Interprofessional practitioners' opinions on features and services for an Augmentative and Alternative Communication-Brain-Computer Interface device

Running Head: PRACTITIONER FOCUS GROUP ON AAC-BCI

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Abstract

Background: Brain-computer interface (BCI) technology is an emerging access method to augmentative and alternative communication (AAC) devices.
Objectives: To identify, in the early stages of research and development, the perceptions and considerations of inter-professional practice (IPP) team members regarding features and functions for an AAC-BCI device.
Design: Qualitative research methodology applying a grounded theory approach using focus groups with a follow-up survey of participants using NVivo analysis software supporting inductive coding of transcription data.
Setting: Focus groups held at university, clinic, and industry conference rooms. Discussion was stimulated by a 14-minute video on an AAC-BCI device prototype. The prototype hardware and electroencephalogram (EEG) gel and dry electrode headgear were on display.
Participants: Convenience sample of practitioners providing rehabilitation or clinical services to individuals with severe communication disorders and movement impairments who use AAC and/or other assistive technology.
Interventions: Not applicable
Main Outcome Measures: Descriptive statistics using thematic analysis of participants' opinions, input, and feedback on the ideal design for a non-invasive, EEG-based P300 AAC-BCI device.
Results:
Interrater and interjudge reliability were at 98% and 100% respectively for transcription and researcher coding. Triangulation of multiple data sources supported theme and subtheme identification that included design features, set-up and calibration, services, and effectiveness. An AAC device with BCI access was unanimously confirmed (100%) as a desirable commercial product. Participants felt that the AAC-BCI prototype appeared effective to meet daily communication needs (75%). Results showed that participants' preference on headgear types would change based on accuracy (91%) and rate (83%) of performance. A data logging feature was considered beneficial by 100% of participants.
Conclusions: IPP teams provided critical impressions on design, services, and features for a commercial AAC-BCI device. Expressed feature and function preferences showed dependence on communication accuracy, rate, and effectiveness. This provides vital guidance for successful clinical deployment.

Keywords: Stakeholder feedback, Complex Communication Needs, Augmentative and alternative communication, brain-computer interface, focus group, survey, Amyotrophic Lateral Sclerosis

Introduction

Augmentative and alternative communication (AAC) is a field of assistive technology (AT) that uses a range of low-to-high expressive communication technology that includes speech generating devices (SGDs) to support voice output and written communication. Properly matched AAC interventions enhance the participation of individuals with complex communication needs (CCN) in daily-living activities, increase their independence, and improve their quality-of-life.[1, 2] Individuals with CCN co-occurring with severe movement impairment

frequently require alternative access methods as the control interface for their SGD technology.[3] Today's interprofessional practitioners provide clinical services to individuals with diagnoses that include, but are not limited to, amyotrophic lateral sclerosis, brainstem stroke and locked-in syndrome, cerebral palsy and traumatic brain injury.[2] Alternative access may include selection methods such as switch scanning, head tracking, or eye-gaze.[4] Brain-computer interfaces (BCIs) offer an exciting innovation as a future commercial AAC alternative access method for SGDs.[5]

Background

BCIs for communication are advancing toward commercialization that will expand their availability and accessibility as an AAC option. BCIs have been used independently in homes for everyday communication needs [6, 7] and for artistic expression.[8, 9] A current commercial BCI system sold by a hardware manufacturer (IntendiX, Guger Technologies) offers letter-by-letter spelling features, but little AAC functionality. Research and development to move BCIs out of the laboratory as an access method as a commercial AAC product is growing.[5, 10] The prototype for this National Institutes of Health (NIH) funded study uses a non-invasive electroencephalogram (EEG)-based P300 BCI design [11] because it has been one of the most successful and least cognitively taxing, non-invasive BCI designs for communication.[6, 12] In the AAC-BCI prototype, the P300 BCI provides access to the AAC device software displays of the industry partner.

BCI end-users should be involved in user-centered design efforts.[8, 13] Surveys and focus groups provide insights into the requirements for a clinically useful BCI.[14, 15, 16, 17, 18] New algorithms support independent usage by enabling self-paced selections and automatic detection of when the BCI is available to the user but not actively in use.[19, 20, 21] Small Business Technology Transfer Research (STTR) projects such as this study are providing consumer-centered evidence to support commercialization of an AAC-BCI system.

AAC clinical services are provided as interprofessional practice (IPP) as defined by the World Health Organization.[22] IPP occurs when multiple service providers provide comprehensive healthcare by working with individuals and their families/caregivers to deliver the highest quality of care across settings.[23] IPP teams delivering AAC services include speech language pathologists (SLPs), occupational and physical therapists, AT specialists, and rehabilitation engineers. In the United States, the SLP is designated as the team member responsible for conducting the comprehensive evaluation and trial for an SGD for funding by the Centers of Medicare and Medicaid Services (CMS).[24] IPP collaboration is pivotal for successful treatment. However, the trend toward increasing end-user involvement in BCI research has (with only one known exception[25]) not been extended to IPP professionals. This study recruited IPP team members working in AAC technology to provide feedback and opinions on AAC-BCI design during the research and development phases and thus contribute to technology transfer and commercialization.

Methods

Qualitative research methods based on a grounded theory (GT) approach [26, 27] were used to gather field opinions from IPP AAC practitioners who provide clinical services to individuals who might benefit from an AAC-BCI system. GT applies systematic inductive reasoning and researcher-based coding of data to identify as many categories as possible to stimulate conceptual ideas. Data were collected using focus groups with a follow-up survey as a triangulation method.[28, 29] Participants were recruited through notices posted on professional

discussion lists, a distribution list provided by the industry partner, and local clinics near the universities.

Focus group procedures

Focus groups were held at two university settings and a location of the industry partner. Informed consent was obtained prior to a one-hour discussion. Inclusion criteria for participants were: 1) therapists or AT professionals who provide AAC services to people with significant physical impairments; and 2) native English language speakers. Participants who had a history of hearing loss were excluded.

The moderator started the discussion with a prepared script describing the research project, discussion process, and ground rules for contributing to the discussion. After participants agreed to the procedures, a 14-minute video on the AAC-BCI project, prototype, and proposed services was shown with the prototype, gel cap and supplies on the conference table. The video covered the following aspects of prototype development: overview of commercialization stages, how EEG BCIs work, prototype hardware and software, gel and dry electrode headgear, calibration, and proposed services. Figure 1 depicts images from the video representing the design of the AAC-BCI at the time of this study.

The moderator opened the discussion with the first open-ended prompt: "I'm going to start the discussion by asking your thoughts about the AAC-BCI device" and promoted comments, critiques and discussion among participants, allowing for a type of "structured eavesdropping." Also, the moderator employed typical techniques[30, 31] to encourage contributions related to the prompts such as "what do you consider a primary feature?", "what else could you add to that comment?" For example, moderator pausing was timed to allow all participants at least one opportunity to add input, which helps in building group dynamics that elicit more critiques.[32] The moderator ensured that no one participant dominated the discussion or shifted the discussion away from a topic introduced by another participant (despite possible relevance to AAC service delivery).

At the end of the focus group, participants were given an access code to complete a Qualtrics survey (Qualtrics, Provo, UT). The Likert-type scale survey contained 4 questions about the participants' background and 24 questions about the AAC-BCI prototype and topics covered in the video. A comment field was provided after each question and at the end of the survey to reinforce the value of participant opinions.

Data Analysis

Focus groups were video recorded and transcribed. Researchers were trained in language sampling word-by-word transcription procedures and achieved intrarater (agreement among repeated measures by single rater)[33, 34] reliability at 98% or above prior to working on research data. The video recordings were transcribed for each focus group. Transcribers wore earphones to cancel out background noise in the laboratory and improve the audibility of the recorded discussions during transcription. The transcriptions from each focus group were merged into one document in no particular order and then loaded into NVivo Quantitative Data Analysis Software (QSR International Pty Ltd. Version 12, 2018) for further analysis.

Researchers were trained in NVivo to conduct a thematic analysis [35, 36] to identify patterns and emerging themes or topics that appeared in the merged transcript. NVivo allows for inductive methods and coding to identify themes using word search strategies with an annotation tool to record impressions. General themes were further divided into more specific subthemes

based on the hierarchical relationships found during analysis. As results were evaluated, researchers used the text search and visualization features to support findings.

Researchers were trained in survey development, survey data analysis and use of the Qualtrics (Qualtrics, Provo, UT) program. A different research team worked on survey development than the team performing the NVivo coding to avoid survey questions influencing theme and subtheme coding. Only the principal investigator was common to both teams. Although Qualtrics automatically calculated the results for each survey question, researchers were able to select the methods of statistical calculations reported once the NVivo coding was completed. Researchers also selected how the data were visualized to compare survey results with the analysis of themes to support triangulation and interpretation of the data.

Results

Reliability

Interrater reliability and interjudge reliability were calculated for the transcription and theming processes.[33, 34] Interrater reliability among three researchers was 98% for 20% of the transcripts for word-by-word agreement. In the case of a disagreement, interjudge reliability was used to establish 100% reliability. The same process was used with NVivo for identifying themes and subthemes. All themes and comments were reviewed and discussed among three judges, one of whom was not one of the data coders. Agreement of 100% was achieved for interjudge reliability of the themes and subthemes. Survey results were automatically compiled in Qualtrics and compared with the coded NVivo results. The study theme and survey results were reviewed by the principal investigator and commercial partner not involved in the reliability and data analysis processes as a final peer review step.

General focus group participant information

The three focus groups had a total of 12 individuals who also completed the Qualtrics survey (three males and nine females, ages from 20-30 year-olds to over 60). Table 1 summarizes participants' demographic and professional background information. The participants included nine professional SLPs, two professional AT specialists, and one rehabilitation engineer.

Participants represented a range of experience providing AAC services with 50% (6/12) having 0-7 years, 8% (1/12) having 8-15 years and 42% (5/12) having more than 16 years of AAC service experience. Most participants reported spending more than half their weekly clinical service time on AAC (Table 1 and Figure 2).

AAC-BCI response themes

Six (6) major themes were identified and ranked by NVivo automatically based on the amount of discussion: 1) design; 2) services; 3) headgear; 4) set-up and calibration; 5) effectiveness; 6) ethics. Each major theme was divided into subthemes to clarify the perspectives of the participants.

Design

Design had the largest number of comments and was divided into five subthemes: 1) device appearance; 2) comfort; 3) durability; 4) ease-of-use; and 5) software. ***Appearance*** described the appearance of the AAC-BCI device (concerns about the user's appearance focused on the headgear and are discussed below). Appearance concerns first centered on the extra

components needed by an SGD to provide BCI access such as the EEG amplifier, which were thought to increase size and decrease portability. Secondly, participants wanted a design that accommodated access both in bed and from a wheelchair. Overall, participants wanted a smaller, lighter, portable, integrated AAC-BCI system.

All comments regarding ***comfort*** were related to the headgear. Regardless of type, the headgear should not place any pressure on the head, be itchy, or cause friction or rubbing to create discomfort. Participants felt that the headgear should be comfortable for a long wearing time in various positions, i.e. resting the head on a pillow in bed or against the headrest of a wheelchair were mentioned. Although expected wearing time was not mentioned by participants.

Participants commented that a ***durable*** commercial AAC-BCI product should be expected to last the five (5) years required before seeking to upgrade an SGD based on current CMS funding policies. Participants also expressed durability concerns about the security or stability of positioning and mounting the device to a bed or wheelchair.

Ease-of-use was identified as a subtheme within Design, with varied opinions about what constitutes ease-of-use. Although most participants agreed that the AAC-BCI device may be intimidating at first encounter, they indicated that the device did not appear to be hard to use after training. Participant comments focused on the requirement of learning and the need for training. Participants did not separate learning to use the communication software from learning the procedures for BCI access. Two relevant comments were the need for the system to be intuitive and that the device should be useable by the least capable caregiver.

The communication ***software*** used by the AAC speaker was identified as a design component. Consensus occurred across focus groups on the principle that the language software should remain consistent as alternative access methods change for AAC speakers experiencing progressive degeneration of abilities. In addition, participants agreed that communication software should have flexible options (language representation methods). Specifically, letter-by-letter spelling should not be the only language representation method to generate messages, but the software should include other methods such as symbol/icon representation. In addition, flexibility of the software should allow for use by populations with different ability levels. To quote one participant, "always lean on the side of having more (software) options." Finally, participants had design and feature recommendations to improve the user interface or software display (Table 6).

Several survey questions related to design qualified the opinions expressed by focus group participants. In general, participants responded to the survey by providing agreement and neutral responses to questions which was consistent to feedback and opinions provided during the discussions. Table 2 represents the response frequency for design features. While 67% of respondents agreed that the appearance of the AAC-BCI headgear (see Figure 3) was pleasing and consistent with other high-quality technology, 17% gave a neutral response. While 67% of respondents agreed that the durability (endurance, resistance to breakage) appeared consistent with other high-quality computer-based technology, still 17% remained neutral on this question. Survey responses showed mixed results regarding ease-of-use. For example, 58% of respondents agreed that the AAC-BCI appeared as easy to use as other computer-based technology. However, 25% remained neutral and 17% disagreed with this statement. In addition, 50% of respondents agreed on the ease of making adjustments to the software while 42% remained neutral and 8% strongly disagreed. Only the opinion that the AAC-BCI appeared to be safe and secure once set-up achieved 100% agreement.

Service

Service feedback was categorized into five subthemes: data logging, training, professional services, follow-up, and repair. Participants all agreed on the ***data logging*** subtheme **(**Figure 4), that is on the importance of monitoring and measuring communication performance not only for persons using the AAC-BCI devices, but any AAC technology. One participant identified log file data as "hard" data and others noted that these data supported evidence-based practice, therapy planning, reinforcement, and encouragement

Training was a key subtheme for a commercial SGD with BCI access. All focus groups agreed that different training programs were needed for practitioners and for caregivers and users. Further, participants were convinced that training on the language software is separate and distinct from training on BCI as the access method. To quote one participant, "knowing the language system…is first and foremost." Participants were convinced that the SLP should teach the device and that resources for training and practice should be available for clinical services. Finally, they agreed that competency in operational skills should be evaluated to ensure independence of the user and the caregiver team. Comments on who conducts trainings were included in the ethics theme.

The ***professional services*** subtheme overlapped with the training subtheme with comprehensive services emphasized as critical. However, participants did not clearly differentiate the roles of the manufacturer and practitioners. Participants felt that contacting a manufacturer should result in quick access to support. A critical feature of practitioner services was to verify that set-up, installation, and training was properly done for long-term use.

Comments verified that the ***follow-up*** and ***repair*** subthemes are needed services after purchase. Participants expected follow-up to be provided by the manufacturer with an emphasis on the qualifications of employees providing the service. Specific services mentioned included warranties and access to a help desk. Video calls were suggested for live chats. Suggestions related to repairs included the need for easy access to quality technical support with loaner devices. A participant quote that summarizes the comments on these subthemes was "with high tech solutions come high tech problems."

The **survey** responses (Table 3) did not offer new insights into these service areas. Respondents (75%) agreed that the proposed training program (3-4 day intensive hands-on workshop for clinicians with continuing education units available, 1 day intensive workshop for family members) appeared well-planned to develop the necessary skills of the trainee. That the proposed repairs and maintenance servicing appeared convenient for problem resolution was agreed with by 75% of respondents and the proposed technical support services appeared easy to access was agreed with by 67% of respondents. Monitoring performance using the data logging feature was agreed as beneficial and important by 100% of respondents.

Headgear

Participant opinions on the **type of headgear** considered an EEG gel cap and a dry electrode headset (Figure 3). Overall, the gel cap was a bigger concern for participants who mentioned set-up challenges, cleaning, care, and durability. Participants felt that the dry electrode headset appeared "less medical" and had futuristic appeal. Suggestions were offered to increase acceptance by enhancing the attractiveness of the headgear.

The survey results showed a strong trend toward dislike of the gel cap's appearance. Yet, a trend in agreement was found that the set-up for the gel-cap was acceptable. The likelihood of using the gel-cap with an AAC-BCI user was rated from 5 and above (on a 10-point

scale). Similarly, the likelihood of using the dry electrode helmet was rated 5 or above with slightly higher scores. However, for both types of headgear, performance (accuracy and rate) superseded preference in headgear. In other words, professionals would select or recommend the highest-performing headgear.

Set-up and Calibration

Opinions on the **set-up and calibration** of the AAC-BCI prototype focused on time requirements, positioning of the user, and dependence on the system operator. Participants repeatedly commented that the initial set-up and calibration process appeared quite time-consuming before the person could use the AAC-BCI system for independent communication. However, positive comments were repeated about not having to re-calibrate for every use.

Survey results reinforced that both setup and calibration appeared time consuming and required training from a well-trained practitioner. However, some survey responses reflected split opinions. The responses were spread among the various ranges for both the question on whether the set-up process appeared complicated (Table 4) and on whether the calibration process appeared difficult. However, slightly more people felt it would not be difficult. Written survey comments reflected concern for the time required to train a person and suggested having both face-to-face and written instructions.

Effectiveness

Discussion about the **effectiveness** of the AAC-BCI focused on type of use and performance outcomes. The participants' comments identified the importance of face-to-face communication while performance was identified as rate of communication and reducing keystrokes. Although environmental control features remain unfunded, participants expressed the value environment controls have to overall quality-of-life and independence at no added cost. One remark ranked environmental control over email and even communication. Survey results indicated a strong trend in agreement that the AAC-BCI would meet the needs for daily communication, email, and environmental control (Table 5).

Ethics

The participants expressed concerns related to **ethical** issues for practitioners providing BCI-related clinical services. Participants agreed that the SLP needed to be independent from an AAC manufacturer and fully inform the user of available options. Consensus was not achieved on the roles and responsibilities of various providers. The idea of independent "centers of excellence" for conducting trainings, evaluations and guiding treatment was mentioned as ethical considerations related to beneficence and non-maleficence with careful attention to avoid perceptions of manufacturer bias. The survey did not contain questions related to ethics.

Summary of recommendations

Table 6 lists focus group participant recommendations within each theme for improving specific features and support services for commercialization of an AAC-BCI device based on our prototype. Identified items are from both focus group discussion and open-ended survey questions and thus are not prioritized. Items considered proprietary to the industry partner were removed to arrive at a group of features that could be considered essential for any commercial AAC-BCI product.

Discussion

Focus group participants expressed overwhelming support for the commercialization of an AAC-BCI device. Enthusiasm for an AAC-BCI available in the near future as an alternative access option for clients was tempered by realistic expectations of improving the current prototype based on testing. Although each focus group suggested improvements to the prototype or associated services, survey responses indicated satisfaction with the overall direction of the prototype. Focus group participants reached strong agreement on satisfaction and suggestions. Participants' survey responses showed a wider range of opinions upon reflection.

Focus groups reached consensus that the preferred AAC-BCI hardware would be a commercial AAC system with added BCI components similar to how eye-gaze (camera) components are added to current AAC systems. This approach is gaining acceptance in BCI research [37, 38] and some testing has been performed.[39, 40, 41] However, 75% of the survey responses reflected agreement on the dimensions (size, height) of the prototype (a laptop computer with separate EEG amplifier) as appropriate and acceptable. This suggests that the prototype is acceptable, but not the preferred final solution for a commercial product. In addition, 50% of respondents agreed on the ease of making adjustments to the software while 42% remained neutral and 8% strongly disagreed. Based on focus group discussions, we interpreted these data to reflect the suggestions for improving displays to guide independent set-up and calibration by the user.

Participants expressed a strong trend toward agreement about services, however, neutral responses surfaced on the survey. During the discussion, participant comments reflected an expectation of services typically provided by AAC manufacturers such as technical support, warranties, loaner devices, and training. However, participants may have been more cautious in survey responses about services since details were not provided. Comments related to ethics were tied closely to clinical and manufacturer services. The ethical principles of beneficence and non-maleficence were associated with services provided by IPP clinicians. For example, beneficence requires that the clinician develops and maintains a high level of knowledge and skills and is trained in the most current and best practices to maximize benefit to the AAC-BCI user. Non-maleficence was associated with comments related to doing no harm or showing no manufacturer bias or conflicts of interest in decision-making.

Introduction of a new commercial alternative access product would require training on the AAC-BCI device prior to trialing the device with a user. Access and availability of AAC training has been identified as a limitation for clinical AAC providers.[2] Training to build knowledge and skills of AAC-BCI technology and clinical practices is even more limited. Notably, the proposed 3-4 day workshop to train clinicians exceeds the training available for most AAC devices. However, training availability must be considered when selecting an AAC-BCI device for an individual.[5] Without proper training practitioners may rely too heavily on the manufacturer, creating bias toward a particular device or access method offered by the manufacturer. One participant summarized the overall focus group opinions, "Providing ethical practices and services is critical. Manufacturers should not be providing the overall BCI training and their role needs to be clearly defined with barriers to manufacturers conducting assessments".

Interactive daily communication and email communication with family were the primary goals expressed by participants. Effectiveness and competence were considered the standards for performance measurement, especially for the language program. One participant commented

"keep in mind we (society) are moving away from face-to-face communication for the internet." Overall, communication effectiveness was perceived as a critical quality. This echoed the opinion of end-users.[18]

Study Limitations

Focus group participants represent a convenience sample from a limited geographical region of the United States. Although all participants represent professions frequently represented in IPP AAC teams, a majority were SLPs. Given recruitment procedures, SLPs were the earliest respondents and available on the target dates. The high response rate for SLPs may reflect increased motivation related to their role and responsibility in the AAC assessment process required by CMS in the United States. Participants did not use the AAC-BCI but responded to a video demonstrating its use with some components (prototype, gel cap and supplies) available to view/handle during the discussion.

Conclusions

Clinical practitioners working with individuals using current SGDs are enthusiastic about BCIs as a new access method. Many of their comments on AAC-BCI design mirror those of end-users, including the importance of communication performance and effectiveness as an overriding concern that supersedes some inconveniences of device usage. However, their experience in AAC service delivery leads them to identification of the crucial importance of durability, warranties, and prompt and reliable support services for the sustainability of BCI as a clinical device. They also raise unique ethical concerns regarding appropriate training not only of end-users and their caregivers, but also of practitioners so that AAC-BCI provision is insulated from the potential self-interest of manufacturers. These insights provide valuable guidance to support the research and development of AAC-BCI products toward market readiness.

References

1. Hill, K. Advances in augmentative and alternative communication as quality-of-life technology. Phys Med Rehabil Clin N Am 2010:21:43-58.
2. National Academies of Sciences, Engineering, and Medicine (NASEM). (2017). The Promise of Assistive Technology to Enhance Activity and Work Participation. Washington, DC: The National Academies Press. https://doi.org/10.17226/24740.
3. Beukelman, D. R., & Mirenda, P. (2013). Augmentative and alternative communication: Supporting children & adults with complex communication needs. Baltimore, MD: Brookes.
4. Chen, S. K., & O'Leary, M. (2018). Eye gazing 101: What speech-language pathologist should know about selecting eye-gaze augmentative and alternative communication techniques. Perspectives of the ASHA Special Interest Groups, 3(1), 1-9.
5. Hill, K., Kovacs, T., & Shin, S. (2015). Critical issues using brain-computer interfaces for augmentative and alternative communication. Arch Phys Med Rehabil, 3, 96, S8-15. Doi:10.1016/j.apmr.2014.01.034
6. Sellers, E. W., T. M. Vaughan & J. R. Wolpaw. (2010). A brain-computer interface for long-term independent home use. *Amyotrophic lateral sclerosis : official publication of the World Federation of Neurology Research Group on Motor Neuron Diseases*, 11**,** 449-455.
7. Wolpaw, J. R., R. S. Bedlack, D. J. Reda, R. J. Ringer, P. G. Banks, T. M. Vaughan, S. M. Heckman, L. M. McCane, C. S. Carmack, S. Winden, D. J. McFarland, E. W. Sellers, H. Shi, T. Paine, D. S. Higgins, A. C. Lo, H. S. Patwa, K. J. Hill, G. D. Huang & R. L. Ruff. (2018). Independent home use of a brain-computer interface by people with amyotrophic lateral sclerosis. *Neurology*, 91**,** e258-e267.
8. Botrel, L., E. M. Holz & A. Kübler (2015) Brain Painting V2: evaluation of P300-based brain-computer interface for creative expression by an end-user following the user-centered design. *Brain-Computer Interfaces*, 2**,** 135-149.
9. Holz, E. M., L. Botrel, T. Kaufmann & A. Kubler (2015) Long-term independent brain-computer interface home use improves quality of life of a patient in the locked-in state: a case study. *Archives of Physical Medicine and Rehabilitation*, 96, S16-26.
10. Gosmanova, K. A., Carmack, C. S., Goldberg, D., Fitzpatrick, K., Zoltan, B., Zeitlin, D. M., … Vaughan, T. M. (2017). EEG-Based Brain-Computer Interface Access to Tobii Dynavox Communicator 5. *RESNA*.
11. Farwell, L. A., & Donchin, E. (1988). Talking off the top of your head: toward a mental prosthesis utilizing event-related brain potentials. *Electroencephalography and Clinical Neuropsychology*, 70, 510-523.
12. Zickler, C., Halder, S., Kleih, S. C., Herbert, C., & Kubler, A. (2013). Brain painting: usability testing according to the user-centered design in end users with severe motor paralysis. *Artificial Intelligence in Medicine, 59*(2), 99-110. doi:10.1016/j.artmed.2013.08.003
13. Liberati, G., A. Pizzimenti, L. Simione, A. Riccio, F. Schettini, M. Inghilleri, D. Mattia & F. Cincotti. (2015). Developing brain-computer interfaces from a user-centered perspective: Assessing the needs of persons with amyotrophic lateral sclerosis, caregivers, and professionals. *Appl Ergon*, 50**,** 139-46.
14. Huggins, J. E., A. A. Moinuddin, A. E. Chiodo & P. A. Wren (2015) What would brain-computer interface users want: opinions and priorities of potential users with spinal cord injury. *Archives of Physical Medicine and Rehabilitation*, 96**,** S38-45.e1-5.

15. Huggins, J. E., P. A. Wren & K. L. Gruis. (2011). What would brain-computer interface users want? Opinions and priorities of potential users with amyotrophic lateral sclerosis. *Amyotrophic Lateral Sclerosis,* 12**,** 318-324.
16. Collinger, J. L., M. L. Boninger, T. M. Bruns, K. Curley, W. Wang & D. J. Weber (2013) Functional priorities, assistive technology, and brain-computer interfaces after spinal cord injury. *Journal of rehabilitation research and development,* 50**,** 145-160.
17. Zickler, C., V. Di Donna, V. Kaiser, A. Al-Khodairy, S. Kleih, A. Kübler, M. Malavasi, D. Mattia, S. Mongardi, C. Neuper, M. Rohm, R. Rupp, P. Staiger-Sälzer & E. J. Hoogerwerf. (2009). BCI Applications for People with Disabilities: Defining User Needs and User Requirements. In *Assistive Technology from Adapted Equipment to Inclusive Environments,* eds. P. L. Emiliani, L. Burzagli, A. Como, F. Gabbanini & A. L. Salminen, 185-189. Amsterdam: IOS Press.
18. Blain-Moraes, S., R. Schaff, K. L. Gruis, J. E. Huggins & P. A. Wren (2012) Barriers to and mediators of brain-computer interface user acceptance: focus group findings. *Ergonomics,* 55**,** 516-525.
19. Aloise, F., P. Aricò, F. Schettini, S. Salinari, D. Mattia & F. Cincotti. (2013). Asynchronous gaze independent event-related potential-based brain-computer interface. *Artif Intell Med,* 59**,** 61-9.
20. Aydin, E. A., O. F. Bay & I. Guler. (2018). P300-Based Asynchronous Brain Computer Interface for Environmental Control System. *IEEE J Biomed Health Inform,* 22**,** 653-663.
21. Alcaide-Aguirre, R. E., S. A. Warschausky, D. Brown, A. Aref & J. E. Huggins. (2017). Asynchronous brain-computer interface for cognitive assessment in people with cerebral palsy. *J Neural Eng,* 14, 066001.
22. World Health Organization (WHO). (2010). Framework for action on interprofessional education & collaborative practice. Retrieved from https://apps.who.int/iris/bitstream/handle/10665/70185/WHO_HRH_HPN_10.3_eng.pdf;jsessionid=A9C3C1522745A4EC5705CCB8D0C68CE1?sequence=1
23. American Speech-Language-Hearing Association (ASHA). (2019). Interprofessional Education/Interprofessional Practice. Retrieved from https://www.asha.org/Practice/Interprofessional-Education-Practice/
24. American Speech-Language-Hearing Association (ASHA). (n.d.). Medicare speech-generating devices information. Retrieved from https://www.asha.org/SLP/healthcare/Medicare-Speech-Generating-Devices-Information/
25. Zickler, C., Al-Khodairy, A., Kubler, A., Hoogerwerf, E., Kleih, S., Rohm, M., Mattia, D., … Kahane, P. (2010) "BCI-Applications: Needs and requirements of disabled end-users and professional users. 4th Int'l BCI Meeting, D-4.
26. Glaser, B. G., Strauss, A. L., & Strutzel, E. (1968). The discovery of grounded theory: strategies for qualitative research. Nursing Research, 17(4), 364.
27. Glaser, B. G., & Strauss, A. L. (2017). The discovery of grounded theory: strategies for qualitative research. NY: Routledge. ISBN 13:978-0-202-30260-7.
28. Patton, M. Q. (1999). Enhancing the quality and credibility of qualitative analysis. *Health Services Research, 34*(5 Pt 2), 1189-1208.
29. Heale, R., & Forbes, D. (2013). Understanding triangulation in research. *Evidence Based Nursing, 16*, 98. doi: 10.1136/eb-2013-101494.

30. Basch, C. E. (1987). Focus group interview: An underutilized research technique for improving theory and practice in health education. *Health Education Quarterly, 14*(4), 411-448.
31. Kitzinger, J. (2005). Focus group research: using group dynamics to explore perceptions, experiences, and understandings. In Holloway, *Qualitative Research in Health Care* (pp. 56-71). New York, NY: Open University Press.
32. Holloway, I. (2005). *Qualitative Research in Health Care.* New York, NY: Open University Press.
33. Hill, K. Kovacs, T., & Shin, S. (2014). Reliability of brain-computer interface language sample transcription procedures. *JRRD, 51*(4), 579-590. doi:10.1682/JRRD.2013.05.0102
34. Kovacs, T., & Hill, K. (2015). A Tutorial on Reliability Testing in AAC Language Sample Transcription and Analysis. *Augmentative and Alternative Communication, 31*(2), 159-169. doi:10.3109/07434618.2015.1036118
35. Boyatzis, R. E. (1998). Transforming qualitative information: Thematic analysis and code development. Thousand Oaks, CA: Sage.
36. Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, *Qualitative Research in Psychology, 3*(2), 77–101.
37. Brumberg, J. S., Nieto-Castanon, A., Kennedy, P. R., & Guenther, F. H. (2010). Brain-computer interfaces for speech communication. Speech Communication, 52(4), 367-379. doi:10.1016/j.specom.2010.01.001
38. Millan, J.D., Rupp, R., Muller-Putz, G. R., Murray-Smith, R., Giugliemma, C., Tangerman, C., … Mattia, D. (2010). Combining brain-computer interfaces and assistive technologies: state-of-the-art and challenges. *Frontiers in Neuroscience, 4*, 161. doi:10.3389/fnins.2010.00161
39. Thompson, D. E., Gruis, K. L., & Huggins, J. E. (2013). A plug-and-play brain-computer interface to operate commercial assistive technology. Disability and Rehabilitation: Assistive Technology, 9(2), 144-150. doi:10.3109/17483107.2013.785036
40. Huggins, J. E., Alcaide-Aguirre, R. E., & Hill, K. (2016). Effects of text generation on P300 brain-computer interface performance. Brain-Computer Interfaces, 3(2), 112-120. doi:10.1080/2326263X.2016.1203629
41. Ryan, D. B., Frye, G. E., Townsend, G., Berry, D. R., Mesa-G, S., Gates, N. A., & Sellers, E. W. (2010). Predictive spelling with a P300-based brain-computer interface: increasing the rate of communication. International Journal of Human-Computer Interaction, 27(1), 69-84. Doi:10.1080/10447318.2011.535754.

Suppliers

NVivo Quantitative Data Analysis Software (QSR International Pty Ltd. Version 12, 2018)
Qualtrics (Qualtrics, Provo, UT)

Tables

Table 1. Demographic summary of focus group participants

Variable		n	%
Sex	Male	3	25
	Female	9	75
Age range	20-30 years	5	42
	31-40 years	1	8
	41-50 years	2	17
	51-60 years	3	25
	>60 years	1	8
Professional background	SLP	9	75
	Assistive Technology (AT) Specialist	2	17
	Rehabilitation Engineer	1	8
AAC service experience range	0-7 years	6	50
	8-15 years	1	8
	>16 years	5	42
AAC clinical effort range per week	0-25%	2	17
	25-50%	1	8
	50-75%	5	42
	>75%	4	33

Table 2: Survey responses related to design

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q3. Finding a permanent home location and storage of supplies for the AAC-BCI will be difficult for most families.	5 (41.67%)	3 (25%)	1 (8.33%)	1 (8.33%)	2 (16.67%)
Q4. Internet for the AAC-BCI is likely to be unavailable for most families.	2 (16.67%)	4 (33.33%)	3 (25%)	2 (16.67%)	1 (8.33%)
Q6. The dimensions (size, height, length, width) of the AAC-BCI appeared appropriate and acceptable.	0 (0%)	0 (0%)	3 (25%)	7 (58.33%)	2 (16.67%)
Q7. The overall appearance of the AAC-BCI hardware appeared pleasing and consistent with other high quality technology.	0 (0%)	2 (16.67%)	2 (16.67%)	6 (50%)	2 (16.67%)
Q10. The ease of making adjustments (customizing for an individual) to the communication software of the AAC-BCI appeared acceptable.	1 (8.33%)	0 (0%)	5 (41.67%)	2 (16.67%)	4 (33.33%)
Q11. The AAC-BCI appeared to be safe and secure once set-up for the individual.	0 (0%)	0 (0%)	0 (0%)	5 (41.67%)	7 (58.33%)
Q12. The durability (endurance, wear and tear, resistance to breakage) of the AAC-BCI appeared consistent with other high quality computer-based technology.	0 (0%)	2 (16.67%)	2 (16.67%)	5 (41.67%)	3 (25%)
Q13. The AAC-BCI appears as easy to use as other computer-based technology for an individual.	0 (0%)	2 (16.67%)	3 (25%)	4 (33.33%)	3 (25%)
Q14. The AAC-BCI appears to be comfortable for an individual to use.	0 (0%)	1 (8.33%)	4 (33.33%)	5 (41.67%)	2 (16.67%)

Table 3. Survey responses related to service.

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q18. Monitoring the performance using the data logging feature would be beneficial and important.	0 (0%)	0 (0%)	0 (0%)	4 (33.33%)	8 (66.67%)
Q19. The proposed training program (procedures, length of time to learn) appeared well planned and would develop necessary knowledge and skills.	0 (0%)	1 (8.33%)	2 (16.67%)	4 (33.33%)	5 (41.67%)
Q20. The proposed repairs and servicing (maintenance) would be convenient to have problems resolved.	0 (0%)	0 (0%)	3 (25%)	2 (16.67%)	7 (58.33%)
Q21. The proposed professional services (regional consultants, information, attention) would be comprehensive and beneficial.	0 (0%)	0 (0%)	2 (16.67%)	3 (25%)	7 (58.33%)
Q22. The proposed follow-up services (technical and continuing support services) will be easy to access.	0 (0%)	0 (0%)	4 (33.33%)	2 (16.67%)	6 (50%)

Table 4. Survey responses related to AAC-BCI set-up and headgear

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q1. The set-up process for the AAC-BCI did not appear complicated	1 (8.33%)	3 (25%)	3 (25%)	2 (16.67%)	3 (25%)
Q2. The calibration process for the AAC-BCI appeared difficult.	3 (25%)	4 (33.33%)	2 (16.67%)	1 (8.33%)	2 (16.67%)
Q5. Washing the current gel-based AAC-BCI headgear peripherals appears acceptable.	0 (0%)	5 (41.67%)	2 (16.67%)	2 (16.67%)	3 (25%)
Q8. The appearance of the current gel-based AAC-BCI headgear peripherals appeared pleasing.	1 (8.33%)	6 (50%)	3 (25%)	2 (16.67%)	0 (0%)
Q9. The ease of making adjustments (setting up) the current gel-based AAC-BCI headgear appeared acceptable.	1 (8.33%)	2 (16.67%)	2 (16.67%)	5 (41.67%)	2 (16.67%)
Q26. My preference for headgear peripheral would remain the same even if they resulted in less accurate performance.	3 (25%)	8 (66.67%)	1 (8.33)	0 (0%)	0 (0%)
Q27. My preference for headgear peripheral would remain the same even if they resulted in slower performance.	3 (25%)	7 (58.33%)	1 (8.33)	1 (8.33)	0 (0%)

Table 5. Survey responses related to overall effectiveness.

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q15. The AAC-BCI system appears to be effective (the degree to which the AAC-BCI meets communication needs) for an individual to use for daily interactive communication.	0 (0%)	0 (0%)	3 (25%)	4 (33.33%)	5 (41.67%)
Q16. The AAC-BCI system appears to be effective (the degree to which the AAC-BCI meets written communication needs) for an individual to use for daily written and email communication.	0 (0%)	1 (8.33%)	2 (16.67%)	5 (41.67%)	4 (33.33%)
Q17. The AAC-BCI system appears to be effective (the degree to which the AAC-BCI functions to control electronic appliances) for an individual to use as an environmental controller.	0 (0%)	4 (33.33%)	2 (16.67%)	1 (8.33%)	5 (41.67%)

Table 6. Summary of recommendations to evaluate and/or add to a commercial AAC-BCI product.

DESIGN: HARDWARE	**DESIGN: SOFTWARE/USER INTERFACE**	**HEADGEAR: GEL & DRY ELECTRODE**	**TRAININGS**	**SERVICES**
• Smaller • Lighter • Portable • Integrated components • Alternative mounting options	*Suggested displays to enhance useability and user preferences* • Calibration display • Status display (active/pause indicator) • Performance display (usage measures) • Warning notice • Undo key • Variety of software options to select.	• Comfort • Attractiveness – color choices, head cover choices • Wig solutions • Wear in bed & in wheelchair • Doesn't rub Doesn't itch	• Trainings based on role • Less training time for caregiver/user • Evaluations of knowledge & skills based on training. • Multiple types of training, face-to-face, webinar, etc. • Resource materials • Independence from manufacturer	• Manufacturer & clinical services • Video chat for technical support • Warranties • Repairs • Technical support • 24/7 technical support • Identify qualifications of technical support • Centers of excellence to conduct evaluations

Figure Legend

Figure 1. Images from the video that represent the design of the AAC-BCI as presented to the focus group participants
Figure 2. Pie chart representing percentage of focus group participants' weekly clinical service time dedicated to AAC
Figure 3. Photo comparing BCI headgear types: gel electrode cap (left) and dry electrode headset (right)
Figure 4. Bar graph representing responses to importance of data logging feature (Q18)