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Abstract
As brain-computer interface for augmentative and alternative communication access (BCI-AAC) development continues to consider avenues for translation into the clinical setting, the perspectives of clinician experts in AAC should be considered. Therefore, 11 USA-based speech-language pathologists who are experts in AAC completed a semistructured interview along with Likert scale measures to assess their perspectives on BCI-AAC. The interviews and scales explored the potential impact of BCI-AAC, along with barriers and solutions to BCI-AAC implementation. Speech-language pathologists estimated that 1.5% to 50% of their caseload may benefit from BCI-AAC across various settings. Further, identified barriers and solutions included (a) BCI-AAC

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implementation and support, (b) funding and access, (c) applicability and literacy skills, (d) assessment and training in supporting outcomes, and (e) motivation and customization. Results reinforce and extend existing directions for BCI-AAC translation such as user-centered assessment, stakeholder support, and populations who may benefit from intervention, such as children.

Keywords: Brain-computer interface, augmentative and alternative communication, funding; customization, translation; assessment, training; clinical

High technology augmentative and alternative communication (AAC) techniques utilize computer software to produce auditory and text-based messages that may give individuals with complex communication needs a voice to bolster their participation and overall well-being. For instance, an individual with severe physical impairments may access high technology AAC devices via eye-tracking systems to create messages by orienting their eyes on a desired communication item, such as a word or letter, and then perform a predetermined action for the item selection [e.g. an extended gaze fixation or dwell; 1]. The field of AAC serves a heterogeneous population of individuals who each present their own unique cognitive, sensorimotor profile and preferences. AAC intervention is not a one-size-fits-all process; rather, it is designed to maximize each individual's unique cognitive- sensory-motor and linguistic strengths to support communication success [2]. Currently, some individuals with complex communication needs may find existing AAC system access methods ineffective or inefficient due to severe physical impairments [e.g. 3, 4]. Thus, it is crucial that the field of AAC continue to explore new technologies, such as brain-computer interface technologies (BCI), to provide individuals with an efficient form of AAC access that matches their unique and changing profile across their life span [e.g. 5].

Non-invasive BCI for augmentative and alternative communication access (BCI-AAC) may provide an avenue for AAC device control without requiring physical movement. Non-invasive BCI-AAC commonly utilizes electroencephalography (EEG) techniques [e.g. 6]. To use EEG-based BCI-AAC techniques, the individual wears an EEG cap which records brain activity at the level of the scalp. The BCI-AAC software then extracts specific brain activities and translates that activity into communication device control, such as a letter selection or cursor movement. Different types of BCI-AAC devices are in development which target a range of brain activities, such as those associated visually evoked potentials and modulation of one’s attention (e.g. auditory and visual P300, steady state visually evoked potentials, and auditory steady state response), and sensorimotor modulations (e.g. though the performance of motor imagery or attempted/executed movements). One specific BCI-AAC example is based on the P300 event-related potential. Specifically, to control a P300-based BCI-AAC device, the individual focuses their attention on a desired or novel communication element (e.g. a specific letter in a grid), while all items within the grid are randomly highlighted. Approximately 300 ms after the target element is highlighted, a positive deflection occurs in the EEG signal. This positive deflection is known as the P300 event-related potential. After multiple target highlights, the BCI-AAC then selects the item co-occurring with the P300 brain response [7]. Other BCI-AAC techniques exist, but a detailed review of BCI-AAC techniques is beyond the range of this paper. Therefore, readers are referred to 8, and 2, for a review of commonly used BCI-AAC methods.

As BCI-AAC technology continues to progress in the home and laboratory setting [e.g. 9], it becomes increasingly important to consider the challenges and solutions associated with the translation of BCI-AAC technology to clinical practice [e.g. 10, 11]. The field of AAC is inherently multidisciplinary with optimal AAC services occurring with a team-based approach [12]. Further, incorporating a range of stakeholder perspectives, including those of AAC professionals, individuals using AAC, and their support networks, during research and development is a key element of implementation research and the translation of basic science innovations into real-world practice [13,14]. For example, both implementation science [e.g. 14] and user-centered design frameworks [e.g. 15–17] note the importance of iteratively including a range of stakeholders in BCI-AAC design development. Additionally, the inclusion of a variety of stakeholders assists with the development of research trajectories and enables multidisciplinary teams to pursue shared goals [18]. Therefore, to support user centered BCI-AAC design and development, BCI-AAC research has begun recognizing the importance of incorporating diverse feedback to elucidate individuals’ experiences using BCI-AAC systems, existing barriers to everyday use, person-centered outcomes, and desired BCI-AAC functions to support participation [e.g. 3, 9, 10, 19–23].

BCI-AAC development may additionally benefit from identifying multidisciplinary clinical viewpoints including those of the professionals prescribing AAC systems [14,17]. Therefore, to date, a limited number of studies have sought the perspective of AAC interventionists regarding BCI-AAC development and translation [e.g. 4, 17, 24–26]. These studies have laid a crucial foundation for BCI-AAC research. Of most relevance, a survey by 25, identified that physician specialist caring for those with severe disability believed communication was an important priority for BCI applications. In addition, a focus group study by 26, explored the viewpoints of a heterogeneous range of rehabilitation professionals including 5 speech-language pathologists [SLPs). Their findings identify a range of considerations for BCI maturation, such as specific diagnoses of individuals who may benefit from BCI intervention, the use of multimodal systems, socially acceptable designs, and improving BCI set up, cost effectiveness, and portability. Further, as multiple barriers to BCI-AAC utilization persist, 26, note obstacles to BCI implementation. For example, their participants describe the negative impacts of cognitive impairment and extraneous movement on BCI control, the cognitive load associated with BCI use, and the need for increased levels of usability and reliability. More recently, an interview study by 4, evaluated the perspectives of two special education teachers, one teacher's aide, and one occupational therapist on BCI-AAC design and implementation. Their findings corroborated those of 26, discussing important concepts such as the need for technical support and effective training methods, bolstering usability and customization, along with developing systematic assessment procedures that incorporate multidisciplinary input. Further, 4, found that while participants indicated that BCI is still in the early stages of development, their experience with the BCI-AAC system parallels current AAC methods, describing that as eye-gaze technology has rapidly progressed toward clinical use these technologies may follow similar developmental paths.

Clinicians may be well suited to identify directions that put patient and family desires at the center of research [25]. As communication professionals who are part of the AAC team, SLPs who are AAC experts may provide valuable perspectives on current barriers to BCI-AAC implementation and provide future research directions for supporting the clinical success of BCI-AAC. Furthermore, AAC experts may serve a variety of clinical populations with severe physical impairments who use AAC. Therefore, they may provide a general snapshot regarding how many individuals on their caseload have difficulties with existing AAC access methods, in addition to providing details regarding current expectations for BCI-AAC devices and avenues to support translation. However, there is currently a paucity of information regarding the perspectives of SLPs who are clinical experts in AAC on BCI-AAC implementation. Therefore, the aim of this study was to investigate the perspectives of SLPs regarding the potential clinical impact of BCI-AAC and identify barriers and solutions to BCI-AAC use. These perspectives may help elucidate clinical attitudes towards BCI-AAC, promote avenues for human-computer interaction, and guide BCI-AAC research and development to support the effective integration of BCI-AAC to existing clinical practice.

1. Methods

Our study included both qualitative semi-structured interviews (hereon referred to as interviews), alongside quantitative methods. Prior to the interview and Likert scale measures being completed, a short presentation about BCI-AAC was given to participants to provide an overview of BCI-AAC methods and provide context for stimulating discussion. This presentation also served to help standardize the knowledge of experts who participated in the study. The presentation included a general description of BCI-AAC recording and set up (e.g. common use of gel), and provided links to six public videos showing different P300, motor (imagery), and steady state visually evoked potential-based BCI-AACs in use, along with the control task to make an item selection (e.g. focus attention on the item they wish to select). Prior to the beginning of each interview, the lead author ensured that the participant viewed the presentation along with answering any questions participants had about the information. Participant interviews began only when any participant questions were answered, and they felt comfortable proceeding.

The interview guide was developed to fill gaps in current literature regarding (a) SLPs' expectations on the possible clinical impact of BCI-AAC and (b) barriers and solutions for BCI-AAC translation. Additionally, the researchers sought to further assess expectations regarding the potential impact of BCI-AAC on the clinical field of AAC, in general, and on participant's specific caseloads. Interviews were completed in a single session via video conferencing lasting approximately 45 minutes. All sessions were audio recorded. To facilitate systematic data collection, all interviews followed a guide. Recruitment began in January 2020, with the lead author completing all interviews between January and May 2020. During interviews, the interviewer asked follow-up questions, and requested clarifications to ensure accurate coding and to further elucidate participants' perspectives.

In addition to the interview, participants completed Likert scales to measure their beliefs about (a) BCI-AAC techniques having the potential to improve the quality of life for a range of individuals who may benefit from AAC interventions and (b) the potential of BCI-AAC to improve the quality of life for those on their caseloads. Participants also rated their openness to implementing BCI-AAC technology in the future. Finally, participants were asked to indicate approximately what percentage of their caseload they thought could benefit from BCI-AAC access technology. All scale measures incorporated a 5-point Likert scale. For scales related to improvement, 1 indicated they *highly disagree* with the statement, and 5, *highly agree*. For openness to future BCI-AAC implementation, 1 indicated *very unlikely*, and 5, *extremely open*. See supplemental material A for the interview guide and associated rating scale questions.

1.1. Participants

The participants for this research were 11 United States-based SLPs who were experts in AAC (10 females, 1 male: M = 44.5 years, SD = 9.8, range = 31–57). The researchers defined AAC experts as those who currently perform roles such as executing AAC research, helping prepare preservice students in AAC, helping prepare AAC policy, and/or having at least 50% of their caseloads dedicated to individuals using AAC, based on 1, and 12. AAC experts employed in a range of settings (e.g. hospital, school, private practice, rehabilitation center, university clinic) were purposefully targeted to help ensure inclusion of a diverse array of participant experiences. Only individuals who were AAC experts with a minimum of two years' experience in AAC service provision were included in this study. All participants exceeded our minimum inclusion criteria for AAC expertise (M = 16.4 years, SD = 9.6, range = 4– 30). Participants 2 through 11 were all currently serving individuals who use AAC in the clinical setting, with at least 50% of their caseload supporting AAC users. Further, P11 reported actively conducting and publishing research related to AAC. P1 was actively conducting AAC research and training preservice AAC professionals, having seen patients who use AAC in the clinical setting until 1.5 years prior to study participation. All participants

Table 1. Participant demographics.

Participant	*Gender*	*Years of Experience in AAC*	*Setting*	*Reported Exposure to BCI-AAC*
P1	Female	4	University Clinic	Previously worked at a university conducting BCI-AAC research
P2	Female	8	University Clinic	Has previously viewed videos on BCI-AAC use
P3	Female	25	School	Has read about BCI-AAC in articles
P4	Female	20	University Clinic	Heard about BCI-AAC spelling-based devices at a conference
P5	Female	30	Private Practice	Has witnessed BCI-AAC device setup and use
P6	Female	10	Rehabilitation Center	A motor-based BCI-AAC device was used for limb rehabilitation at a prior place of work
P7	Female	28	Private Practice	No specific exposure reported
P8	Female	15	Outpatient Clinic /Hospital	Has previously tried BCI-AAC technology
P9	Female	10	Private Practice	Saw a demonstration on BCI-AAC technology
P10	Male	5	Hospital	No specific exposure reported
P11	Female	25	Research & Treatment Center for Those with Severe Physical Impairments	Brief experience noted with BCI-AAC about 20 years ago

reported experience with high technology AAC techniques, such as eye gaze, with P1, P5, P9, P10, and P11 reporting experience with AAC intervention for both children and adults, P4, P6, P7 and P8 with adults, and P2, and P3 with children. See **Table 1** for further participant demographics, including years of AAC experience and exposure to BCI-AAC.

Approval from the institutional review boards at the University of Nebraska–Lincoln and the University of Nebraska Kearney was obtained prior to study commencement. Participants were recruited through word of mouth, social media posts, and direct email, when publicly available. Data collection and analysis were ceased at saturation, when collecting new data no longer revealed new insights, and all members of the research team agreed topics had been discussed in sufficient detail [27]. Specifically, data collection and analysis for this investigation stopped when no new codes were identified for six consecutive participants, and the research team that comprised four members – three certified SLPs (two with experience in AAC implementation and AAC research and one with additional experience in BCI-AAC) and one undergraduate student in speech-language pathology, reached 100% consensus that the identified themes were fully comprehensible.

1.2. Data analysis

Procedures for data analysis were based upon prior qualitative works in the field of AAC [e.g. 28, 29]. All the interviews were audio recorded and transcribed verbatim. After initial transcription, a second graduate assistant checked transcription accuracy, with discrepancies discussed to 100% consensus. Following transcription, files were imported into NVivo software for analysis (QSR International, 30). Using a grounded theory approach [31], interview themes were grouped using NVivo's coding features using a constant comparison approach through which new data were incorporated into the existing coding structure, with new codes added as the latest information emerged [32]. Following coding, a codebook was developed, including the two major themes, six subthemes, and 10 example codes identified (see supplementary material B). Participant statements regarding barriers and solutions could overlap. For instance, a participant stating that BCI-AAC research should incorporate more children could be seen as both a barrier and a solution. Therefore, to improve data clarity and support reliability coding, data regarding barriers and solutions were collapsed into single representative codes. Following codebook generation, the lead author along with a trained graduate assistant reevaluated all transcripts to obtain a subjective assessment of codebook consistency. Codebook discrepancies were discussed among all team members to reach a final consensus. After consensus, an evaluation of reliability was conducted. Specifically, 27% (three of 11) randomly selected interview transcripts were coded independently by a trained research assistant using the codebook. The large number of themes identified in this study reduces the possibility of coding agreements occurring by chance. Therefore, based upon the research of 33, and 29, percent agreement [34] was utilized for evaluating reliability. Intercoder reliability was performed independently until a minimum of 80% accuracy was achieved at the level of the example code by a trained assistant [29]. For the current investigation, we exceeded our minimum requirement with an average of 95.6% ($SD = 7.7$; range: 86.7–100%) intercoder reliability obtained across the three selected interview transcripts. Descriptive statistics including mean, median, range, and standard deviation were utilized for analysis of quantitative measures (i.e. Likert scale measures and caseload reports).

1.3. Data credibility

The researchers used multiple techniques to ensure data quality and credibility including peer debriefing and review, member checking, and triangulation [e.g. 31, 32]. In more detail, the second and third authors both completed peer review analysis of study methods, findings, and conclusions throughout the study. Further, member-checking procedures were completed both during and following the interview. During the interview, member checking was completed to ensure correct understanding by the interviewer by (a) providing summary statements and (b) requesting participants to elaborate on unclear statements. After each interview, a discussion summary was sent to each participant asking them to confirm their ideas were represented accurately. Ten of 11 participants responded to the request, all indicating agreement with summary content. A triangulation methodology was incorporated by utilizing a team approach (including all authors and a trained research assistant) during data analysis to decrease the possibility of lead author bias. Finally, following creation of the codebook, a peer debriefing [35] was completed with one individual who had 25 years' experience related to AAC intervention and research for individuals with severe physical impairments. The peer debriefer agreed that study findings were consistent with current AAC research and directions for clinical practice.

Procedural reliability was tracked via spreadsheet for procedures related to transcription, distribution and receipt of the BCI-AAC presentation, and distribution of participant member checks. All procedures were completed with 98% accuracy as one participant (P10) indicated they did not receive the sent BCI-AAC presentation prior to meeting. Therefore, for P10, the presentation was reviewed/ discussed immediately prior to the interview to ensure consistency with other participants.

2. Results

The following section first outlines interview data, which is arranged by theme, subtheme, and example. **Table 2** provides a summary of identified themes, subthemes, and examples with the full codebook provided in supplemental material B. Next, Likert scale and caseload proportions are discussed, with a summary provided in **Table 3**. A summary of recommendations based on findings is provided in **Table 4**.

Table 2. Themes, subthemes and example codes.

Theme	*Subtheme*	*Example*
Professional expectations for BCI-AAC	Impact	Potential for a large impact for those struggling with AAC access
Barriers and solutions for BCI-AAC translation	BCI-AAC implementation and support	Caregiver and stakeholder training and support
		Helping make BCI-AAC setup simple and intuitive
	Funding and access	Insurance coverage, evidence, and advocacy
		Integrating or adding BCI-AAC with existing AAC access techniques
	Applicability and literacy skills	Children and pictorial displays
	Assessment and training in supporting outcomes	Timely/early access to BCI-AAC devices
		Assessment guidelines
	Motivation and customization participation	Device customization and functional
		Opportunities to learn and explore

Table 3. Number scale data and caseload percentages.

Participant	*Improve quality of life for those who may benefit from AAC*	*Improve the quality of life for individuals on their caseloads*	*Caseload proportion (%)*	*Openness to implementing BCI-AAC in the future*
P1	3	N/A	N/A	5
P2	5	4	30	5
P3	5	5	1.5	5
P4	4	4	15	5
P5	5	5	20	5
P6	5	5	25	4
P7	5	5	7	4
P8	5	5	16	5
P9	5	5	15	5
P10	4	2	10	5
P11	5	5	50	5

Table 4. A summary of considerations for BCI-AAC.

Continue existing efforts to consider BCI-AAC access for a broad range of diagnoses who may struggle with utilizing existing AAC systems.
Consider BCI-AAC access for adults and children with limited and/or emerging language and literacy skills through avenues such as pictorial symbol-based displays, and existing methods to support literacy development (e.g. dynamic text, displays incorporating story book content, and activities incorporating phonological and sight word approaches).
Consider methods for stakeholder support including efforts to make BCI-AAC setup simple and intuitive (e.g. auto calibration), remote support, wireless connectivity, step-by-step instructions within simple user manuals, video/picture tutorials, and hands-on experience with device use, though restricted access to BCI-AAC may prove an existing barrier.
Consider avenues for BCI-AAC integration with existing AAC methods to help support adaptability, alongside engineering advancements that help ensure BCI-AAC is implementable in an easy and timely way, supported with advocacy efforts, and developed through strong evidence-based practice to support future funding coverage.
Continue developing user-centered assessment guidelines across a range of methods that focus on individualization and participatory frameworks, such as precision AAC and feature matching, guided by the ICF model.
Consider avenues for developing flexible and customizable systems (e.g. inclusion of activities and stimuli of relevance, curricular access to support educational inclusion), and access to preferred/motivating activities, in addition to supporting early/timely intervention.

2.1. Interview themes

2.1.1. Impact

During interviews, all 11 of our participants indicated that BCI-AAC has the potential for a large impact on those individuals currently struggling with AAC access, possibly helping individuals become more independent. In more detail, participants described that looking into new AAC access options is beneficial, as some individuals may have difficulty efficiently using existing AAC techniques. Difficulty in accessing the AAC system may ultimately mean these people may be underestimated or 'sold short', as P5 described:

> *There are a lot of truly locked-in people out there. And I think that, in general, people who are completely unable to communicate and may be completely locked in are frequently under—we, we sell them short on what we think their abilities are because they can't communicate, and I think that BCI has the potential to really level that playing field some.*

Further, P8 and P3 succinctly embodied the need for continued AAC development by respectively explaining *'I think looking at alternative options for people is always a good idea. Because I don't, I mean I don't think any of the ones that we have are absolutely perfect for anyone'* and

> *Every day you can do better with our kids. So, I just feel like if something better is out there, you should at least give the opportunity to try it. You can't work in technology and not think that tomorrow there isn't gonna be something better.*

Regarding specific individuals who may have difficulty efficiently accessing existing AAC systems, participants identified a range of diagnoses for whom BCI-AAC may be beneficial including those with muscular dystrophy, spinal muscular atrophy, Rett syndrome, locked in syndrome, amyotrophic lateral sclerosis, cardiovascular accident, cerebral palsy, cortical visual impairment, multiple sclerosis, hypoxic events, spinal cord injury, brain injury, and those who are ventilator dependent. However, while participants felt BCI-AAC had the potential for clinical impact, participants' expectations were cautious, explaining that progress in BCI-AAC development still needs to occur.

2.1.2. Barriers and solutions for BCI-AAC translation

2.1.2.1. BCI-AAC implementation and support. All participants discussed the importance of considering how BCI-AAC devices can be implemented into the lives of those who may use it, along with how to support BCI-AAC implementation by a range of AAC stakeholders. Nine participants specifically discussed the area of caregiver and stakeholder training and support, describing that as caregivers will play a crucial role BCI-AAC setup, maintenance, and troubleshooting, it is important to limit implementation burdens, and help individuals become comfortable and successful in their roles. For instance, P7 stated *'I just really strongly believe that family should be families and that* [e.g. duties associated with device setup, programming] *should be minimal on them'*. It was also described that individuals may be apprehensive about AAC and BCI-AAC technology, and BCI-AAC may not be currently parent- or school-friendly. For example, P3 outlined this concern by stating,

> *I don't feel right now that that BCI is parent-friendly or school team friendly, that I could bring it in and I wouldn't get these*

> *big eyes from school teachers. I bring in an eye gaze system and I get the big eyes.*

To facilitate BCI-AAC use, participants also identified multiple avenues for facilitating training and support, including (a) providing access to knowledgeable personnel in the individual's geographical area, including technical support (e.g. via in-person, phone, telehealth methods), (b) creating video and picture tutorials on device setup and function, (c) providing step-by-step instructions and simple user manuals that are ideally written by a BCI-AAC novice and accessible externally to the device itself, and (d) allowing stakeholders to obtain hands-on experience with BCI-AAC devices.

Five participants also discussed the need for making BCI-AAC setup simple and intuitive. In this regard, it was noted that BCI-AAC setup may currently be difficult and cumbersome due to factors such as wires, electrode placement, and gel application. For example, P6 said,

> *I think that physically, it requires a lot of caregiver assistance in terms of being able to get electrodes in the right places. Certainly, the dry electrodes are a huge benefit over the wet ones. But still I think it just it's, it can be exhausting, and you know sometimes for people who are profoundly impaired the amount of time that it takes to set it up has now completely used up their energy.*

Further, P9 indicated, *'Because that's definitely one of the biggest obstacles, um and like reasons for AAC abandonment. Especially, I mean in pediatrics, is if it's too hard, like if the family deems that it's too hard, then they abandon the device'*. Therefore, participants described the benefit of future research aiming to decrease setup burdens by making the BCI-AAC positioning, electrode placement, and calibration intuitive and quick, possibly by utilizing dry electrode systems. Regarding goals for BCI-AAC setup, P5 explains,

> *If you're simply able to like somehow just put a cap on somebody's head and have it like wirelessly connect to like the technology in the system like that would be like the easiest. You know, like no fuss, no mess, just like put it on. Boom. It's connected. Ah, but I don't know if the technology is at that point where it's able to do that.*

In addition, P5 indicated she hoped BCI technology may become intuitive enough to pass a 3-minute rule, indicating *'if I can't figure out how to do it in three minutes, I'm calling tech support!'*

2.1.2.2. Funding and access. Ten participants described the role of funding in BCI-AAC implementation. Specifically, nine participants discussed the theme of insurance coverage, evidence, and advocacy. In more detail, our experts discussed that BCI-AAC may be costly and obtaining funding for BCI-AAC use is an existing barrier for successful BCI-AAC device implementation, as P1 explained:

> *Getting partial or full coverage for that [BCI-AAC], I mean, that is a huge thing. I just feel like for it to be practical and be used in the clinic we have to get over that hump for insurance and covering it.*

Further, in addition to funding for the device itself, P5 described the importance of considering funding for the time it takes to complete BCI-AAC assessments, noting:

> *So, it's not just enough that they pay for the equipment, they need to pay for your time and my time to be doing the evaluation. And, and working with the patient. If it takes 45 minutes to set something up, then we also are going to need the next 45 minutes to have our session and the 30 minutes to break it down. So, if all we're getting reimbursed is $96 because it's you know it's a single [billing] code. Then we're never going to be able to implement this stuff because we're never going to be able to get paid to do our jobs, unless we're working in a university clinic or have a grant or have really rich people.*

Regarding potential avenues to help facilitate insurance coverage, participants outlined a range of considerations including the continued development of evidence-based practice that shows BCI-AAC works, developing systems with a high cost-to-benefit ratio, and advocacy. In highlighting cost-to-benefit ratio and advocacy, P10 said,

> *Their [the funding agency's] job is essentially to make sure that the things we're recommending are absolutely medically necessary and the most cost-effective option, and I can respect that, to*

> *a certain extent. So if, uh, there's another option that's cheaper that could achieve the same results in terms of its effectiveness and efficiency and it's durable medical equipment, they're going to push for that every time,*

with P6 also noting,

> *I think having people also fight for it, and Team Gleason's done amazing things to help get AAC to be a little more, to be in a, a better light, I think by Medicare and insurance. And I think that advocacy is huge.*

Alongside considerations around surrounding device implementation, six participants discussed the benefits of being able to add BCI-AAC to existing AAC devices or possibly developing integrated all-in-one systems to help facilitative funding coverage and help BCI-AAC to be considered alongside existing access methods. For instance, regarding funding, P4 described,

> *Like now we can give somebody a device that has eye-gaze capabilities, but there's no eye-gaze activated on it. So, the brain computer interface would almost need to be able to be . . . . Either activated on a system that you could go up to a hierarchy for, you know, you could use eye-gaze if you needed it instead of brain-computer.*

with P11 reinforcing this perspective by saying, '*Because of the insurance model that we have in this country, I think something that could um, transition* [with the patient's abilities] *would be really essential'.*

2.1.2.3. Applicability and literacy. Five participants discussed that BCI-AAC research seems to largely focus on supporting spelling-based communication to literature adults. Participants indicated that while this literate adult focus is a good place to start for BCI-AAC development, it may limit BCI-AAC access, and potentially restrict interest in BCI-AAC developments to AAC professionals working with patients who are literate, due to a lack of perceived applicability by those working with other populations. For instance, P1 described her concern, indicating:

> *So, for if you have a child, who for whatever reason was locked in, couldn't use eye gaze or something else, you know, another*

> *access form, and wanted to use BCI, to me: the issue is that many of these children in the schools are sort of looked at, uhm [pause]. They are underestimated I guess is the best way to say it. So, some of these kids are not even exposed to literacy instruction and don't learn how to read without literacy instruction. So, I think then about okay this is the only access method that would work for them, but yet they don't have the literacy skills, which seem almost like a pre-requisite skill to using BCI, to me right now. It seems like it would be really tough to have a child use BCI unless they had some level of literacy skills.*

Therefore, it may be beneficial to consider BCI-AAC access for children and to use pictorial displays to provide to support to communication for those with limited or emerging literacy skills. For example, P1 additionally explained that,

> *Things out there now are letter based and spelling-based systems. Thinking about how these systems could be adapted for you know non-literate clients. That could also have a huge impact," with P10 indicating, "I mean, if there, if BCI was compatible with um, symbol-based systems. Like if I could throw it on a Word Power or LAMP or Unity, Proloquo, I would probably put that number of kids [on my caseload] that would be eligible to trial this system, who may benefit at maybe like 30ish percent.*

2.1.2.4. Assessment and training. Nine participants provided commentary about BCI-AAC assessment and training. Six participants specifically discussed BCI-AAC assessment guidelines, describing that future attention should be given to how BCI-AAC fits in alongside existing AAC technology. For instance, P1 commented, '*The SLP who is that AAC specialist definitely knows direct selection, switch scanning, eye gaze, head mouse, pointer. I feel like BCI needs to be added to that list*'. Within this example code, participants indicated that while it is important to remember every person is different making the AAC assessment process '*kind of organic*' (as described by P11), developing guidelines (e.g. a chart/flowchart, check boxes, screening tool) could be a helpful step in identifying which form of AAC access is most likely to facilitate an individual's success. In relation to the development of assessment tools and guidelines, P10 said,

> *Maybe someone's exploring eye gaze versus BCI, that chart might help them kind of whittle down exactly what those differences may be, and they can help determine with the evaluating clinicians, what pros and cons work best for that particular patient", with P3 saying, "Yeah, it would be nice if it had a nice little assessment that you knew, little clientele assessments or screening to say, yep, this would be a good match.*

Regarding the assessment process, our participants also noted that trials are an important component to the AAC process that allow individuals to try the device to assess outcomes and to inform their own unique opinion. Regarding trials for BCI-AAC, P11 elaborated,

> *So um, I think I would kind of want to do BCI in the same way [said in relation to allowing the individual to see/try different eye-gaze systems]. Like if there's one device that does P300 and another device that does imagery, you know, um, I might want to try both of them to see which one worked better for them and that might direct which, which hardware we might get for them.*

Beyond considering access to BCI-AAC devices for trial during assessment, seven participants identified the importance of having timely/early access to AAC-BCI devices to support training. Specifically, it was noted that, similar to current eye-gaze training protocols, providing early/timely BCI-AAC access may improve training outcomes by allowing increased time for individuals to practice and learn BCI-AAC control. P11 embodied the concept of early/timely intervention when saying,

> *I like to do early tracking on my patients with different devices even if they do not necessarily need them, such as eye gaze. The reason I do this is because if they end up needing a more complex communication device down the road, they will likely be able to transition to them easier after already being exposed. This same concept could be applicable to BCI devices.*

Further, the provision of timely/early intervention may help support consistency in AAC use across the lifespan or disease course, as P9 explained:

> *So, like the same idea just to show that even with maybe no movement that these individuals can still activate a switch if*

> *they previously were activating a switch, I think. Not having to change the access method for somebody, you know, that could be really . . . That can be really valuable too as someone's declining if you're able to continue to use an access method that they're familiar with.*

However, participants explained that it may be currently difficult for AAC stakeholders to obtain BCI-AAC devices for testing, demonstrations, trials, and practice, creating a barrier to implementation and lowering awareness about BCI-AAC devices. Therefore, increasing availability of BCI-AAC devices, possibly through equipment loans, could be helpful for implementation and raising awareness about BCI-AAC technology, as P11 explained:

> *Um, I think it [BCI-AAC] could have a big impact if it was um, more readily available. I, I have a feeling like if I could get that device, I would probably try it out more often and, and maybe use it for people who didn't even, that wasn't even the only method they could use.*

2.1.3.1. Motivation and customization. All participants discussed the importance of motivation and customization in BCI-AAC to meet individuals' needs. In further detail, eight participants discussed the area of device customization and functional participation. Specifically, they commented on the importance of building devices that are flexible and can support customized programming to include personally relevant pictures and sounds, and support access to individuals' favorite Internet games, social media, websites, preprogrammed phrases, and relevant circular materials (e.g. site words, focal story characters, responses to teachers' questions). As customization may play a role in bolstering motivation, these considerations may help motivate individuals in AAC use while supporting participation in educational, social, and other functional activities. Regarding personalized programming, P5 explained, *'I would also, you know, encourage something, things that that have a lot of options for programming. So, I want things that I can stick meaningful relevant pictures and sounds in'*. P5 went on to say,

> *So I, you know, in talking with his family about what's interesting to him, and learning that he has, you know, the guys come*

> *over and hang out. And so, what do guys talk about when they come over and hang out? Well, one of the things that they do is they pick their players for fantasy football. Well, you know, you can't swing a dead cat without hitting somebody who plays fantasy football. Right. So that's a functional thing. So, I would like to be able to pull the guys and their uniforms and stick those pictures in there.*

When considering customization, the importance of considering stakeholders' preferences in BCI-AAC design was highlighted. An example of this is customizations made by device users such as color or other aesthetic adaptions, as described by P10:

> *You know, some of our parents, they talk about what they want. Maybe they want the device, a certain color or they want the smallest one so it takes up the least amount of space and it's not as distracting. Um, but just thinking how that those kinds of comments and feedback would translate to BCI.*

To support functional public participation by AAC users, participants also indicated that BCI-AAC systems need to be portable, as current devices seem cumbersome due to factors such as size and extraneous wires.

Finally, five participants described the role of providing motivating opportunities to learn and explore the BCI-AAC system. To elaborate, participants discussed how software, such as games, and selection of other preferred activities (e.g. choice making) can provide opportunities for individuals to learn cause and effect and help the professional evaluate the client's intentionality with device use. Further, it was described that, similar to existing AAC practice, the use of games may allow people to try AAC access with decreased cognitive demand in comparison to a communication-based task and provide a platform for building task difficulty and purpose. For instance, P2 illustrated this point in the following commentary saying:

> *Sometimes in a lot of our devices currently, they would like, if there's little practice things that they can do with them, you know, so sometimes there's little practice uh pages on the device, or even with a communication board there's even a practice thing. And then our practice activities, then they go and*

> *generalize them. Um, usually my school teams like that, if I can bring little practice things out for them. So that they can, and then actually, in that little practice thing, the staff person's learning just as much as the student is, and they don't feel like—if you call something a 'practice,' then they don't feel like they, they're like 'Oh, we're all practicing it.' And so, they don't feel so much pressure from that.*

2.2. Professional expectations for BCI-AAC

2.2.1. Likert scale measures

2.2.1.1. The belief that BCI-AAC techniques may improve the quality of life for those who use AAC. Participants largely agreed with the statement that BCI-AAC techniques have the potential to improve the quality of life of those who may benefit from AAC interventions with an average rating of 4.64 (*SD* = 0.67), ranging from 3 (*unsure*) to 5 (*highly agree*). The median rating was 5.

2.2.1.2. The belief that BCI-AAC techniques have the potential to improve the quality of life for individuals on their caseloads. Participants largely agreed with the statement BCI-AAC techniques have the potential to improve the quality of life for those on their caseloads with an average rating of 4.5 (*SD* = 0.97), ranging from 2 (*disagree*) to 5 (*highly agree*). The median rating was 5. As participant P1 was conducting AAC research but not actively seeing clients who use AAC for treatment, they did not complete this rating.

2.2.1.3. Openness to implementing BCI-AAC. On a 5-point scale, participants indicated they were open to implementing BCI-AAC technology in the future with their clients by providing an average rating of 4.82 (*SD* = 0.4), ranging from 4 (*between neutral–extremely open*) to 5 (*extremely open*). The median rating was 5.

2.3. Caseload proportions

Participants provided a range of responses when asked to indicate approximately what percentage of their caseload could benefit for BCI-AAC access technology, providing an average value of 18.95% (*SD* = 13.71%), and ranging from 1.5% in the school district to 50% in the research & treatment center for those with severe physical impairments. The median value was 15.5%. As participant P1 was not currently seeing clients who use AAC, they did not complete this item.

3. Discussion

Incorporating the perspectives of AAC experts in BCI-AAC in research and development may facilitate the translation of research into real world practice [14] by empowering professionals to work toward shared goals [18] and providing future research directions for overcoming existing barriers associated with BCI-AAC implementation. Through this study, participants indicated their perceived impact of BCI-AAC. Further, participants identified multiple avenues for BCI-AAC implementation, including (a) BCI-AAC implementation and support, (b) funding and access, (c) applicability and literacy, (d) assessment and training, and (e) motivation and customization. These findings are consistent with previous investigations in the areas of implementation science [e.g. 14] and technology uptake [e.g. 36]. For instance, the field of implementation science considers the impacts of areas such as: adaptability, cost, considering personal attributes, and stakeholder support on intervention uptake. In addition, 36, notes the impact of factors such as ease of use, and perceived usefulness on technology acceptance. Following, we provide and discuss the implications of the themes along with Likert scale measures, and caseload proportions. Themes are discussed individually for increased clarity.

3.1. Impact and professional expectations for BCI-AAC

Interview data and number scale measures revealed participants were positive in their expectation that BCI-AAC could have a significant impact on the field of AAC in the future by increasing independence and participation for those who may currently struggle with existing AAC methods. Specifically, on average, participants agreed-strongly agreed that BCI-AAC techniques may improve the quality of life for who use AAC, including those on their caseload. Only one participant who worked in the hospital setting disagreed that BCI-AAC may help patients on their specific caseload, possibly because they worked in a primarily pediatric hospital setting. In relation to interview themes, our experts highlighted the need for continued development of new AAC devices and access methods for those with severe physical impairments to bolster independence, participation, and help prevent people being 'sold short' or underestimated in their abilities due to difficulties with motor components of communication.

When considering the populations who may benefit from BCI-AAC access technologies, participants identified a range of heterogeneous individuals who should be considered for BCI-AAC development and implementation. Traditionally, BCI-AAC development has largely focused on supporting adults with locked in syndrome, commonly due to a diagnosis of amyotrophic lateral sclerosis [e.g. 11, 37], a population who may struggle with access to existing AAC technologies [e.g. 5]. However, our participants describe a range of diagnoses for whom BCI-AAC may be considered and highlight the importance of bolstering existing efforts to consider BCI-AAC access for a broad range of diagnoses who may struggle with utilizing existing AAC systems, such as those with cerebral palsy [see also, 38, 39], cardiovascular accident [see also, 40], visual impairment [see also, 41–43], spinal cord injury [see also, 44, 45], brain injury [see also, 41, 46], or ventilator dependency [see also, 42, 47, 48]. Additional, diagnoses identified by participants as possibly benefiting from BCI-AAC included individuals with the following: multiple sclerosis, muscular dystrophy [see also, 49], spinal muscular atrophy and Rett syndrome [see also, 26].

Reports regarding what percentage of participants' caseload could potentially benefit from BCI-AAC were variable, ranging from 1.5% in the school district to 50% in the research and treatment center for those with severe physical impairments. However, participants in our study identified that, on average across various settings, 18.95% of their caseload could benefit from BCI-AAC. That all participants noted BCI-AAC may benefit individuals on their caseload likely underscores participants' openness to BCI-AAC implementation, and why they believe BCI-AAC has the potential to significantly impact the field of AAC. However, while our metric is important for highlighting the possible impact of future BCI-AAC developments in the clinical setting, the percentage reported by our participants requires further research and should be interpreted with caution. For example, as BCI-AAC is currently aimed towards individuals with physical impairment, there is an increased likelihood that individuals volunteering to participate in this study focused on serving those with severe physical impairments, skewing our averaged caseload metric above AAC experts serving those with other diagnoses (e.g. those with intellectual disability without physical impairments). In addition, participants trend towards validating perceived experimental hypothesis [e.g. 50], which may have also impacted results on number scale measures. Finally, as described above, participants described a range of populations for whom BCI-AAC may be applicable, but for whom research is still in the early stages. Therefore, as the feasibility of BCI-AAC access for these individuals requires further study, it is plausible this caseload metric may best reflect the number of individuals who may benefit in general from new AAC advancements that optimize, supplement, or provide an alternative option to existing options.

Realistic expectations are an important component for improving AAC outcomes [51], and supporting realistic expectations for AAC professionals, users, and their support network is an important ethical matter for BCI-AAC [52–54]. Therefore, it is encouraging that while expectations for BCI-AAC impact from participants were positive, consistent with previous reports, participants caveated their optimism for BCI-AAC by noting multiple barriers and avenues that still need to be overcome for BCI-AAC to be a clinical option [24, 26], as described in the following sections.

3.2. Barriers and solutions for BCI-AAC translation

3.2.1. BCI-AAC implementation and support

Families and AAC stakeholders play a crucial role in the provision of high technology AAC methods. However, BCI-AAC devices still may not be parent- or school-friendly due to incurred effort associated with setup, calibration, and operation, which may hamper AAC-BCI implementation in the daily setting [e.g. 4, 53]. Supporting stakeholders and perceived ease of use may bolster implementation of AAC technology and decrease device abandonment [55]. Therefore, participants discussed the need to consider how to implement BCI-AAC devices and support stakeholders through a range of avenues, including making setup simple and intuitive. The importance of developing simple devices that function ‘out of the box’, along with the creation of streamlined devices that lower technical and setup-related burdens, such as those utilizing auto calibration [56] are reported elsewhere [e.g. 4, 17, 57] and aligns with our findings. Further, the field of BCI-AAC is considering remote support to caregivers with positive results [9, 57]. Thus, study findings corroborate and extend existing discussions by providing a range of considerations for supporting BCI-AAC implementation. Specifically, in addition to the provision of technical/ clinical support, participants noted the importance of providing step-by-step instructions within simple user manuals, ideally written by novices, and video/ picture tutorials on BCI-AAC use, both of which are known clinical strategies that may help facilitate the success of high-tech AAC methods [58]. Finally, participants noted the benefit of allowing individuals the ability to get hands-on experience with device use to facilitate comfort with technology. However, restricted access to BCI-AAC devices due to factors such as cost may present an immediate hurdle in providing support for hands-on learning and device trials [10].

3.2.2. Funding and access

It is well documented that in developed countries obtaining funding to cover the cost of AAC device is an ongoing barrier for the implementation of AAC devices [1, 59, 60], including BCI-AAC [e.g. 53, 61]. In the United States, AAC reimbursement is commonly provided through health insurance companies and programs. To support BCI-AAC reimbursement, advocacy was noted as an overarching principle by participants. The need for stakeholders to be outspoken about BCI-AAC implementation was previously noted in works such as 53, and is currently demonstrated by recent advocacy efforts from initiatives such as the Steve Gleason project, which successfully overturned Medicare cuts and supported AAC access for those with physical impairments [62]. Thus, it is imperative that BCI-AAC implementation be supported by AAC stakeholders, including multidisciplinary researchers, through involvement in AAC advocacy efforts at the local, state, and international levels.

In addition to advocacy, more specific considerations were also provided to support BCI-AAC funding and clinical integration by participants. Specifically, participants noted that, in the United States, insurance reimbursement for a new AAC device may be difficult to obtain, especially if the original purchase was made within the past five years. Therefore, similar to eye-gaze technology, participants discussed that obtaining reimbursement may be facilitated if BCI-AAC technology could be added as a peripheral access method to an individual's previously purchased AAC device or integrated with a commercial AAC system to support changes in motor ability. BCI-AAC access to a commercial AAC device was recently identified as a desirable product by multidisciplinary AAC professionals [24], with current investigations already aiming to support AAC users through BCI access to commercial AAC paradigms and software [e.g. 24, 63–65]. Therefore, continued work in this area may help support funding coverage, continuity in AAC access across the life span, and bring BCI-AAC alongside existing AAC software and technology [11]. Beyond funding for the device itself, participants also noted that consideration needs to be given to reimbursement of BCI-AAC assessment and clinical services. For instance, reimbursement for training is often limited by insurance reimbursement policy. Therefore, future efforts may be necessary to support advocacy actions regarding revision to reimbursement policies, alongside engineering advancements that help ensure BCI-AAC is implementable in an easy and timely manner.

Finally, participants noted the importance of trying to minimize cost and provide evidence-based practice, including peer-reviewed research, clinical expertise, and patient values [66] to help express a positive cost-to-benefit ratio for BCI-AAC in comparison to existing AAC access options, and assist in decreasing costs for those without sufficient insurance coverage. Regarding cost to benefit, previous studies have also reported that a barrier to reimbursement may be the small number of end target users [67]. Therefore, considering a range of end target users for BCI-AAC intervention, including those outlined in this paper, may also encourage industry and financial support.

3.2.3. Applicability and literacy

Participants discussed that providing BCI-AAC access to adults who are literate provided a solid foundation for BCI-AAC development. However, they noted literacy skills seemed almost like a prerequisite to BCI-AAC use, thereby, restricting BCI-AAC access and limiting its relevance to some individuals with complex communication needs. Even with associated challenges (e.g. developing neurophysiology), there is currently increased discussion regarding BCI-AAC access for children with limited and/or emerging language and literacy skills [e.g. 11, 37, 38]. Additionally, clinicians should consider that adults with complex communication needs may still possess the ability to learn language and literacy skills [1] and language/literacy intervention should also be considered for adults with minimal or emerging language and literacy skills. To support communication and help build language and literacy skills, participants noted the importance of continuing to build on existing research aiming to support BCI-AAC access to pictorial symbol-based displays [24,39,68]. Further, the field of BCI-AAC may wish to consider existing methods for supporting literacy through avenues such as dynamic text [e.g. 69], displays incorporating story book content (e.g. book pages, pictures, characters, and vocabulary) and activities incorporating phonological (e.g. letter-sound correspondence, blending) and sight word approaches [70, Mandak et al., 71.

3.2.4. Assessment and training in supporting outcomes

Consistent with the perspectives of special education staff and caregivers identified by 4, our AAC experts noted the benefit of developing guidelines to help guide AAC assessment across a range of methods, including BCI-AAC and traditional forms of AAC access (e.g. eye-gaze, switch scanning, pointers). In more detail, while one participant noted an organic component to AAC assessment, participants described that assessment tools and guidelines could help clinicians identify which form of AAC access could best support communication success and help BCI-AAC to be added to the list of access methods considered during AAC assessment. In the 1970s, a candidacy-based model for AAC intervention was commonly incorporated which dictated that only certain individuals had the ability to be AAC candidates based on requisite levels of skills (e.g. cognitive, motor). This prerequisite or candidacy-based approach had a negative and exclusionary impact on the field of AAC and was thus replaced by a strengths-based participation approach in the United States, which focuses on the principle that all individuals can enhance their communication through AAC [72]. Therefore, paralleling personalized or precision medicine that seeks to tailor care to each patient [73], in the United States, precision AAC [74] commonly utilizes feature matching to identify an AAC device, access method, and system features that best suit an individual. This feature-matched device is identified based on their unique current and future; cognitive, sensory, motor, and linguistic profile, alongside their trial-based preferences, environment, communication needs and levels of support [1]. As with existing AAC methods, varying cognitive-linguistic-sensory-motor and environmental factors may impact BCI-AAC performance [e.g. 2]. Therefore, individualized, trial-based information needs to be collected to provide evidence for funding applications and identify most suitable AAC techniques. Unfortunately, feature-matching research is challenged by BCI researchers and clinicians being unable to obtain a variety of BCI-AAC technologies [10]. However, future BCI-AAC research aiming to elucidate factors impacting BCI-AAC success and the user experience, both between different BCI-AAC techniques (e.g. P300, evoked potential, motor imagery) and other AAC technologies, may help inform guidelines and tools for BCI-AAC assessment [10, 75, & 2, 76]. Future works regarding user-centered BCI-AAC assessment and intervention may continue to expand on early efforts in this area, including the development of a clinically based feature-matching framework which provides a detailed review of existing literature regarding how a variety of both internal (e.g. cognition, motor-[imagery], sensory, medical) and external (e.g. environmental) factors influence BCI-AAC performance across nine different BCI-AAC methods [2], alongside a subsequent BCI-AAC screening protocol for completion by those with physical impairments [76].

Beyond feature matching, recent works focused on BCI-AAC evaluation have also highlighted consideration of the World Health Organization's International Classification of Functioning (ICF) Disability and Health framework for guiding and standardizing BCI-AAC procedures [e.g. 10, 14, 75, 77, 78]. In more detail, the ICF provides a framework describing considerations in the areas of body functions and structures, activities, and participation as impacted by environmental and personal factors [75, 79]. Thus, consistent with existing AAC practice, the ICF framework supports consideration of a range of factors impacting BCI-AAC outcomes and emphasizes the importance of considering individuals' ability to engage in daily activities and participation. The ICF framework provides a promising model to support future efforts to clinically integrate BCI-AAC into clinical practice and provide a systematic framework for evaluation.

Finally, in supporting positive outcomes, participants discussed the potential benefits of providing early/timely intervention. Specifically, participants described that in current clinical practice they ideally begin assisting the individual to learn an AAC access method (e.g. eye-gaze) before it becomes their primary access method. This is done to facilitate transition and support continuity in AAC access. Regarding the application of timely/early intervention for BCI-AAC, research is limited. However, a recent investigation did provide support for the benefit of early/timely intervention in promoting motor-based BCI-AAC success for two adults with amyotrophic lateral sclerosis who had a mild cognitive impairment [64]. Further, recent reports have noted that similar to existing AAC practices that aim to provide communication supports to children with complex communication needs as early as possible [80], early BCI-AAC intervention for children may support participation and learning across the lifespan [25]. However, further study is needed in this area.

3.2.5. Motivation and customization

Participants identified the need for BCI-AAC devices to be flexible and support customized programming. They discussed the benefits of customization when supporting access to curriculum and learning for children to bolster educational inclusion. Additionally, customization may increase engagement and motivation of BCI-AAC users, factors related to improved BCI-AAC success and human computer interactions [2, 81, 82]. For instance, the inclusion of personally relevant stimuli in AAC may help support success [83], and, as one participant described, promote improved social participation. Therefore, future BCI-AAC efforts may wish to consider device customization that incorporates stakeholders' preferences. For instance, from a visual P300-BCI perspective, while performance factors still need to be considered, evaluating the impacts of allowing an individual to choose their own personally relevant custom flash stimuli, such as a face, object, symbol, or scene [e.g. 84–86] on both their user experience [e.g. 23] and social participation are examples of avenues for BCI-AAC customization. Therefore, future research on how interfaces can be designed to meet end user wishes is required [e.g. 87]. Further, beyond the display, participants described the importance of considering avenues for customization of system hardware regarding options for choice of color, and adaptions to make BCI-AAC aesthetically pleasing, and portable for use in the public setting.

Within the motivation and learning theme, participants also discussed the importance of considering the use of BCI-AAC to provide access to preferred activities. Specifically, individuals learn to build intentional communication by understanding they can control their environment to achieve their goals [e.g. social closeness; 1]. Therefore, to provide a foundation for developing intentional communication and to support social participation [33], participants validate current efforts to support BCI-AAC access to engaging, motivating, and cause and effect-related activities. Motivating activities provide opportunities for individuals who use AAC to learn cause and effect through avenues such as requesting, choice making, and toy interaction, with current BCI-AAC works already laying a foundation in this area [e.g. 38, 88–90]. Further, participants explained that similar to existing AAC software such as Timocco™ (Timocco, Akron, OH) and Look to Learn (SmartBox Assistive Technology Ltd., New Kensington, PA), engaging activities may lower the cognitive demand needed to learn a new access method and may help support comfort with BCI technology for AAC users and multidisciplinary professionals.

4. Limitations and future directions

The themes identified through interviews with AAC experts who are SLPs provide multiple considerations for the clinical integration of BCI-AAC technologies. However, further research in this area is warranted to confirm study findings and identify the perspectives of a full range stakeholders in AAC, including clinicians, caregivers, and those who use AAC. For instance, while data saturation was reached, the study only included a small sample of 11 AAC experts, all based in the United States. Therefore, as AAC implementation and funding considerations may vary between countries, additional work seeking to identify the perspectives of AAC experts on an international level will help elucidate a full range of factors that may facilitate BCI-AAC success internationally. Further, this study was limited to only the perspectives of SLPs who specialize in AAC intervention, targeting experts across a broad range of settings. An array of settings was targeted for this study to provide a range of considerations for BCI-AAC implementation that cut across the lifespan/disease. However, it is plausible that focusing on BCI-AAC implementation for one age group (e.g. children, adolescents, adults), diagnosis, or setting may help identify more specific considerations for BCI-AAC implementation, especially as perspectives may differ between different stakeholder groups [3]. Thus, while the AAC expertise of participants provided a firm foundation for clinical considerations for the field of speech pathology, further work is needed to evaluate the perspectives of multidisciplinary professionals making up the AAC team including: AAC facilitators and communication partners, collaborating professionals, research and policy specialists, manufactures/vendors, funding agency personnel, and AAC technology training agency personnel [12]. Additionally, we provided all participants with a short presentation on BCI-AAC technology to provide context for discussion and answered any questions prior to starting the interview process. However, it should be considered that specific BCI-AAC experience varied among participants (see Table 1). This variable experience may have limited some of their abilities to provide specific considerations for BCI-AAC. Therefore, future work should consider providing participants with a hands-on BCI-AAC experiences [e.g. similar to 4], or provide further detail about the current state of science for BCI-AAC prior to interview conductance to bolster discussion, identify new themes, and build upon this work. Finally, as many of the themes addressed are in the early stages of research, collaborative works focusing on both implementation and basic science discoveries that incorporate a range of perspectives (e.g. BCI-AAC engineering, human-computer interaction, neuroscience, neuropsychology, clinical professionals) are warranted to demonstrate the feasibility of the proposed BCI-AAC approaches.

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