2012 STATE OF THE SCIENCE CONFERENCE IN AAC: AAC-RERC FINAL REPORT

Communication Enhancement for People with Disabilities in the 21st Century

The Rehabilitation Engineering Research Center for Communication Enhancement (AAC-RERC) offers this comprehensive report on the final outcomes of the State of the Science Conference held in Baltimore, MD on 28 June 2012 to meet a National Institute on Disability and Rehabilitation Research (NIDRR) requirement for this center.

This report was released on 31 December 2012 and is available at www.aac-rerc.com for download and dissemination.

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Communication Enhancement for People with Disabilities in the 21st Century

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INTRODUCTION

This paper summarizes the likely contexts and realities within which the AAC effort will evolve over time; identifies challenges; and, suggests future directions for the AAC community. It is the culmination of a NIDRR sponsored project undertaken by the Rehabilitation Engineering and Research Center for Communication Enhancement (AAC-RERC).[1] Initially, AAC-RERC partners authored articles that were published in the *Assistive Technology Journal* (March 2012). In June 2012 the State of the Science Conference (SOSC) on Communication Enhancement was held in Baltimore and attended by 75 invited leaders, representing key stakeholder groups. Each participant received a copy of the special issue of the *AT Journal* prior to the conference. AAC-RERC partners gave key presentations, which were followed by breakout discussion groups about the current status of AAC, challenges faced, and future directions, especially with regard to research and development of AAC technologies. To ensure the active participation of AAC consumers and their family members, individuals with complex communication needs (CCN) were given multiple ways to participate in the SOSC, both in person and virtually. Throughout the conference AAC partners and attendees documented comments and discussion points. Following the conference, videos and power point slides of the presentations were posted on the AAC-RERC website (http://aac-rerc.psu.edu/). Finally, conference participants were encouraged to submit additional comments through the AAC-RERC website.

In August 2012, the AAC-RERC SOSC was featured in a session at the International Society of Augmentative and Alternative Communication (ISAAC) Biennial Conference in Pittsburgh PA. During the session, several AAC-RERC partners shared highlights from the SOSC and then asked for additional comments from international leaders who were attending the conference from 52 countries. This content and the comments partners collected at the AAC-RERC booth and throughout the ISAAC Conference during informal discussions were also documented. Finally, the draft of this report was sent to all participants of the SOSC for review and comment.

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[1] AAC-RERC is a virtual center with partners from Augmentative Communication, Inc., Boston Children's Hospital, Duke University, InvoTek, Oregon Health and Science University, Penn State University, Temple University, University of Buffalo, and University of Nebraska at Lincoln.

This report summarizes content collected from all these activities and forums, and has systematically involved all AAC stakeholder groups. It is offered to serve as a guide for AAC researchers, developers and policy makers in setting a reasonable course for the future. The content from the report is summarized in Appendix A and the participants in the SOSC are noted in Appendix B. We are indebted to all who have so willingly shared their time, experiences, ideas and visions of AAC today and in the future.

FRAMING THE FUTURE AGAINST A BACKDROP OF SHIFTING REALITIES

> "There is no typical person who uses AAC. They come from all age groups, socioeconomic groups, and ethnic and racial backgrounds. Their only unifying characteristic is the fact that they require adaptive assistance for speaking and/or writing because their gestural, spoken, and/or written communication is temporarily or permanently inadequate to meet all of their communication needs"
>
> (Beukelman & Mirenda, 2013)

The AAC field has evolved (and will continue to evolve) within the social, technical, medical, educational, cultural, and policy contexts of the future. Over the past forty years, for example, governments, national and international organizations have begun to recognize the rights of people with disabilities, including people with complex communication needs (CCN). Concurrently, medical advances have extended the life span and often altered the nature of disabling conditions that result in speech, language and communication difficulties. Our society is increasingly multi-cultural, multi-linguistic, and global due in large part to a heretofore unimagined revolution in mainstream technologies. In fact, the nature of how many people communicate today is drastically different from the past, as a result of the exponential increase in access to and use of information and communication technologies. A brief summary follows and considers some of the contexts, conditions, and realities likely to affect the future of AAC research and development over the next decade.

Increasing numbers of people who need access to AAC resources

Approximately 1.4% of all people (4.05 million Americans) have such significant communication disabilities that they require AAC strategies to meet their daily communication needs (Beukelman & Mirenda, 2013). In the future, this number will increase:

- The life expectancy for the overall population (Administration of Aging—based on U.S. Census) is increasing. This includes people with developmental and medically related disabilities. In addition, more elderly Americans will acquire disabling conditions that affect communication.
- The numbers of children and youth with development and medical complications who survive because of increased medical capability worldwide also means more will have life-long disabilities.
- There are growing numbers of people who can benefit from temporary use of AAC technologies such as those in intensive care units (ICU) or long-term care hospitals (LTACH) who are intubated or have limited English proficiency to communicate in health care or emergency situations.
- Millions of people who live in developed and emerging economies are becoming aware of, and will wish to use AAC and assistive technologies (AT) so they can access information, communicate more effectively, and be able to participate in family life and community activities.

Changing disability profiles and the impact on future design

The characteristics of people with CCN who benefit from AAC technologies have always shaped the evolution of our field. Several decades ago, the problems we confronted were most often motoric difficulties (*e.g.*, how to access the alphabet using your head; how to increase communication rate). Today, children and adults with CCN have disabling conditions that are more severe, often involving cognitive and social challenges. These individuals require AAC/AT technology designs and treatment protocols that reflect the results of investigations that demonstrate how to support their unique communication needs across environments (Halfon Houtrow, Larson, & Newaheck, 2012; Wise, 2012; Yorkston, Miller, Strand, & Britton, 2012).

Technological innovations shaping the nature of ability and disability

Wise (2012) suggests that technological innovation is both transforming the prevalence and functional impact(s) of disability and will likely influence the type and extent of disability. For example, as mainstream technology increasingly uses speech recognition technologies as environmental controls (e.g., car, phone, computer control), individuals with speech disabilities become more seriously disadvantaged. Also, children who use AAC technologies want to use the same technologies as their peers in school and community environments. This increasingly challenges us to design new technologies that help mitigate rather than exacerbate the level and type of the communication challenges they confront.

Rapid technological changes presenting ongoing challenges to the field

Rapid technical change will undoubtedly continue to influence the design and development of AAC tools and technologies, as well as how industry responds and how professionals and agencies/organizations/institutions provide clinical services. For example, the emergence of relatively inexpensive mobile technology has dramatically affected patterns of technology acceptance and use by increasing the number and types of technology options available to people with CCN and their families (AAC-RERC White Paper, Mobile Devices and Communication, 2011). These new patterns are profoundly influencing the AAC and AT industry, providers who currently serve the field, and people with CCN and their families.

While exciting for some, rapid technical changes can force others to “adjust”. In some cases, this may even mean their communication system no longer works for them (Wise, 2012). As Michael Williams writes, “Computer technology used to be thought of as ‘the great equalizer’; now I feel people with disabilities are in danger of being shut out by these added ‘features’ that can be utilized by the public at large, but are frustratingly useless to people with significant disabilities.” He continues, “I will say that I'm mightily concerned about these gesture-based OSs that are coming into prominence, as well as the increasing use of voice recognition in everything, including television sets. These factors have serious implications for people with complex communication needs and other disabilities that aren't being addressed or even identified by folks in our field.” (Personal communication, 2012).

Adaptive AAC technologies supporting learning and communication performance

Sophisticated adaptive technologies already exist which incorporate smart, sequential strategies and support knowledge growth and skill development. For example, electronic gaming provides many different levels of adaptive performance opportunities; and while games designed for the masses often do not meet the special requirements of people with disabilities, even at their most introductory levels of operation, these electronic learning environments are designed to accommodate differences in learning and performance. Similarly, adaptive AAC/AT technologies could (and should) be designed in ways that assist people with disabilities to accommodate to changes that occur over time and usage. For example, AAC technologies could support children as they develop language, as well as provide scaffolding for adults who are adapting to loss, recovery, or degeneration of communication skills. Adaptive technologies could be designed to help people develop and/or maintain physical, visual, and cognitive capabilities. To address these needs will require extensive, collaborative research and development focused on targeted populations.

Changing policies, practices, and cultures and the impact on the field

The AAC field will continue to evolve under the influence of shifting demographics as well as changes in service delivery, technology, cultural and linguistic factors, and political and policy climates. Factors such as financial support for medical conditions, reimbursement per diem caps, declining rural populations, distance instruction/ intervention, shifting educational policies/ practices, will influence practice. Importantly, people with CCN and those who support them must continue to participate throughout the technology design lifecycle (Newell, Gregor, Morgan, Pullin, Macaulay, 2011; Story, 1998) and to advocate aggressively for communication access as a human rights issue (Collier, Blackstone & Taylor, 2012).

CONSIDERING FUTURE CHALLENGES, OPPORTUNITIES AND PRIORITIES: MAJOR THEMES

Against these contextual backdrops, AAC stakeholder leaders considered the current and future challenges facing the AAC field and discussed priority areas for future research and development. As one might imagine, stakeholder comments and discussions were often intense and wide reaching. However, several major themes emerged and are woven throughout this paper. There was, for example, agreement that our greatest opportunities and challenges are to complete the ongoing research and development that will result in children and adults with CCN participating actively in a changing world. Among the major themes expressed were:

- Continue to listen to and learn from those who rely on AAC, as well as their families, caregivers, and AAC interventionists using an iterative, participatory research and design processes.

- Develop technology designed to support users across multiple contexts and activities.
- Learn how the field of AAC can best utilize evolving mainstream technologies.
- Include a focus on new AAC populations including primary progressive aphasia, neurodementia, and those with AAC needs who are also second language learners.
- Learn more about incorporating visual content into AAC technologies and how these features can support the co-construction of messages.
- Focus on strategies to enhance text learning by children with AAC needs (transitioning from pictographic to text).
- Develop technology that supports the changing needs of individual users' physical, linguistic, and cognitive skills over time.
- Influence developers and manufacturers of new technologies to incorporate features important to people with CCN.

In short, the SOSC activities underscored a need to continue to do the research and the development that reflect sound scientific knowledge and that systematically demonstrate positive outcomes valued by individuals with CCN across the life span.

In the next sections, we consider challenges in two key areas: (1) language, learning and cognitive science and (2) adaptive access. The challenges are <u>not</u> listed in order of priority. Each section critically relates to the opportunities offered by new technologies to address the unmet needs of people with CCN.

LANGUAGE, LEARNING AND COGNITIVE SCIENCE: CHALLENGES, OPPORTUNITIES AND FUTURE DIRECTIONS

AAC interventions are typically multi-faceted, involving the development of AAC systems as tools for communication as well as direct intervention with the individual who requires AAC and partner instruction. Of these, the component of AAC intervention that is the most easily amenable to change is the AAC technology itself (Light & McNaughton, 2012). Unfortunately, most AAC technologies are not research-based; as a result, current designs may not be maximally effective for many individuals with CCN (Light & Drager, 2007). There is a critical need for research to develop AAC technologies that reflect sound scientific knowledge in order to improve outcomes for individuals with CCN across the life span. We believe that the AAC field has much to learn from the research and theory in related areas of study. Specifically, we consider three key examples (out of many potential examples): (a) study of the qualitative and quantitative shifts that occur in language skills over time (e.g., with language development, loss, or recovery); (b) study of working memory and dual task demands; and (c) study of visual cognitive processing. We consider these issues across the life span. We appreciate the many differences in the challenges confronted by children with developmental disabilities who are language learners and the challenges confronted by adults with acquired disabilities who experience sudden or gradual language loss. However, we also believe that there is common ground in these challenges that make these types of issues relevant across the life span and to the design of AAC technologies.

Challenge 1: Qualitative and quantitative changes in language skills over time

Across the life span, individuals experience substantial changes in their speech and language skills: children with developmental disabilities learn more complex language skills over time as they grow; adults with acquired disabilities may experience sudden loss of skills (e.g., due to traumatic brain injury or cerebral vascular accident) and then recovery of some language function; and adults with degenerative neurological disorders may experience gradual loss of speech and/or language function over time. Although the specifics vary significantly across individuals, in each case, the passage of time is defined by substantial change – not only quantitative shifts but also qualitative shifts in language skills.

Research on child language development and implications for AAC. As children learn language, they progress through a series of stages: from pre-intentional to intentional but pre-symbolic, to early symbolic development, to the development of syntax and morphology, to the development of metalinguistic and literacy skills (e.g., Paul, 1997). At each of these stages, they experience significant quantitative and qualitative changes as they acquire more and more knowledge (e.g., know more words, communicate longer messages) and as they think about the world in fundamentally different ways. Through early childhood, their language systems differ significantly from those of adults. As a result, AAC systems that reflect adult representations, organizations, and layouts may be difficult for young children with CCN to learn or understand (Light & Drager, 2007; Light & McNaughton, 2012). For example, Light et al. (2008) asked young children of different cultural backgrounds to draw 10 early emerging abstract language concepts (e.g., want, who) and later to identify 10 traditional AAC symbols (i.e., PCS) used to represent these language concepts. The children had significant difficulty identifying the AAC symbols and their drawings differed significantly from the traditional AAC symbols. Specifically, the children's drawings: (a) depicted entire events or scenes, with the concepts embedded in context; (b) included complete objects and people, rather than isolated body parts or partial objects that required inference of the whole and the intent; and, (c) focused on meaningful and familiar events. The children's representations sometimes reflected very different underlying meanings (e.g., the children represented the concept, big, as one denoting power and capability, whereas the PCS of big depicts a relative size concept). Most AAC symbols typically rely on the semantic memory system to define concepts as neurotypical adults do (e.g., who is a question about a person). In contrast, young children learn language through their experiences and they draw on these experiences or event schema and embed concepts within context (e.g., I saw this guy and I asked my mom, "Who's that?").

The importance of context for children who are learning language is further illustrated by recent research on the layouts of AAC displays. Preliminary results by Wilkinson and Light (2012) suggest that infants show greater attention to, and interest in, visual scene displays (i.e., photos of meaningful events where vocabulary concepts are embedded within the scene) compared to traditional grid layouts of isolated AAC symbols (i.e., PCS) organized in separate boxes in rows and columns. Furthermore, research by Drager, Light, Curran-Speltz, Fallon, and Jeffries (2003) demonstrated that toddlers are more accurate locating vocabulary using VSDs than grid displays. It is not until 4-5 years of age that children are able to perform as accurately with grid displays as with VSDs (Light et al., 2004); by this age, typically developing children have developed much more sophisticated language systems and they are beginning to develop metalinguistic skills and literacy skills. Even by 4-5 years of age, however, children continue to demonstrate greater accuracy locating vocabulary using traditional grid displays or VSDs than using iconic encoding (i.e., encoding systems where pictures representing multiple meanings are used as codes to retrieve vocabulary).

The research on child language development also suggests that beginning communicators with CCN may benefit from AAC technologies that differ substantially from those that use traditional AAC symbols in grid layouts; they may perform better with AAC technologies that embed language concepts within the contexts in which they occur, thus providing more robust contextual support for language learning (e.g., Drager et al., 2003). Furthermore, as language systems develop, children actually require AAC technologies that will accommodate both quantitative and qualitative changes, i.e., the use of VSDs in the early stages of language development to the use of traditional orthography as literacy skills develop.

Research on loss and recovery of language function and implications for AAC. Just as young children experience significant changes in their language systems over time, many adults with acquired disabilities may experience gradual loss of language function over time or sudden loss with subsequent recovery of some function. What does the research suggest about the representation and organization of language concepts in aided AAC displays for adults with CCN? Fried Oken and Doyle (1992) found that adults recovering language function after TBI benefited from the use of traditional orthography (which had been overlearned pre-injury), rather than graphic AAC symbols. Fried Oken, Rowland, & Gibbons (2010) found that adults who are losing language because of primary progressive aphasia retain single word reading during loss of word retrieval skills; they concluded that AAC systems should include simple written words and phrases to support communication during language loss. Adults with chronic aphasia seem to benefit from personally relevant, contextualized photographs to support their communication rather than non-contextualized iconic drawings or photographs that are not personally relevant or contextualized photographs (McKelvey, Hux, Dietz, & Beukelman, 2010). As with children, performance with aided AAC is affected not just by the representations used for language concepts, but also by the layouts of the AAC displays. For example, adults with chronic aphasia seem to perform better with a navigation bar multi-level system compared to a traditional grid multi-level system (Seale, Garrett, & Figley, 2007). That is, when a visual scene display is presented along with pictures on a side bar that represent different levels of scenes, the adults with chronic aphasia are more communicative than when provided with just grids of pictures that did not include side bars to help them navigate to different pictures. Also, adults with traumatic brain injury perform differently with AAC displays based on their level of cognitive flexibility (Wallace, Hux, & Beukelman, 2010).

Similar to children learning language, the research suggests that some adults with acquired disabilities may benefit from AAC technologies that differ substantially from the technologies used by neurotypical adults or from AAC technologies with traditional grid layouts of graphic symbols. Furthermore, adults with acquired disabilities require AAC technologies that accommodate the quantitative and qualitative changes that occur as their language systems change with continued loss of function or with recovery following sudden loss.

Future research directions to accommodate changes in language function. Understanding the quantitative and qualitative shifts in language skills for children and adults with CCN over time poses considerable challenges for the AAC field. Future research is required to improve AAC technologies and interventions: (1) How do we effectively map the internal language systems of individuals with CCN to external AAC technologies? (2) How do we determine the most appropriate designs for AAC technologies (e.g., vocabulary concepts, representations, layout, organization) for individuals with CCN at different stages of language development, loss, or recovery? (3) How do we know when and how to adjust the features of AAC technologies to accommodate the qualitative and quantitative shifts in language skills over time? (4) How do we design AAC technologies that accommodate these qualitative and quantitative changes seamlessly over time as children develop language (e.g., progress from first words to literacy skills) or adults adapt to loss, recovery or degeneration of language skills? (5) Can we harness AAC technologies to provide scaffolding support to individuals with CCN as their language skills change over time?

Challenge 2: Working memory and dual task demands

One fundamental consideration to improve the design of AAC technologies is the working memory demand imposed by the technologies. Working memory is defined as the ability to hold in mind and mentally manipulate information over short periods of time (Baddeley, 1992). Working memory involves many cognitive processes (e.g., attention, concentration, sequencing), and also relies, at least to some extent, on motor and sensory skills. Examples of working memory demands in daily life include: remembering a new telephone number while trying to find a pen and paper to write it down; driving while trying to follow directions that were just given (e.g., "Go left at the first intersection, then take the next right, and then go left at the second traffic light"); remembering a sentence that the teacher says to write down, while spelling the individual words with legible handwriting; and, measuring and combining ingredients from a recipe when no longer looking at the cookbook. Children and adults with CCN confront significant working memory demands in their use of AAC: for example, learning the name of a new toy and trying to find the new symbol on a grid with 10 symbols to request the toy; remembering a question on a history test and trying to answer it using an auditory scanning system that presents options orally one at a time; answering questions about recent medical procedures by using eye gaze to navigate through screens to find the correct vocabulary items on an speech generating device (SGD); and giving directions to the bus driver by finding the correct sequence of messages to select on an SGD.

Research from the field of cognitive science demonstrates that performance is negatively impacted as task demands increase (Boudreau & Costanza-Smith, 2011). Specifically, as working memory demands increase (with increased task demands), the adequacy of cognitive resources available to support performance declines significantly. These findings suggest that communication via AAC may be negatively impacted if the AAC technologies impose too many working memory demands. Current AAC technologies tax working memory and require considerable resources during language formulation for both children and adults with CCN. The working memory demands of AAC technologies are of particular concern because many children and adults with CCN are vulnerable to deficits in working memory.

Working memory capacity is extremely limited in young children; in fact, the working memory capacity of a 4-year-old child is only half that of an adult. Working memory capacity in children increases gradually over time until adolescence. Children with language impairments (Boudreau & Costanza-Smith, 2011) and those with developmental disabilities (Thistle & Wilkinson, 2012) are especially vulnerable to working memory deficits. There are age-related changes in working memory associated with aging as well; older adults cannot store as much or process as much complex information as younger adults because of changes in executive control (Salthouse & Babcock, 1991). Older adults may be vulnerable to dual task demands such as those required in the use of AAC (e.g., operation of AAC devices while formulating communication messages). For example, Kemper and Herman (2006) found that language was degraded in older adults following stroke when they were presented with dual task demands (i.e., retelling a story while following a circle on screen with a mouse).

Research in cognitive science suggests that intervention strategies may be utilized to address working memory deficits and thereby improve performance: (a) evaluating the working demands of learning activities; (b) reducing working memory loads as required; (c) reducing processing demands to limit working memory demands; (d) repeating important information frequently; (e) using external memory aids; and (f) developing memory-relieving strategies (Gathercole & Alloway, 2007). These working memory interventions from the field of cognitive science have potential implications for AAC interventions. Specifically, if performance goals for children with working memory listed above are adapted for individuals with CCN who have working memory limitations, then they may benefit from interventions that: (a) evaluate the working memory demands of AAC devices; (b) reduce the operational demands (dual task demands) of devices as much as possible; (c) reduce the cognitive processing demands of the AAC devices (see the section on visual cognitive processing demands that follows); (d) provide opportunities for repeated practice of operational skills to build automaticity; (e) provide supports to reduce the demands of language generation (e.g., prediction, word completion); and, (f) organize language within the devices according to the strengths of the individuals who use them.

Future research directions to reduce working memory and dual task demands. Clearly future research is required to reduce the working memory and the dual task demands of AAC technologies and thereby enhance the communication performance of children and adults with CCN: (1) How do we design AAC technologies to lessen the working memory demands? (2) How do we minimize dual task demands when using AAC technologies? (3) How can we optimize device learning, especially for individuals with working memory challenges? (4) Can we harness AAC technologies to compensate for working memory deficits?

Challenge 3: Visual cognitive processing

One strategy to reduce dual task and working memory demands is to reduce the cognitive processing load of AAC technologies. Different AAC displays (utilizing different representations, layouts, and organizations) impose different visual cognitive processing demands; these displays may serve to support or impede communication based on their designs (Wilkinson, Light, & Drager, 2012). For example, as noted earlier, the AAC field has traditionally used grid displays with AAC symbols organized in separate boxes in a row and column layout. More recently visual scene displays (VSDs) have been introduced as an alternative to reduce the processing demands and provide contextual support for young children with CCN (e.g., Light & McNaughton, 2012) and for adults with significant language impairments (e.g., Beukelman, Fager, Ball, & Dietz, 2007). The research in the field of visual cognitive processing provides additional support for the use of VSDs with individuals who are most vulnerable to learning demands. This research demonstrates that neurotypical individuals process scenes very rapidly, typically at a speed of 200 milliseconds or less (e.g., Fletcher-Watson, Findlay, Leekam, & Benson, 2008; Oliva & Torralba, 2007). They recognize the overall context as well as the elements of the scene in the first glance. In general terms, scenes seem to exploit real-world experiences and support rapid recognition and activation of experience-based schemas (see Wilkinson et al., 2012 for further discussion). In contrast, the research on visual cognitive processing suggests that it is more difficult to process isolated symbols presented in arrays, even though the symbols may be "simpler" in terms of the number of elements (e.g., lines, shapes; see Wilkinson et al., 2012). Research in the AAC field bears out these findings on visual cognitive processing demands. Preliminary research by Wilkinson and Light (2012) showed that typically developing infants demonstrate a strong visual preference for VSDs compared to grid displays of AAC symbols; they look first and /or longest to the VSDs. Furthermore, research suggests that it is the people within VSDs that attract attention. Wilkinson and Light (2011) found that attention was drawn to the humans in the scene more rapidly and for proportionally longer than virtually all other elements. These results were found to be robust across photo scenes even when the humans were very small and even when there were multiple competing items in the scenes.

Future research directions to capitalize on visual cognitive processing. Understanding basic visual cognitive processing may serve to enhance the design of AAC displays to maximize the effectiveness and efficiency with which information in the display can be perceived, identified and used by individuals with CCN and their partners (Wilkinson et al., 2012). Different

AAC display designs impose different loads on visual cognitive processing and these designs may thereby serve to enhance or impede communication for individuals with CCN. In addition, future research is urgently required to investigate the following questions: (1) How do we design AAC displays that minimize visual cognitive processing demands and maximize effectiveness and efficiency of performance for children and adults with CCN? (2) How can we exploit visual cognitive processing preferences to engage individuals with CCN in AAC interventions (e.g., very young children, individuals with limited attention, and people with intellectual disabilities, those with difficulty with joint attention, and those with intellectual disabilities)? (3) How can we best support the performance of individuals with visual impairments, including those with cortical visual impairment (CVI)?

Final thoughts regarding the role of research from cognate fields

These challenges – changes in language function over time, working memory and dual task demands, and visual cognitive processing - are just three examples of the many language and cognitive science considerations in the design of AAC technologies for children and adults. Designing AAC interventions to enhance the communication of individuals with CCN is a complex process that requires consideration of many variables. We have much to learn from cognate areas such as language development, neuroscience, cognitive science, visual processing, biomechanics, kinesiology, etc. Research from these related fields can serve to advance our understanding and ultimately improve AAC practice.

However, it is critical to note that the research in these cognate areas does not specifically address children or adults with CCN and results from this research, often focused on neurotypical adults or children, may not generalize. Individuals with CCN may process information and perform differently or in similar ways depending on the effects of different disabilities, concomitant sensory perceptual /motor impairments, age or life experience, and environment or culture. Research and theory from cognate areas is best used to suggest hypotheses to be tested in future research specifically applied to the AAC field. In order to improve outcomes for individuals with CCN, we need to reach out to cognate fields and forge multidisciplinary collaborations for future research to expand our understanding and ultimately improve outcomes for children and adults with CCN.

ADAPTIVE ACCESS FOR PEOPLE WITH DISABILITIES AFFECTING COMMUNICATION, MOTOR AND COGNITION: CHALLENGES, OPPORTUNITIES AND FUTURE DIRECTIONS

The AAC field has effectively designed and integrated a range of adaptive access strategies into AAC devices and, as a result, thousands of people with complex communication needs (CCN) are using communication technologies with hand/finger, foot, head, or eye movements. Unfortunately, too many individuals with physical and/or cognitive challenges continue to find existing access options difficult to use, too slow, and fatiguing. In addition, children and adults with CCN need strategies that enable them to access the universally designed technology that has, in fact, changed the very nature of communication today.

People with CCN need AAC technology to access the world for face-to-face communication, as well as to use a range of widely available electronic communication options (e.g., email, texting, social media, and cellphones). Without access to these mainstream technologies, individuals with CCN are not able to participate in a wide range of social, care, educational, volunteer, employment, financial, healthcare related activities and environments. In the following sections we discuss considerations that affect adaptive access.

Challenge 4: Evaluating consumer performance and need across multiple social and technical contexts

AAC researchers and developers are investigating how AAC users and their partners use AAC technologies and other strategies to organize their interactions (Bloch & Wilkinson, 2004; Clarke & Wilkinson, 2007, 2009; Engelke & Higginbotham, in press; Goodwin, 2003; Higginbotham & Engelke, in press; Higginbotham & Wilkins, 1999; Wilkinson, Bloch & Clarke, 2011). For example, we have detailed accounts of how people with CCN use their communication technologies, e.g., a speech generating device (SGD), while also using body-based modes (e.g., gestures, signs, eye pointing) and, in some cases, non-electronic communication tools. By evaluating device use within naturalistic performance contexts as well as in more tightly controlled experimental or clinical trials, researchers have found that all forms of social communication, whether conducted face-to-face, by phone, Skype, email, Facebook or instant message, are affected by the physical presence or influence of communication partners, as well as by the temporal constraints and properties of specific communication modalities and contexts. We believe that the study of communication interaction in authentic communication contexts is critical because it helps to inform the design and development process for AAC technologies in ways that can positively affect interactive communication (Higginbotham & Caves, 2002; Higginbotham & Engelke, in press).

Future research directions in consideration of consumer performance across contexts. As researchers and manufacturers engage in further research and development, we strongly encourage they ask the following questions: (1) Does the innovation really matter when used during everyday interactions? (2) Are the operational requirements too complex and/or do they limit an individual's attention to other aspects of the communication task in ways that compromise the potential impact of the new technology? (3) What are the benefits (e.g., speed, efficiency, greater information access) when compared to the costs (e.g., needing to learn a new access method, set of operations, or new symbol set) of an innovation? (4) Does the innovation provide smooth, secure and consistent access to the internet?

Challenge 5: Developing and evaluating multi-modal access strategies

Traditionally, people who use AAC technologies have used single access methods to operate their system. While capitalizing on targeting movement reliability, a single access method can easily cause fatigue, as well as overuse and movement-related injuries. For example, adults with CCN who have been using head sticks and switches over many years report anecdotally that they experience head and neck pain, making it increasingly difficult for them to use their head sticks and/or switches. In addition, having only one option can actually restrict an individual’s access to communication throughout the day and may ultimately limit participation in some contexts and/or during some activities.

With the introduction of new access technologies, such as eye-gaze, wireless head pointers, etc., it is increasingly possible for individuals to consider using *multi-input strategies.* The potential benefits of such strategies are increased (1) efficiency, (2) access to different technologies, (3) access throughout the day, and (4) movement learning/training opportunities, as well as (5) lower the risk of repetitive movement injuries.

One example of a multiple input strategy is supplemented speech recognition (SSR). This approach utilizes dysarthric speech recognition, first letter identification and language modeling to operate a word predictor (Fager, Beukelman, Jakobs, & Hosom, 2010). Individuals with moderate to severe dysarthria simply type the first letter of the target word before using their speech. A bi-gram language model provides the speech recognizer with multiple sources of information (e.g., acoustic signal, first letter, and language modeling), thereby increasing the accuracy of recognition. Another approach to dysarthric speech recognition is to use multiple sources of information by adding sEMG to the acoustic signal. This also helps the system disambiguate the dysarthric speech increasing recognition accuracy (Deng et al., 2009).

Future research directions in developing and evaluating multi-modal access strategies. By leveraging multiple signals, individuals may be able to increase their access to AAC technologies, as compared to a single input strategy. The problem is that current AAC technology does not support multiple input methods. Further research and development is needed to investigate the following questions: (1) What physical access methods are most intuitive and natural for individuals with CCN to use in combination? (2) What communication and computer tasks are most efficiently executed using multiple access methods? (3) How can the use of multiple access methods promote movement recovery? (4) What limitations do single and multi-modal access approaches impose on interactive communication?

Challenge 6: Accessing mainstream/universal technologies using AAC devices

There is a strong desire among AAC consumers to use mainstream computers and other devices, so they can access their email, Facebook and other web-based applications. General computer use is a frequently requested feature function for AAC devices (Ball et al., 2010). Despite the importance and popularity of general computer access in the AAC community, most funding sources do not cover the costs of computer-based technologies or applications that enable individuals to use a cellphone, email, text, participate on social media sites, browse the web and so on. Further, different interfaces are often required to run mainstream computer applications and operate the AAC program; these may not be well integrated into today's AAC systems (AAC-RERC White Paper, Mobile Devices and Communication, 2011).

Among the current problems are that interfaces are often visually distracting, limit the space available for an AAC application, and require controls that may be inconsistent with how individuals access an AAC device.

Future research directions in accessing mainstream/universal technologies using AAC devices. The current challenges for developing adaptive general computing software are a lack of optimal, integrated interfaces that can take advantage of the individuals current computer skills and practices (e.g., over-learned skills), and minimize visual distractions, cognitive, and physical demands. We need research agendas and development work that investigates the following questions: (1) how can we improve access technologies while decreasing the need for specialized interfaces that require new learning? (2) How can SGD access be integrated with general computer navigation and computing tasks? (3) How can our knowledge of access methods be used to leverage mainstream technologies so that individuals with CCN can preserve, enrich, and expand their communication opportunities?

Challenge 7: Accessing virtual social networking resources

Social networking, including texting, chat, instant messaging, and a bevy of social network sites, has become a common form of communication. Many persons use these communication technologies daily, and for some, hour by hour. Facebook and a number of related social networking technologies are especially appealing to those with limited face-to-face interaction opportunities. They enable people who have difficulty using their speech to interact with others who share their interests without the time constraints imposed during a face-to-face conversation. Further, social networking provides opportunities for self-expression and interaction that many people with CCN have never had. Currently, however, social media sites are not well integrated into most AAC devices, a problem which is exacerbated by the ever expanding number of social networking and social media sites available[2] including some designed specifically for the AAC community (ACOLUG) (https://listserv.temple.edu/cgi-bin/wa?A0=ACOLUG)

[2] A recent examination of Wikipedia's "social media" entry (Wikipedia, June, 2012) indicated that there were 23 social networking technologies and over 100 social media sites.

Future research directions in accessing virtual social networking resources. Social network integration needs to be seamless with AAC applications and hardware. Currently, it is not. Interfacing SGDs with web-based social networking sites will continue to be challenging for developers because of the rapid evolution of social network functions and corresponding challenges of rehabilitation technology companies to respond. Research and development efforts need to consider the following questions: (1) how can we integrate texting and instant messaging into AAC strategies? (2) How can we build in access to social media across all pertinent communication technologies (dedicated devices, mobile technologies, laptops, and cellphones)?

Challenge 8: Incorporating AAC strategies in mobile devices

Mobile computing has changed the how, where, when, why and with whom we communicate. As was stated numerous times by participants at the SOSC conference, the incredibly rapid pace in which both the hardware and software applications continue to evolve, is disrupting the AAC "status quo" related to clinical, manufacturing and funding frameworks established to provide needed service functions. As with social networking, the rapid development cycles of mobile technologies eclipse the pace of AAC research and development. Further, the low cost, widespread availability, and perceived simplicity of mobile devices encourage families and people with CCN to purchase them, without considering carefully how they will help an individual communicate and too often without the benefit of professional AAC expertise and training.

Future research directions in AAC strategies and mobile devices. Despite the huge popularity and potential of mobile devices for people with CCN, access to them and their optimal use is currently limited. Future research is required to address physical access, app development and the use of add on features. Examples of questions are: (1) Can individuals with hand tremor, and limited mobility operate interfaces that require precise touch, and multi-finger contact gestures like pinching and rotating? (2) Can iOS and Android systems (e.g. iPhone or Galaxy tablets) be used as a system interface to navigate between devices or control general purpose software? (3) How can gesture-based technologies be expanded to learn person-specific access solutions? (4) Sophisticated devices beg for transparent access options:

how can consumers have equal access across applications? (5) Can storing interface specifications on the Cloud help to integrate the technologies an individual uses? (6) How can people with CCN use gaze, head, and other non-contact movements for pointing, gesture and selection?

Challenge 9: Incorporating the benefits of Natural Language Processing to AAC applications

Natural Language Processing (NLP) techniques are ubiquitous with current AAC technologies, as evidenced by at least 30 years of research and the commercial use of word prediction and specialized keyboard layouts. (Higginbotham, Lesher, Roark, & Moulton, 2012). One new area of NLP is context leveraging, i.e., using GPS, the internet, and information from local physical and social environments to structure the content of the consumer's AAC device. Also, researchers have examined the use of the internet and the language of a communication partner to provide dynamic vocabulary support (Fulcher, Seale, & Higginbotham, 2012). We expect that additional NLP improvements in word prediction will be minimal, while context leveraging provides real possibilities for improving writing and social interaction performance.

Future research directions in Natural Language Processing to AAC applications. Important work in NLP should focus on: (1) leveraging the context (e.g., the internet, location of the speaker) to improve vocabulary access, as well as priming information displays with location and interlocutor relevant vocabulary, (2) how to develop systems that use but are not dependent on intermittent internet access for their successful operation, (3) what are the underlying language database needs for NLP based systems? Finally, (4) how do we use NLP to integrate real-life information, and personal and relationship information into a device to promote rapid and engaging communication?

Challenge 10: Adapting information displays to meet the diverse needs of people with CCN

Most AAC technologies designed to support face-to-face communication generate messages using text or symbols and then transmit the message via speech output and/or on a visual display to a communication partner. Some SGDs also connect to computers so individuals can write, surf the web, *etc*. However, there is a continuing need to explore how to organize and display information on AAC technologies to make them more easily accessible and to support multiple functions.

Visual displays. AAC-RERC researchers have demonstrated that photographs depicting familiar scenes (visual scene displays) are preferred and more accessible to young children and adults with limited language skills/severe aphasia (Beukelman et al., 2007; Fried Oken, Beukelman, & Hux, 2012; Light & McNaughton, 2012; Shane, Blackstone, Vanderheiden, Williams, & DeRuyter, 2012) than symbols in boxes. For example, display screens are often simultaneously used during face-to-face interactions by both partners to co-construct meaning and support communication (Engelke & Higginbotham, in press; Higginbotham & Engelke, in press).

Speech synthesis. The spoken voice is a main vehicle for the expression of one's identity. Dan Keplinger states, "there is no way in hell a computer voice can express the emotion I have inside of me". Colin Portnuff (2008) also noted that despite the intelligibility gains in modern speech synthesis, it provides little in the way of conveying ones identity, expressing emotion or providing real time prosodic control, a major means of conveying meaning, social affiliation and pragmatic impact.

Future research directions in ways to adapt information displays to meet diverse needs. (1) What are the best research approaches that can be used to "design out" identified problems and "design in" socially interactive displays? (2) What will it take to provide individualized voices, emotive speech for the next generation of SGDs? (3) What are the best technology designs for supporting communication partners and ensuring engaging face-to-face interactions?

SUMMARY

There is no question that the AAC field has made substantial gains over the past 40 years. There is a growing body of research that demonstrates that AAC interventions and AAC systems can have a positive impact on the communication and participation of individuals with complex communication needs (CCN). These positive benefits have been demonstrated across individuals of all ages, across individuals with a range of disabilities, and across different environments (e.g., Branson & Demchak, 2009; Fried-Oken et al., 2012; Ganz et al., 2012; Ho, Weiss, Garrett, & Lloyd, 2005; Lasker, Hux, Garrett, Moncrief, & Eischeid, 1997; Machalicek et al., 2010; Schlosser, Sigafoos, & Koul, 2009; Wendt, 2009). Moreover, the benefits of AAC have been demonstrated at no risk to speech development or recovery (e.g., Garrett & Beukelman, 1995; Millar, Light & Schlosser, 2006; Schlosser & Wendt, 2008). Although the positive benefits of AAC interventions have been documented, it is by no means clear that the benefits of AAC interventions have, in fact, been maximized. Many individuals with CCN continue to struggle to attain communicative competence and participate actively in their families, schools, worksites and communities. Research to enhance the effectiveness of AAC technologies and interventions is urgently required to improve outcomes for individuals with CCN and to allow them to attain their full potential.

The communication enhancement effort continues to evolve rapidly. While face-to-face interaction has always been essential to participate in life activities, technological developments such as social media, distance communication, and virtual access support participation while decreasing the need for physical mobility and travel. Thus, participation options and opportunities are dramatically increasing, while technologies designed for the general public are also rapidly evolving. Unfortunately, technologies designed for the masses continue to fail to take into account the needs of those with disabilities and, at times, actually exacerbate disabilities. The need for a research and development and an RERC on Communication Enhancement is ever more crucial (See Appendix A). There are groups of people who are still not well served by AAC options of the past (aphasia, dementia, and adults with developmental disabilities), and for whom research and development efforts must continue. In order to improve outcomes for individuals with CCN, we need to reach out to cognate fields and forge multidisciplinary collaborations for future research to expand our understanding and ultimately improve outcomes for children and adults with CCN.

APPENDIX A

SUMMARY OF MAJOR CHALLENGE AREAS AND PRIORITY RESEARCH AND DEVELOPMENT AREAS	
Major Challenge Areas	**Future Directions and Priorities in AAC Research And Development**
1. Accommodating changes in language function.	1. How do we effectively map the internal language systems of individuals with CCN to external AAC technologies?
	2. How do we determine the most appropriate designs for AAC technologies (e.g., vocabulary concepts, representations, layout, organization) for individuals with CCN at different stages of language development, loss, or recovery?
	3. How do we know when and how to adjust the features of AAC technologies to accommodate the qualitative and quantitative shifts in language skills over time?
	4. How do we design AAC technologies that accommodate these qualitative and quantitative changes seamlessly over time as children develop language (e.g., progress from first words to literacy skills) or adults adapt to loss, recovery or degeneration of language skills?
	5. Can we harness AAC technologies to provide scaffolding support to individuals with CCN as their language skills change over time?
2. Reducing working memory and dual task demands.	1. How do we design AAC technologies to lessen the working memory demands?
	2. How do we minimize dual task demands when using AAC technologies
	3. How can we optimize device learning, especially for individuals with working memory challenges?
	4. Can we harness AAC technologies to compensate for working memory deficits?
3. Capitalizing on visual cognitive processing	1. How do we design AAC displays that minimize visual cognitive processing demands and maximize effectiveness and efficiency of performance for children and adults with CCN?
	2. How can we exploit visual cognitive processing preferences to engage individuals with CCN in AAC interventions (e.g., very young children, individuals with limited attention, and people with intellectual disabilities, those with difficulty with joint attention, and those with intellectual disabilities)?
	3. How can we best support the performance of individuals who have visual impairments such as cortical visual impairment (CVI)?
4. Considering consumer performance across multiple social and technical contexts	1. Does the innovation really matter when used during everyday interactions?
	2. Are the operational requirements too complex and/or do they limit an individual's attention to other aspects of the communication task in ways that compromise the potential impact of the new technology?
	3. What are the benefits (e.g., speed, efficiency, greater information access) when compared to the costs (e.g., needing to learn a new access method, set of operations, or new symbol set) of an innovation?
	4. Does the innovation provide smooth, secure and consistent access to the internet?
5. Developing and	1. What physical access methods are most intuitive and natural for individuals

evaluating multi-modal access strategies.	with CCN to use in combination?
	2. What communication and computer tasks are most efficiently executed using multiple access methods?
	3. How can the use of multiple access methods promote movement recovery?
	4. What limitations do single and multi-modal access approaches impose on interactive communication?
6. Accessing mainstream/universal technologies using AAC devices.	1. How can we improve access technologies while decreasing the need for specialized interfaces that require new learning?
	2. How can SGD access and be integrated with general computer navigation and computing tasks?
	3. How can our knowledge of access methods be used to leverage mainstream technologies so that individuals with CCN can preserve, enrich, and expand their communication opportunities?
7. Accessing virtual social networking resources.	1. How can we integrate texting and instant messaging into AAC strategies?
	2. How can we build in access to social media across all pertinent communication technologies (dedicated devices, mobile technologies, laptops, cellphones)?
8. AAC Strategies and Mobile Devices	1. Can individuals with hand tremor, and limited mobility operate interfaces that require precise touch, and multi-finger contact gestures like pinching and rotating?
	2. Can iOS and Android systems (e.g. iPhone or Galaxy tablets) be used as a system interface to navigate between devices or control general purpose software?
	3. How can gesture-based technologies be expanded to learn person-specific access solutions?
	4. Sophisticated devices beg for transparent access options: how can consumers have equal access across applications?
	5. Can storing interface specifications on the Cloud help to integrate the technologies an individual uses?
	6. How can people with CCN use gaze, head, and other non-contact movements for pointing, gesture and selection?
9. Applying Natural Language Processing to AAC applications	1. How to leverage the context (e.g., the internet, location of the speaker) to improve vocabulary access as well priming information displays with location and interlocutor relevant vocabulary?
	2. How to develop systems that use but are not dependent on intermittent internet access for their successful operation?
	3. What are the underlying language database needs for NLP based systems?
	4. How do we use NLP to integrate real-life information, and personal and relationship information into a device to promote rapid and engaging communication?
10. Ways to adapt information displays to meet diverse needs	1. What are the best research approaches that can be used to "design out" identified problems and "design in" socially interactive displays?
	2. What will it take to provide individualized voices, emotive speech for the next generation of SGDs?
	3. What are the best technology designs for supporting communication partners and ensuring engaging face-to-face interactions?

APPENDIX B

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