Augmentative and Alternative Communication Technologies

Carol (Heins) Gonzales [a], Gondy Leroy [a], and Gianluca De Leo [b]

[a] Claremont Graduate University, Claremont, CA, USA
[b] Old Dominion University, Norfolk, Virginia, USA

Abstract

Communication is a dynamic process that creates and conveys a mutual understanding between two or more people. Since this process is complex and not easily taught, there exist many communication disorders ranging from a physical limitation, such as ALS, to a cognitive language disorder, such as autism. Augmentative and alternative communication systems (AACs) help people with communication disorders by providing them substituted means for communicating. These systems range from non-technical solutions, such as a paper-based PECS (Picture Exchange Communication System), to elaborate technical solutions, such as a plasma picture communication table. Due to the increased attention to AACs, the Worldwide Health Organization (WHO) provides a framework to evaluate effectiveness. Using this framework as a basis, we identified barriers and support factors for AAC effectiveness and subsequently best practices for AAC designs. We conclude with a case study of adapting a paper-based picture-based communication system to mobile devices using open source development for use by children with severe autism.

Introduction

Augmentative and alternate communication (AAC) technologies present an opportunity to improve the quality of communications in real life situations for millions of people who experience communication disorders. Despite the opportunities that AAC solutions provide, these AAC solutions are often disparate and may not facilitate equal or effective communication with communication partners. Communication commonly combines verbal and non-verbal techniques to send a message from one person to another (Alant, Bornman, & Lloyd, 2006). Prior research has shown that multiple modes of communication, such as gestures, spoken or written language, or symbols, are used by those with complicated communication needs. The mode of communication chosen relies on the person's skill, the context of the conversation, who they are communicating with and the intent of the message (Light & Drager, 2007).

In the United States, 42 million people (1 in 6) are estimated to have a communication disorder. Communication disorders affect the person's ability to send or receive messages using one or more modes of communication. They range from language disorders that inhibit the person's ability to use and understand language, such as autism or traumatic brain injury, to physical problems that impact a person's ability to speak or hear language, such as aphasia in stroke victims or hearing loss. Annual costs estimates in the United States are from $30 billion to $154 billion in lost productivity, special education and medical costs (ARHQ, 2002). Additionally, people with communication disorders face barriers to employment and community participation (Blackstone, Williams, & Wilkins, 2007). Although many low-tech systems exist to help lessen the impact of communication disorders, inexpensive hardware and software have led to an enormous increase in the use of digital and mobile devices for assistive communication. Technology provides the opportunity to improve the communication for individuals with communication disorders as well as the opportunity to improve therapies and community participation. This chapter focuses on such technology-based assistive communication devices.

The objectives of this chapter are to review research, designs, and common problems and successes related to augmentative and assistive communication devices. We discuss problems leading to unsuccessful AAC devices, designs improvements and research suggestions to increase their future success.

Background

Language and communication are social in nature. Communication functions as a means for making requests as well as interacting socially (Banzhoff & O'Connor, 2009). Successful participation in communication suggests that participants should feel equal in the interaction and have access to the same resources and attention. Communication should be synchronized so that each participant can respond in a timely manner. The partners should each feel comfortable communicating accurately and genuinely. Active participation also requires shared comprehension to produce and understand messages (Alant, et al., 2006).

Augmentative and alternative communication systems (AACs) are meant to improve communication by providing devices that substitute or supplement communication. According to the American Speech-Language-Hearing Association, 8 to 12 people per 1,000 experience communication impairments that require AACs (ASHA, 2008). The two most important goals for AAC users are the ability to say what they want to say and to say it as fast as possible (AACI, 2008). AACs use symbols, pictures and text to communicate gestures, verbal and written communications. Several different types of AACs exist and they can be tailored to the intended user's limitations and needs, such as someone with a language disorder versus someone with a motor impairment. For example, hearing disorders can be augmented with written text. For those with cognitive and/or language processing disorders, pictures can be used as with the paper-based Picture Exchange Communication System (PECS). Teachers often use flash cards to communicate the daily schedule to a child with autism; an elderly stroke victim can use pictures to communicate a list of items needed to a caregiver. However, paper-based systems can limit vocabulary, spontaneity, communication partners, and communication situations. Electronic AACs can improve upon the non-technical solutions by improving the quality and synchronicity of communication. For example, a synthetic voice can be produced from text or symbols to produce speech which can allow communication partners to be more at ease.

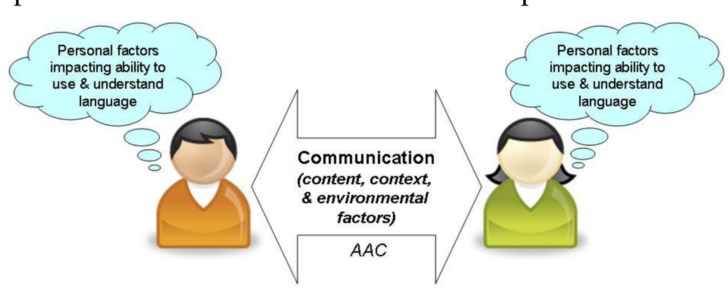

Figure 1: AAC communication process

The goal of any AAC solution is to supplement and augment users' skills to meet their communication needs and goals (Hill, 2006). An AAC solution may supplement impairments by producing spoken speech for those who lost their speech or augment limited cognitive skills by improving the use of language through the selection of symbols. Users prefer solutions that allow them to initiate communication without the receiver needing to understand a unique language or method ("Voices for Living," 2008). Existing AAC hardware and software solutions can contain text, signs, symbols, images, or even generated speech with many having a combination of these components (Pennington, Marshall, & Goldbart, 2007) and using a variety of AAC electronic solutions. They range from complete proprietary systems to niche software solutions for off-the shelf hardware. Electronic AACs can provide features such as multiple languages, word/phase prediction, access to popular commercial applications, as well as Internet and Bluetooth access. Device selection is based on the intended user's abilities and their anticipated daily communication requirements and goals.

To determine the effectiveness of a given therapeutic or clinical intervention, evaluation feedback is needed, ideally, using metrics that can be compared and contrasted regardless of the person's disability and function, or the intervention used. The World Health Organization's (WHO) International Classification of Disability, Functioning, and Health (ICF) provides a conceptual framework for classifying factors that affect the outcome of a given treatment or intervention. The ICF is a revision of the 1980 International Classification of Impairments, Disabilities, and Handicaps (ICIDH) and was approved by the World Health Assembly in 2001 (Raghavendra, Bornman, Granlund, & Bjorck-Akesson, 2007). Outcomes for AAC users are measured in terms of a person's ability to effectively participate in different communication settings and with different partners (Lund & Light, 2007) (Pennington, et al., 2007). The ICF concentrates on health, physical, social and environmental factors that contribute to the person's ability to participate in life situations as opposed to the cause of the disabilities (Raghavendra, et al., 2007) (Lund & Light, 2007). It consists of domains of these factors, such as body functions, activities and participation, body structures and environmental factors. Each domain provides classifications for a given set of related factors (WHO, 2001), such as "voice and speech function" classification within the "body functions" domain, and "communication" classification within the "activities and participation" domain (WHO, 2001). Multiple outcomes from one specific intervention can be evaluated simultaneously as well as one specific outcome from multiple interventions (Raghavendra, et al., 2007).

The ICF is appropriate to evaluate AAC therapy outcomes because it is holistic and is not limited to a single factor. With regard to communication, several contributing factors are included within the ICF: "Conversation and use of communication devices and techniques (ICF classifications d350-d369); "Assisting others in communication" (ICF classification d6602); and "Products and technology for communication" (ICF classification e125). The ICF also includes relevant supporting factors, such as attitudes of family (ICF classification e410, e415), friends (ICF classification e420) and strangers (ICF classification e445); and services for education and training (ICF classification e5850) (WHO, 2001). Table 1 shows samples of the Activities & Participation domain and the Environmental Factors domain. Although the ICF includes many factors, it does have weaknesses. For example, it does not specify a standard method or criteria for measurement. It also does not directly provide the ability to describe the factors related to the communication partners. ICF is also not consistently used in AAC-related studies because of the extra time and costs needed to gather the additional data (Pennington, et al., 2007).

Table 1: ICF Sample (WHO, 2001)

ICF Activities & Participation Domain (sample)	ICF Environmental Factors Domain (sample)
d3: Communication d310 Communicating with & receiving spoken messages d315 Communicating with & receiving non-verbal messages d330 Speaking d335 Producing non-verbal messages d350 Conversation d6. Domestic Life	**e4. Attitudes** e410 Individual attitudes of immediate family members e420 Individual attitudes of friends e440 Individual attitudes of personal care providers and personal assistants e450 Individual attitudes of health professionals e455 Individual attitudes of health related professionals e460 Societal attitudes e465 Social norms, practices and ideologies

d620 Acquisition of goods and services d630 Preparation of meals d640 Doing housework d660 Assisting others **d7. Interpersonal Interactions & Relationships** d710 Basic interpersonal interactions d720 Complex interpersonal interactions d730 Relating with strangers d740 Formal relationships d750 Informal social relationships d760 Family relationships d770 Intimate relationships	**E5. Services, Systems & Policies** e525 Housing services, systems and policies e535 Communication services, systems and policies e540 Transportation services, systems and policies e550 Legal services, systems and policies e570 Social security, services, systems and policies e575 General social support services, systems and policies e580 Health services, systems and policies e585 Education and training services, systems and policies e590 Labor and employment services, systems and policies

Electronic Communication Modalities

Electronic AACs have multiple modalities to make and communicate messages. We focus here on computer-based techniques only. Messages can be created via typed text, or by selecting phrases, symbols or pictures. They can then be communicated from the AAC device via text, symbols/pictures, or generated speech.

Text-based input methods such as electronic notepads allow messages to be created by typing or combing words. It allows rich content in a message but it is a slow communication method given the time necessary to compose a message. Instant messaging is a popular and socially accepted example of this simple communication method that is used by all. Advanced AACs can provide features that support word and phrase prediction as well as a organized library. Text-based solutions are often used by those with aphasia or hearing impairment. However, they require users to understand the meaning of words and so are not effective for those with language or learning disability. UbiDuo Face-to-Face Communicator helps deaf and hard-of-hearing individuals communicate with others by providing two wireless-connected devices that exchange text similar to a TTY (text telephone) device (sComm, 2008).

Graphic-based methods allows messages to be created by combining symbols and images into a complete "sentence" that is displayed or translated to speech. Symbol communication has been a means to communicate between cultures and across time that can be traced back to cave paintings as early as 30,000 BC. A symbol can represents any entity or idea but it should be interpreted equivalently between the sender and receiver regardless of how it is presented (e.g., paper, digital image, etc.). New meanings are created by combining images and symbols (Alant, et al., 2006). Libraries of images can be purchased or users can add their personal images or photographs. This type of communication does not require language literacy and is a common approach for communication with users that have language or learning disabilities. However, communication spontaneity is limited since the messages are restricted to available images. Moreover, communication success and efficiency depends on the co-communicator's ability to interpret the message as intended. The Cyrano Communicator 2 (One_Write_Company, 2008)and PixTalk (CGU/ODU, 2007) are examples of AAC devices and software that use an image library to build messages and communicate them.

Speech generating devices (SGDs) allows message to be created and spoken by typing text, selecting phrases, or combining symbols from a library of images. SGDs speak prerecorded messages or synthesized speech based on the message created by the communicator. Prerecorded messages are those that were spoken and recorded in advance either by the device maker, by the device user, or an assistant to the user. Pre-recorded devices produce more human-like voices and allow words or phrases to be organized by topics and phrases. Prerecorded devices have limited space for storing the prerecorded messages and are less flexible and spontaneous since the messages need to be recorded in advance (NIDCD, 2002). Synthesized speech comes from the combination of electronically-generated speech sounds. It produces a voice that is more robotic since the sounds are combined at the time the message is created. “Type and talk” solutions better support dynamic communication and are the most flexible since they are not constrained by storage limitations and the messages can be dynamically created (NIDCD, 2002). Speech synthesis systems date back to the late 1950’s with the text-to-speech capabilities traced back to the late 1960’s. SGDs can provide various options for physical access, such as a touch screen, keyboard, head stick or eye blinks. SGDs are useful in augmenting users with speech limitations, such as stuttering or aphasia. There are also image-based solutions that are suitable for users with language disabilities. Conversa is an example of a speech generating device on a tablet PC. It includes word and phrase prediction features as the user enters text (One_Write_Company, 2008). The 1-2-3 Speak program similarly provides text-to-speech functionality (Chi_Centers_Inc, 2008). In contrast, MessageMate is a SGD system from Word+ that uses prerecorded messages (Word+, 2008).

Table 2: Comparison of electronic communication modality

Electronic Communication Modality	**Strength & Benefits**	**Weaknesses & Challenges**	**Technology examples**	**Impairment examples**
Text	• Richer message content. • No message limitations.	• Increased time to produce message.	• Cell phone text messaging • Instant messaging • UbiDuo Face-to-Face Communicator	• Aphasia • Hearing impairment
Graphics and/or pictures	• Personalized communication. • Reduced communication delays. • Minimal reliance on communicator’s language literacy. • Expandable library of graphics & pictures.	• Images need to be prepared in advance which limits spontaneity. • Storage limitations • Message interpretation differences influence communication success.	• Cyrano Communicator 2 • Pixtalk	• Cognitive or language impairments such as autism or mental retardation.
Speech generation	• More dynamic & flexible communication. • Pre-recorded words & phrases. • Organization of words & phrases for quick recall. • Word or phrase prediction features. • Flexible input methods to accommodate variations in physical access needs.	• Extra time needed to produce new/original messages. • Storage limitations for pre-recorded messages.	• MessageMate • 1-2-3 Speak • Conversa	• Aphasia • Physical disabilities

Commercial AAC Solutions - Systems and Applications

Commercial AAC solutions, such as those described above, are either complete systems (hardware and software combined) or software only. The use of proprietary and complete AAC devices comes with strengths and weaknesses. Proprietary system designs can be optimized to specific communication goals, environmental conditions (e.g., noise) as well as individual differences such as non-communicative movement and users with visual, hearing, and/or dexterity disabilities. They can also produce superior performance and a better fit for the consumer by accommodating their specific disabilities. For example, users with cerebral palsy or Lou Gehrig's disease would need input methods that accommodate for dexterity because of the physical limitations of their disabilities. Multiple input methods include visual screens, audio output, and voice response (Higginbotham, Shane, Russell, & Caves, 2007). Multiple output methods can assist those with language cognition or hearing disabilities. Examples of output methods include screen displays, hard-copy prints, as well as speech output. However, a balance needs to be achieved because multiple input and output methods may be difficult to navigate and use due to increased complexity (Light & Drager, 2007)

However, proprietary technology limits interoperability between devices as well the availability of enhancements and add-ons. Functional enhancements and bug fixes are subject to the manufacturer's timeline. Additionally, repairs can only be performed by the manufacturer. For example, DynaVox makes several proprietary AAC devices. The EyeMax allows access to the device via the blinking of the user's eyes. It only works with their DynaVox Vmax product and will not work with any other device including personal computers (DynaVox, 2008).

AAC application software takes advantage of off-the-shelf hardware in combination with proprietary software. The AAC application software maker may also augment the hardware design to improve accessibility such as adding alternative input (e.g., touch screen) or output devices (e.g., speakers). With off-the-shelf hardware, developers can take advantage of emerging technologies and use complimentary features, such as wireless, Bluetooth, or complimentary software. Unfortunately, AAC software developers are negatively impacted by new designs of commercial hardware and operating systems if these are not backward compatible. The risk of negative impact may cause them to lag behind due to the risk, high development costs and comparatively low sales volume. Technical support is also a concern since AAC applications are considered a third-party product to the hardware and operating system vendors. Finger-pointing can occur between the AAC application maker and the hardware vendor about who is responsible for corrections when the application does not work as expected. Cyrano Communicator 2 is an example of a commercial AAC solution for the HP iPAQ Pocket PC running the Windows Mobile operating system. It also allows the ability to use pocket versions of compatible software such as Microsoft Office software. (One_Write_Company, 2008). PixTalk is an open source solution developed at two universities, Claremont Graduate University and Old Dominion University. It operates on a touch screen Pocket PC or mobile phone running the Windows Mobile operating system. Word+ provides various AAC speech generating solutions, such as the Say-It! SAM PC software that is written for Windows XP-based PCs (Word+, 2008).

Regardless of whether the AAC solution is a complete proprietary system or utilizing off-the-shelf hardware and operating system, there are common drawbacks. AAC device and software makers tend to be niche manufacturers who do not necessarily have the resources to work with emerging technologies or include resilient features such as water resistance or shock protection. Because of the high costs and limited funding for users, the devices tend to be used longer than other devices and gadgets. Furthermore, there is a lack of standards and interoperability among AAC devices which creates accessibility, integration and support problems (DeRuyter, McNaughton, Caves, Bryen, & Williams, 2007). There are few designs that consider user abilities and preferences in addition to physical and cognitive disabilities (Blackstone, et al., 2007).

Table 3: Comparison of commercial AAC technical solutions

Technology type	Strengths	Weaknesses	Technology Example

Propietary/complete systems	• Optimized to specific communication goals environmental conditions, and individual differences	• Limited interoperability between devices due to lack of standards. • Dependency on the manufacturer for enhancements and add-ons. • Higher sales costs.	• DynaVox V • EyeMax • UbiDuo Face-to-Face Communicator
Proprietary software with off-the-shelf hardware	• Ability to augment/customize hardware. • Access to emerging technologies	• Risk of negative impacts from new hardware designs. • Slower adoption of newer hardware designs. • Higher sales costs. • Limitations to technical support.	• Cyrano Communicator 2 • Word+ Say-it! SAM

AAC Limitations

An AAC solution itself should not introduce limitations to successful communication (Blackstone, et al., 2007). Ideally, AAC developers evaluate the user interactions and the desired outcomes of those interactions and develop the solutions accordingly.

AAC Device Limitations

There are three sets of limitations introduced by AAC use. The first set of limitations comes from the diversity of the AAC device users and their individual and complex communication needs (Blackstone, et al., 2007). Successful AAC outcomes are affected by user ability, knowledge and training of communication partners and the situations where they want to communicate (Blackstone, et al., 2007) (Light & Drager, 2007). The best AAC method and modality for a person needs to be adaptable to their learning and developmental goals, existing abilities, preferences, future communication needs and the situations where they want to communicate such as noisy environments (Light & Drager, 2007) (Higginbotham, et al., 2007) (Blackstone, et al., 2007). As with normal communication, multiple modalities are used to increase the chance of success in communication. Persons with communication disorders can also benefit from multiple modalities to accommodate individual differences such as interference from involuntary movement, visual limitations, hearing loss and/or dexterity disabilities. These additional differences can be solved by providing multiple input methods such as visual screens, audio output, and voice response (Higginbotham, et al., 2007). Examples of multiple output means are screen displays, hard-copy prints, as well as speech output. However, a balance needs to be achieved because multiple input and output methods may be difficult to navigate and use especially by those with cognitive language disabilities (Light & Drager, 2007). The increased redundancy may distract or cause confusion to the device user or communication partner (Alant, et al., 2006).

The second set of limitations follows from a lack of adaptability in different communication events (Higginbotham, et al., 2007) Communicators feel successful when they feel equal in the communication. However, many AAC users do not feel that their devices provide them with communication equality. Current devices are user-centered and designed for scripted dialogues which do not consider the broader social and fluid nature of communication and require increased time to respond to messages and increased attention by the communication partner (Blackstone, et al., 2007). To be effective in social situations, communication partners require training and understanding of the AAC device, however, they do not always assign the same meaning to the symbols (Alant, et al., 2006) (Higginbotham, et al., 2007). In some cases, the communication outcome is further limited because the receiver has physical or cognitive disabilities (Blackstone, et al., 2007). Finally, communication using AAC devices can also affected by differences in cultures. Words and symbols can have different meanings based on culture. Cultural views can also affect the basic acceptance of use of any assistive technology (Blackstone, et al., 2007; Hill, 2006).

A third set of limitations follows from the lack of affordability of AAC devices. Consumers with a low socio-economic status often cannot afford the devices (DeRuyter, et al., 2007). Although Medicare, Medicaid, private insurance, schools and advocacy groups provide funding, their help comes with restrictions and limitation on the devices and features that can be purchased. For example, Medicare reimburses only dedicated devices, so not a PDA with communication software. Medicare also restricts funding to persons who live in the family home or in an assisted living facility and has received a supporting diagnosis from a physician and an evaluation by a speech and language pathologist (AAC-RERC, 2008). Open source provides an opportunity for providing cost effective AAC solutions. pVoice is an example of an open source PC-based AAC solution. It is developed by a parent of a child with a communication disorder and is also a software developer by trade. The parent/developer provides artistic license to the software application for use and modification by others by soliciting other developers to help with adding new features (Visser, 2008).

Figure 2: AAC Device Success Factors

AAC Clinical Limitations

In addition to device limitation resulting from using an intermediate device for communication, there also limits in the ability to obtain direct results regarding their effectiveness and efficiency in life situations. There are many unanswered questions regarding the efficiency and effectiveness of AAC device use for those with cognitive communication disorders (ISAAC, 2008) (NIDCD, 2002). The first set of limitations results from the limited involvement of AAC users themselves (Lund & Light, 2007). Due to the complexity of their communication needs, family members, clinicians, researchers and educators often influence AAC research, development and practice as opposed to the key stakeholder, the actual AAC device user (Blackstone, et al., 2007). The second set of limitations is a lack of data collection and feedback related to the AAC which could lead to improvements in therapy. The paper-based systems do not provide usage feedback and most of the electronic approaches do not include research tools, such as usage tracking, position tracking, or data and device integration (Miller, Leroy, Huang, Chuange, & Charlop-Christy, 2007) (Higginbotham, et al., 2007). Where usage has been tracked, it is often in a clinical setting, for example a few minutes of videotaped therapy, and such clinical use data does not accurately replicate usage in real-life situations (Blackstone, et al., 2007).

Barriers and Contributors to Positive Outcomes

The ICF provides a framework to the evaluate barriers and contributors to successful communication. We used this framework to structure our discussion of the effectiveness of AAC solutions to support a person's communication in life situations. The evaluation is based on the person's ability to participate in life situations; barriers restrict while contributors facilitate participation in and communication with society.

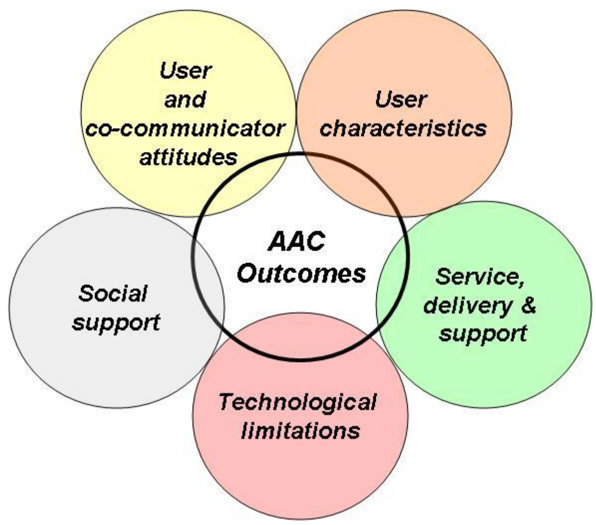

Figure 3: AAC Outcome Factors

Barriers to Positive AAC Outcomes

Barriers to positive AAC outcomes can be introduced by attitudes, culture, technology and the delivery of the service. Attitude related barriers results from the people AAC users interact with when, for example, they resist AAC adoption for fear that it will hamper development of natural speech (Light & Drager, 2007). Culture related barriers speak to the limits of the AAC device to adapt to the culture or language of the AAC users or those with whom they interact. This is especially prevalent with speech generating devices. For example, if the device is limited or the vocabulary is not effectively maintained on the device, a child's development could be artificially constrained (Light & Drager, 2007). Technological related barriers are the technical limitations of the device as well as its stability and reliability (Lund & Light, 2007). For example, current AAC devices are not able to keep up with the normal rate of communication and speech synthesizers have a very low accuracy rate between 55%-77% (Light & Drager, 2007). Lastly, service and delivery related barriers refer to the availability of expertise and collaboration among professionals (Lund & Light, 2007). Outcomes will be inferior if the prescriber is not well versed in the use of the AAC device (Higginbotham, 2007).

Contributors to Positive AAC Outcomes

AAC outcomes can be improved if social support, fitting personal characteristics and support services are present (Lund & Light, 2007). Social support includes the help and encouragement provided by family, friends and schools. For example, if teachers encourage the use of the AAC device in the classroom, the AAC users will achieve more positive results in their class work. Personal characteristics are also critical to the success of AAC usage and AAC users are more successful if they are patient, determined and flexible. An AAC user needs the determination and perseverance to learn the AAC device as well as the ability to adapt the use of the AAC device to different circumstances. Finally, support services are needed to reinforce and assist the person's use of the AAC device. It includes the availability of professionals who are knowledgeable with AAC devices and able to provide support and training before and after the user receives the AAC device (Lund & Light, 2007). Clinicians who prescribe AAC devices also require training in using the devices so that they can prescribe the best device to support the users' needs (Higginbotham, et al., 2007).

Case Study – Open Source AAC System for Children with Autism

Autism is an example of a disorder where communication is severely impaired but where technology can make a positive impact. The growth rate of children diagnosed with autism is enormous. From 1992 to 2003, there has been an 805% cumulative growth rate, and in 2003, 1 out of 264 children was diagnosed with autism (Hollenbeck, 2004). Children with autism have varying degrees of difficulty using and comprehending language. About one-third to one-half of individuals with autism are not able to communicate their daily needs (I. Noens, 2006). To help children with severe autism communicate, the paper-based Picture Exchange Communication System (PECS) is commonly used. Children are taught to compose messages using pictures and caregivers communicate in the same manner with them. Although successful, this approach has shortcomings due to its paper-based nature which hinders systematic measurement of progress and often adds social stigma because the person has to carry a folder of images (Miller, et al., 2007).

The user skills and abilities considered important to success in using an AAC device are learning, memory and language development as well as attention and motor processes since they affect their ability to create and understand messages (Higginbotham, et al., 2007). Because of the complexity of communication and the broad spectrum of skills associated with Autism Spectrum Disorders (ASD), the design of AAC devices is not straightforward. At the higher functioning end, these children can interpret and speak basic language to accomplish simple tasks but they may have difficulty in social communication due to the difficulty interpreting social phrases as well as initiating or sustaining conversation. At the more severe end of the spectrum of autism, children may have no or limited language cognition or verbal skills. Children with ASD may also have unique sensory responses including high or under sensitivity to sight, sound or touch which can limit their fine-motor skills, increase their distraction from too much activity or surrounding sounds. Additionally, special education teachers express a lack of confidence in their technical skills which needs to be considered in the design process using alternative methods for capturing user requirements such as Appreciative Inquiry (Gonzales, Leroy, & De Leo, 2009).

Pixtalk is open-source software for Pocket PCs with touch screens (De Leo & Leroy, 2008). It is designed to allow users with autism and their caregivers to browse and combine images for communication. It can be used in therapy similarly to PECS but with an online library of images to select from. It also provides teachers or caregivers the option to efficiently add custom images for one or more students. It also provides logging capability to capture image use and sentence constructs used by the children. As open-source software, the software is free to download with the ability to access the source code as well. An online community will also be provided to allow the community of caregivers, health professionals, educators, and researchers to work in partnership on ideas, problems and solutions (Leroy & De Leo, 2008) (CGU/ODU, 2007).

Technological needs for children require special focus due to the complexity of their communication needs and their personal interests. In designing Pixtalk, the design team wanted to ensure that the selected hardware and developed software would meet the communication manner, social challenges, and interests of children (De Leo & Leroy, 2008). In looking at popular culture, children are interested in devices that fit in with their peers such as colorful handheld devices like MP3 players and game systems (Light & Drager, 2007). Additionally, children with ASD are shown to interact for longer periods of time when using electronic media (Blackstone, et al., 2007). A handheld device was selected because it is lightweight and portable. It is also less stigmatizing than paper-based systems and other proprietary systems.

The Pixtalk design team researched the situations and manner of their communication for children with autism. They wanted to ensure that the selected hardware and developed software supported the unique sensory responses of children with autism, did not require any extra knowledge by the communication partner in the use of the device, and did not introduce any perceived or real social misperceptions (De Leo & Leroy, 2008). The Pocket PC hardware platform was selected since it was a commercial hand-held electronic device with a commercially available operating system, Windows Mobile. Because it is using mainstream electronic technology and a commercially available operating system, it has a high interoperability with other like devices and complimentary off-the-shelf technology such a cell phone, a camera and desktop software. The touch screen simplifies access and places a direct relationship between the cause and effect of a given action which is important for children with autism.

The open source development approach was selected so that a free user-customizable AAC application could be provided to support financial constraints, provide the opportunity for others to improve upon it as well as the ability to interoperate with other mainstream technologies. Open source development accelerates innovations, new features and utilization of mainstream technologies. It has the benefits of free distribution; access to source code; copyright allowance for modifications and derived works; non discrimination against a particular person or group; no restriction to a particular product or other software; and be technologically neutral (Coar, 2006). As such, it does not place restrictions on a particular vendor to make improvements or personal customizations. Pixtalk will be supported by an online community of caregivers, health professionals, educators, and researchers that will help mitigate the challenges associated with open-source development (e.g., lack of professional support, lack of training, dependence on an informal development community) (DeRuyter, et al., 2007; Leroy & De Leo, 2008).

Future Strategies for AAC Technology Development & Research

Research and development should continue to be driven by the needs of the users of AAC hardware and software solutions. AAC makers and developers need to continue collaborating with the research community, practitioners, users and caretakers to obtain feedback on design and outcome as well as participate in research and testing (Higginbotham, et al., 2007). There are four strategies that would improve the current state of the AAC technology.

First of all, progress is needed to enable fast, real-time communication support for AAC users. To reach that goal, AAC users need more opportunities to interact with “typical” communication partners using natural speech with designs that consider the abilities of the user and communication partners (Alant, et al., 2006) (Blackstone, et al., 2007). Informed designs using universal and participatory design methodologies can be used to create designs that address all types of abilities, cultures, interaction scenarios and communication partners. Those with communication disorders may also have other differences in physical skills and unique behaviors. Cultural differences impact languages, phrases, and context. Communication devices also need to consider the variety in situations where communication occurs and the diverse group that AAC users communicate with. Designs for children offer a particular opportunity to improve learning and social outcomes.

Second, progress is needed to advance the interoperability of AAC devices and software with each other and mainstream technology. The ideal device would be one that knows the user, can be used anywhere that communication occurs, provides interconnectivity with other applications and services and provides metrics to evaluate its use. Current resources and metrics are fragmented since there are many niche solutions and no underlying infrastructure or standards for providing interoperability of the various solutions or the resulting usage data. The technology of AAC devices need to be improved to include interoperability of AAC devices using off-the-shelf hardware (Blackstone, et al., 2007). For instance, wireless and web-based technologies provide unique opportunities to improve access to and use of AAC applications as well as interoperability with other supporting devices and applications (DeRuyter, et al., 2007). Makers and developers of AAC devices and software need to be more responsive to implementing improved designs with off-the-shelf technologies. Open software development has the potential for providing customized solutions using off-the-shelf hardware in a timelier manner for less cost. Additionally AAC solutions need to provide logs of activity with objective metrics about its usage for use in progress evaluations as well as in developing development goals.

Third, progress is needed to make AAC hardware and software solution available to all persons with communication disorders. Currently, availability depends on funding, technical literacy of clinicians and caregivers as well as availability of support and training. Access to any assistive technology by persons with disabilities depends on government, schools and insurances to understand the needs so that they can provide the funding. Many commercial AAC devices exist that are not affordable to the majority of potential users. With software solutions, price is less the barrier than technical knowledge. The access to AAC software solutions depends on the ability for the user to purchase off-the-shelf hardware, install the software, and troubleshoot it when problems occur. Finally, when AAC solutions are prescribed and economically achievable, the necessary training isn't always provided to the clinicians and educators for how to incorporate it into someone's clinical goals.

Finally, progress is needed in research and evidence-based practices to inform design, usability and funding for AAC devices as well as improve the outcomes for the AAC users and clinical approaches (Alant, et al., 2006). Causal research can be instrumental in improving the understanding of the relationship between the usage barriers, support factors and users outcomes when using an AAC device (Lund & Light, 2007). Comparative studies and clinical intervention studies can identify and bridge the gap between research and practice to improve device designs, as well as inform training for practitioners, users, and caregivers (Light & Drager, 2007). Development of research questions, methods and analysis can be informed by AAC users and stakeholders using participatory action research (Blackstone, et al., 2007). ICF can provide the framework for improving research consistency and comparability (Pennington, et al., 2007). Research should also include all types of communicators (e.g., verbal and non-verbal) as well as conventional communication methods to help improve AAC outcomes (Alant, et al., 2006). Inclusion of typical communication and use of natural speech in design and research can help in the evaluation of AAC outcomes especially with children's speech development (Alant, et al., 2006) (Light & Drager, 2007). Usage data from various communication settings with the ICF framework can be used to compare outcomes of different AAC solutions such as manual, complete systems, software, and open source solutions. Research and development can also enlighten support and services available to AAC users, caretakers and family members to improve their communication skills with AAC users (Lund & Light, 2007).

Conclusion

Communication disorders are estimated to affect one out of six persons in the United States. There are many digital devices and tools available to assist those with a communication disorder to communicate with others using text, symbols or recorded and synthesized speech. Electronic communication devices have many advantages over older, paper-based approaches. Electronic AAC solutions provide flexibility in input and output methods (e.g., touch screen), are portable, can be integrated with mainstream technology, and can quickly reference a larger customizable library of symbols and language. Unfortunately, there are also limitations. Sometimes, they cannot be used in every real-life situation due to lack of adaptability to user differences (e.g., physical disabilities or language cognition disorders) and communication situations (noisy or wet environments). Complicating research, development and use is the lack of funding and training. Funding is needed from insurance companies, government and private organizations for the purchase of AAC hardware and software as well as for training and support. Teachers, therapists and caregivers need to be given enough time devoted to learn about AAC solutions and how they can be used most effectively. To be more effective, the AAC community needs feedback from other users and clinicians about the availability of solutions and their effectiveness based on user profiles and related contributing factors. Research studies can be effective in bringing users, stakeholders and developers together to better understand the needs, develop effective designs, and provide a feedback mechanism for the effectiveness of the outcomes.

Acknowledgements

The authors express their gratitude to the children, teachers and therapists who are participating in our communication projects. This project is funded by two grants from Microsoft Research: "Microsoft, Using SmartPhones to Enable Interaction and Communication with Autistic Children" (2007-2008) and "An Online Community for Teachers to Support; Observe; Collect and Evaluate Assisted Communication with Autistic Children." (2008).

References

AAC-RERC (2008). AAC-RERC - Spread the Word, from http://www.aac-rerc.com/

AACI (2008). AAC Institute, from http://www.aacinstitute.org/

Alant, E., Bornman, J., & Lloyd, L. L. (2006). Issues in AAC research: How much do we really understand? [Article]. *Disability & Rehabilitation, 28*, 143-150.

ARHQ (2002). Criteria for Determining Disability in Speech-Language Disorders-Evidence Report/Technology Assessment: Number 52 Retrieved 7/2008, 2008, from http://www.ahrq.gov/clinic/epcsums/spdissum.htm

ASHA (2008). *American Speech-Language-Hearing Association*, from <http://www.asha.org/members/research/reports/aac.htm>

ATIA (2008). Assistive Technology Industry Association Retrieved 10/2/2008, from http://www.atia.org/i4a/pages/index.cfm?pageid=1

Banzhoff, D., & O'Connor, J. K. (2009). *Picture Exchange Communication System Methodology in AAC Devices.* Paper presented at the 24th Annual International Technology & Persons with Disabilities Conference, Los Angelese, CA.

Blackstone, S. W., Williams, M. B., & Wilkins, D. P. (2007). Key principles underlying research and practice in AAC. [Article]. *AAC: Augmentative & Alternative Communication, 23,* 191-203.

CGU/ODU (2007). Using Smartphones to Enable Interaction and Communication with Autistic Children, from http://www.communicationautism.com/

Chi_Centers_Inc (2008). 1-2-3 Speak-augmentative communication device, Speech Generating Device Retrieved 10/3/2008, from http://www.1-2-3speak.com/index.html

Coar, K. (2006). The Open Source Definition Retrieved 9/28/2008, 2008, from http://www.opensource.org/docs/osd

De Leo, G., & Leroy, G. (2008). *Smartphones to Facilitate Communication and Improve Social Skills of Children with Severe Autism Spectrum Disorder: Special Education Teachers as Proxies*. Paper presented at the 7th International Conference on Interaction Design & Children - Workshop on Designing for Children with Special Needs.

DeRuyter, F., McNaughton, D., Caves, K., Bryen, D., & Williams, M. B. (2007). Enhancing AAC Connections with the World. *AAC: Augmentative & Alternative Communication, 23*(3), 12.

DynaVox (2008). "Our Products" Retrieved 10/2/1008, from http://www.dynavoxtech.com/products/default.aspx

Gonzales, C., Leroy, G., & De Leo, G. (2009). *Requirements Engineering using Appreciative Inquiry for an Online Community of Caregivers of Children with Autism*. Paper presented at the ACM Symposium on Applied Computing.

Higginbotham, D. J. (2007). Special issue: State of the science in AAC. *AAC: Augmentative and Alternative Communication, 23*(4), 271-272.

Higginbotham, D. J., Shane, H., Russell, S., & Caves, K. (2007). Access to AAC: Present, Past, and Future. *AAC: Augmentative & Alternative Communication, 23*(3), 14.

Hill, K. (2006). Augmentative and Alternative Communication (AAC) Research and Development:: The Challenge of Evidence-based Practice. [Article]. *International Journal of Computer Processing of Oriental Languages, 19*, 249-262.

Hollenbeck (2004). Autism Prevalence Report Retrieved 7/2008, 2008, from http://www.fightingautism.org/idea/reports/US-Autism-Statistics-Prevalence-Incidence-Rates.pdf

I. Noens, I. v. B.-O., R. Verpoorten, G. van Duijn, (2006). The ComFor: an instrument for the indication of augmentative communication in people with autism and intellectual disability. *Journal of Intellectual Disability Research, 50*(9), 621-632.

ICAN (2000). Interactive Collaborative Autism Network Retrieved 10/4/08, from http://www.autismnetwork.org/index.html

ISAAC (2008). International Society for Augmentative & Alternative Communication, from http://www.isaac-online.org/en/publications/research.html

Leroy, G., & De Leo, G. (2008). *Mobile Communication and Data Gathering Software for Autistic Children and Their Caregivers*. Paper presented at the Positive Design: Technology + Design + Management = Creating New Models of Possibility for All. from http://beta.cgu.edu/Faculty/leroyg/Papers/Leroy-De-Leo-Positive-Design-2008.pdf

Light, J., & Drager, K. (2007). AAC technologies for young children with complex communication needs: State of the science and future research directions. *AAC: Augmentative and Alternative Communication, 23*(3), 204-216.

Lund, S. K., & Light, J. (2007). Long-term outcomes for individuals who use augmentative and alternative communication: Part III--Contributing factors. *AAC: Augmentative and Alternative Communication, 23*(4), 323-335.

Miller, T., Leroy, G., Huang, J., Chuange, S., & Charlop-Christy, M. (2007). Using a Digital Library of Images for Communication: Comparison of a Card-based System to PDA Software.

NCSU (2008). The Center for Universal Design Environment for all Products and People Retrieved 9/24/08, 2008, from http://www.design.ncsu.edu/cud/about_ud/about_ud.htm

NIDCD (2002). NIH Guide: Augmentative & Alternative Communication Strategies for Treatment of Acquired Cognitive-Linguistic Disorders, from http://grants.nih.gov/grants/guide/rfa-files/RFA-HD-02-002.html

One_Write_Company (2008). Cyrano Communicator Adaptive Augmentative Communication Device Retrieved 10/2/2008, from http://www.cyranocommunicator.com/default.htm

Open_Source_Initiative (2007). Home - Open Source Initiative Retrieved 10/5/2008, from http://www.opensource.org/

Pennington, L., Marshall, J., & Goldbart, J. (2007). Describing participants in AAC research and their communicative environments: Guidelines for research and practice. *Disability and Rehabilitation, 29*, 521-535.

Raghavendra, P., Bornman, J., Granlund, M., & Bjorck-Akesson, E. (2007). The World Health Organization's International Classification of Functioning, Disability and Health: Implications for clinical and research practice in the field of augmentative and alternative communication. *AAC: Augmentative and Alternative Communication, 23*(4), 349-361.

sComm (2008). Freedom through Communication Retrieved 3/19/09, 2009, from http://www.scommonline.com/

Visser, J. (2008). pVoice - enabling the disabled Retrieved 10/4/2008, from http://www.pvoice.org/showpage/en/index

Voices for Living (2008). Retrieved 8/25/08, 2008, from <http://www.voiceforliving.com/resources.jsp?pageId=2161392210281178984017412>

WHO (2001). International Classification of Functioning, Disability and Health (ICF) Retrieved 9//27/2008, 2008, from http://www.who.int/classifications/icf/en/

WHO (2002). Towards a Common Language for Functioning, Disability and Health: ICF The International Classification of Functioning, Disability and Health. Retrieved from http://www.who.int/classifications/icf/training/icfbeginnersguide.pdf

Word+ (2008, 9/12/08). Augmentative Communication and Disabilities products by Word+ Retrieved 10/2/2008, from http://www.words-plus.com/index.htm

Key Terms

AAC-RERC - The AAC-RERC (Rehabilitation Engineering Research Center) conducts research or demonstration activities related to AAC technology. It is a collaborative research group dedicated to the development of effective AAC technology (AAC-RERC, 2008).

Assistive Technology (AT): Assistive Technology (or AT) is any piece of equipment, product or system that improves or maintains the functional abilities of persons with disabilities. (ATIA, 2008)

Augmentative and Alternative Communication Systems (AACs): Augmentative and Alternative Communication Systems (AACs) help those with communication disorders by supplementing or substituting communication. AACs range from non technical solutions (e.g., paper-based) to highly technical solutions (e.g., synthesized generated speech) (AACI, 2008).

International Classification of Functioning (ICF): International Classification of Disability, Functioning, and Health (ICF) is a conceptual framework for evaluating outcomes for an individual. It is published by the World Health Organization's (WHO). The ICF is a revision of the 1980 International Classification of Impairments, Disabilities, and Handicaps (ICIDH) (WHO, 2002).

Open Source Software Development: Open source is a development approach that prescribes to distributed development and review by peers. The goals of open source development are to produce better quality, higher reliability, more flexibility, lower cost, and eliminate dependencies on vendors (Open_Source_Initiative, 2007). Open source software provides the benefit of free distribution, access to source code, allowance for modifications and derived works, non discrimination against a particular person or group, not restricted to a particular product or other software, and be technology neutral (Coar, 2006)

Picture Exchange Communication System (PECS): The Picture Exchange Communication System was developed by Lori Frost , M.S., CCC/SLP and Andrew Bondy, Ph.D. at the Delaware Autistic Program in 1994. It is used to teach children with limited functional communication skills to communicate within a social context using applied behavior analysis. Pictures are used to communicate in exchange for the items or task (ICAN, 2000).

Speech Generating Device (SGD): Speech generating devices (SGDs) produce either recorded or synthesized speech based on selected text or images. Speech synthesis systems date back to the late 1950s with the text-to-speech traced back to the late 1960's. SGDs either allow pre-recorded words or phrases to be created or it can produce a synthesized voice based on a selection of images or text (NIDCD, 2002) .

Universal Design: The concept of universal design is to design of products to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design. It considers a variety of characteristics such as people with differences in abilities, gender, age, socio economic status, etc. (NCSU, 2008)