill and practice, and online tutorials. However, the method or combination of methods preferred by the individual is likely to change depending upon factors such as their age, levels of skill, and motivation (Rackensperger, Krezman, McNaughton, Williams, & D'silva, 2005). Consideration of all methods accessible to individuals who use BCI along with preferences and priorities may enhance BCI learning.

Drill-based explicit instruction and aided input are commonly employed techniques in promoting AAC success (Beukelman & Mirenda, 2013), with ongoing services provided by a skilled professional (Hill et al., 2015). Scaffolding techniques accompany these standard procedures, providing varying levels of assistance to facilitate task success and ultimately independence (Light, McNaughton, Weyer, Karg, 2008). During aided instruction, the communication facilitator provides multimodal input by modeling access to the communication display (e.g., by pointing) while communicating verbally, ideally throughout the day (e.g., Beukelman & Mirenda, 2013). In many scenarios, this technique requires that the communication partner can access the AAC system, which may pose a unique challenge for application to BCI. However, modeling and scaffolding used for eye-gaze and head-pointer access techniques may be informative for developing strategies for supporting BCI. For instance, a clinician may place their own head next to a client's while using a head-pointer to demonstrate the relationship between head movements and pointer effects. A similar approach could be adapted for BCIs with clinician support. Specifically, communication facilitators can use their own head mounted laser pointer to model where they are directing their attention in order to improve training and outcomes for attention modulated BCIs modeling an overt attention strategies known to increase BCI performance (Brumberg, Nguyen, Pitt, & Lorenz, 2018; Brunner et al., 2010; Peters et al., 2018).

Another barrier to BCI training is that traditional methods are generally sterile, and boring for participants (Chavarriaga et al., 2017). In contrast, conventional AAC training methods incorporate incidental teaching strategies that provide individuals the opportunity to practice AAC control within meaningful everyday activities (Beukelman & Mirenda, 2013; Light et al., 2008). Focusing on functional communication is important for engaging individuals to learn AAC control, boost self-confidence, and ultimately support access and participation in meaningful activities, social interactions, and societal roles (Blackstone et al., 2007; Rackensperger et al., 2005). In addition, engaging the attention of children while using BCI can be especially challenging, possibly requiring game-based applications and rewards (Huggins et al., 2017). Current AAC practices emphasize engaging children in AAC activities, with commercial software applications such as Look to Learn (SmartBox Assistive Technology Inc., PA, USA) providing a range of fun activities to foster eye gaze access mastery. In a BCI context, these established foundations from the AAC community may be built upon for engaging individuals in BCI learning paradigms by providing BCI access to motivating activities such as: select the animal (e.g., Vansteensel et al., 2016), select the face to throw a pie (SmartBox Assistive Technology Inc., PA, USA), or allowing an individual with severe motor impairment to interact with their environment during goal oriented tasks (e.g. request and receive/interact with a preferred object or environment), with additional opportunities using virtual or augmented reality techniques (Boster & McCarthy, 2017).

Finally, timely/early intervention is an important consideration in current AAC practice to support communication success and device acceptance by permitting time for skill learning, gradual device acclimatization, stakeholder education, and the provision of skilled interventions (e.g., Ball et al., 2010). Unfortunately, the effects of early intervention are unknown for BCI. However, since BCI can be considered as an access method to AAC, it is feasible that beginning BCI intervention early in the disease course may lead to improved outcomes for both motor imagery and attention modulated BCI systems (Marchetti & Priftis, 2015) in comparison to implementing BCI as a last resort option.

Considering ASHA Policies for AAC Practice

The considerations described in this paper have the potential to aid the field of BCI move toward consistency with ASHA policies for AAC practice (e.g., ASHA 1992; 2004) that emphasize person-centered factors such as: the use of meaningful, natural, and interactive/social contexts; ecological validity of assessment and intervention methods; comprehensively evaluating, respecting, and supporting the individual's unique sensory-cognitive-motor-language profile and cultural-linguistic diversity; and providing access to a range of AAC systems/methods. In addition, it is crucial to incorporate a range of individuals (AAC professionals, commercial partners, educators, employers, and those who may use AAC in addition to those whom they interact with daily) in the AAC process to ensure the communication rights of an individual are upheld (ASHA, 1992). Understanding how to best provide for caregivers and AAC professionals during the at home implementations of BCI technology is still in the early stages (Wolpaw et al., 2018; Miralles et al., 2015). Therefore, future progress will depend on working collaboratively to develop best practices for AAC and BCI to promote the successful engagement of the AAC community in the intervention process and improve communication support, and outcomes for both fields. In addition, AAC and BCI researchers should remain cognizant that their work may impact health insurance policies regarding AAC device coverage (Romski & Sevcik, 2018). Currently, BCI research may classify individuals with decreased BCI performances as BCI illiterate; however, the performance criteria for this classification is inconsistent and largely unjustified (Thompson, 2018). While understanding how individuals respond differently to varying BCI techniques will help inform the development of BCI assessment guidelines, consideration needs to be given to the term BCI illiteracy, and how BCI competency is described and established. This is necessary to help ensure individuals are not blocked from all forms of BCI provision, as decreased performance with one BCI technique (e.g., P300) does not necessarily mean decreased performance across all BCI techniques. Furthermore, providing an individual with a consistent form of communication, even with decreased accuracy, is better than no communication at all. In this regard, future BCI research may benefit from existing AAC frameworks supported by ASHA, which seek to provide a multidisciplinary construct for defining AAC communication competency in terms of operational, social, linguistic, strategic, and psychosocial (e.g., motivation, attitude, confidence, and resilience) factors (Light & McNaughton, 2014; ASHA, 2018).

Outcomes and Benefits

BCI technology may provide individuals with severe physical impairment hope and a way to feel unlocked (Blain-Moraes et al., 2012); however, many barriers must be overcome for BCI to be fully incorporated into clinical settings. These hurdles include traditional factors such as the reliability of BCI technology, set-up requirements (e.g., Vansteensel, et al., 2017) imperfect processing algorithms (Lotte et al., 2013), limited sample sizes, and a bias to publishing only positive results (Chavarriaga, 2017). However, while overcoming barriers in these areas is important, a focus solely on the technical aspects of BCI separately from the larger clinical picture of existing AAC developments, policies, and frameworks for which BCI aims to be a part, may ultimately hinder the effective transition of BCI technology into clinical practice.

This paper discussed different considerations regarding how current and future BCI products, policies and practices can build upon existing AAC developments, aiding the clinical translation of BCI technology. For instance, current BCI practice focuses on a small range of potential individuals who may use BCI (e.g., those with ALS, locked-in syndrome), potentially limiting interest in BCI technology from commercial partners (Nijboer, 2015), and the engagement from other AAC professionals. The consistent use of research procedures across disciplines can promote collaborative efforts and teamwork, helping open BCI access techniques to a larger range of individuals who may utilize AAC, by considering BCI as simply another access method within existing AAC frameworks, instead of a fringe technology of last resort for adults with the severest forms of physical impairment.

Declarations

This content is solely the responsibility of the author(s) and does not necessarily represent the official views of ATIA. The present publication was produced with the financial support from the National Institute of Health (NIDCD R01-DC016343).

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