Access to augmentative and alternative communication: new technologies and clinical decision-making

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Access to augmentative and alternative communication: New technologies and clinical decision-making

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Abstract. Children with severe physical impairments require a variety of access options to augmentative and alternative communication (AAC) and computer technology. Access technologies have continued to develop, allowing children with severe motor control impairments greater independence and access to communication. This article will highlight new advances in access technology, including eye and head tracking, scanning, and access to mainstream technology, as well as discuss future advances. Considerations for clinical decision-making and implementation of these technologies will be presented along with case illustrations.

Keywords: Children, AAC, alternative access, assistive technology

1. Introduction

Children with severe physical impairments and complex communication needs (CCN) require alternative methods and strategies to support communication. Many use high-tech communication devices with speech output and augmentative and alternative communication (AAC) strategies such as eye gaze boards and communication books. Some use mainstream technologies such as laptop computers, cell phones, and other mobile technologies to support their communication. The methods they use to access these technologies and strategies vary based upon the physical capabilities of the child.

Access is an integral part of AAC evaluations and interventions [16]. At any age, children with severe physical impairments and CCN need to have the right tools so that they can participate in the routine tasks other children can take for granted. Access to and functional use of these tools is a fundamental component to successful communication, education, and full participation for children with CCN.

1.1. How are access decisions made?

Access decisions should not be made by any one individual, but rather, should result from a collaborative team effort that may include speech-language pathologists, occupational therapists, physical therapists, pediatricians, neurologists, parents, family, teachers, and the child themself. This team approach is essential due to the numerous considerations that facilitate access to communication. For example, physical and occupational therapists address the crucial seating and posi-

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tioning needs of children to ensure that they are comfortable, stable, and ready to use tools and technologies to participate throughout the day. Physicians work closely with the team to provide the pharmacological and surgical management of movement disorders. Other specialists help inform the team about a child's visual, language, hearing, and cognitive skills and abilities that may affect team decisions about access options.

Teams should not recommend a single technique or access strategy. Instead, they can aim to identify multiple methods to enable children with CCN to communicate throughout the day, across contexts, and with multiple partners, regardless of positioning, medication levels, fluctuations in tone, fatigue, etc. In other words, a multimodal approach to access means that clinicians consider several body parts as control sites and systematically expose a child to different ways of operating various technologies to accomplish a range of tasks, while observing the child's skills, abilities, and preferences over time. Clinical observations and trials should provide information about the efficiency and effectiveness of operating various devices using different access techniques to inform the decision-making process.

Teams typically approach physical access with a specific hierarchy in mind. First, they try access options that are more natural, direct, and cognitively transparent, such as using the hand to select an item, pointing directly with the head using a head-stick, or eye pointing. Direct access is typically preferable to indirect access (i.e., selecting a switch to activate a visual and or auditory scanning pattern of the communication interface). Numerous reports have demonstrated that direct access methods are easier than scanning, particularly for young children and for children with severe cognitive deficits [20–23,27,33]. However, when direct methods do not work or are not efficient, the team may try scanning access to communication technologies. To learn more about these different strategies, numerous examples of direct and indirect access options are available on YouTube.

1.2. New access technology for children with severe physical impairments and CCN

The past decade has brought many exciting advances in access technology that open new opportunities for children with severe physical and communication impairments. The goal of this article is to highlight new advances in access technology for children with severe physical and speech impairments by providing brief overviews of these advances, considerations for clinical decision-making and implementation of these technologies, and case illustrations. Case study illustrations presented in this article were exempt from IRB review as they described every-day clinical interventions and all identifying information (e.g., names, specific diagnoses, timelines, and locations) was changed to protect the individuals' identities.

2. Advances in direct access techniques: Eye and head tracking

2.1. Eye tracking

Perhaps the most significant new development in access technologies for children with severe physical disabilities is eye tracking. Eye tracking devices reflect safe, invisible infrared light onto the surface of the eye. The technology then records the reflection pattern using a sensor system and can calculate the exact point of gaze on a device display. Once the point of gaze is determined, it can be shown on the display and the user is able to move the cursor to control a computer or speech generating device (SGD) [10,11].

For most SGDs (e.g., Dynavox's[1] EyeMax, Tobii's[2] C12 and P10, LC Technologies, Inc.[3] Eyegaze Edge, Prentke Romich's[4] ECOpoint), eye tracking technologies require the individual using the system to be positioned approximately 24 inches from the eye tracking camera. Depending upon the type of eye tracking technology used, one or both eyes can be calibrated, visual images used during calibration can be modified, and the rates at which visual images move across the screen and are located on a monitor can be altered to increase the likelihood of a successful calibration. Once calibrated, users can select targets in three ways: dwell, blink, and external switch.

Current eye tracking technologies are tolerant of upper body and head movements so they require recalibration less often than earlier models. Also, proprietary AAC software is customizable, which allows children to access their communication systems using pictures, photographs, symbols, or text. At this time, little re-

[1] Dynavox Mayer-Johnson, 2100 Wharton Street, Suite 400, Pittsburgh, PA 15203, 1-866-396-2869, www.dynavoxtech.com.

[2] Tobii ATI, 333 Elm Street, Dedham, MA, 02026, 1-800-793-9227, www.tobii.com.

[3] LC Technologies, Inc., 10363A Democracy Lane, Fairfax, VA, 22030, 1-800-393-4293, www.eyegaze.com.

[4] Prentke Romich Company, 1022 Heyl Road, Wooster, OH 44691, 1-800-848-8008, www.prentrom.com.

search is available that informs the field about the use of this technology with specific groups of children. However, clinical reports of adults suggest that eye gaze is a promising method of accessing communication, especially for individuals who were previously unable to use direct access methods [1,12].

2.1.1. Clinical decision-making

In making clinical decisions regarding eye tracking, there are three key considerations: (1) the amount of training and practice required to use the technology, (2) adapting calibration routines to increase success, and (3) dealing with limitations of the current technology.

2.1.2. Training time and practice

Advances in eye tracking technology now allow many individuals to access SGDs who previously had difficulty. However, the majority of these reports describe the use of this technology by adults with CCN. The experiences of children may be quite different from the experiences of adults described in current research. Investigations of adults with amyotrophic lateral sclerosis (ALS) who had intact cognition and functional eye motor control, for example, have reported mean training times of 5 hours to become proficient with eye gaze technology [1]. Early clinical evidence with children suggests that, depending on age and/or cognitive issues, many demonstrate difficulty understanding how to use gaze to point to a picture or symbol on a computer screen to communicate. Developmentally, some may have not yet acquired cause and effect. However, with time and specific kinds of practice (as not yet well defined), these children may learn to functionally use this technology. With the widespread availability of eye tracking devices, there is a need for research that documents the learning time required, as well as use patterns of this technology by children with CCN.

2.1.3. Calibration routine modifications

To calibrate eye tracking systems, the user is required to focus his gaze on visual targets as they move to different locations on the SGD or computer monitor. Very young children and/or children with cognitive/attention issues may find this task difficult to complete. Simple modifications can increase the likelihood of the child's ability to stay focused on the calibration task. For example, colorful images of cartoon characters or family pictures may be used as calibration targets. Many eye tracking systems' calibration routines run automatically with predetermined amounts of time between targets; others allow the calibration targets to be advanced with a mouse click or the activation of a switch connected to the SGD. For children who have difficulty attending to the targets, the clinician can wait until the child's eye gaze focuses on the target before advancing to the next one. This decreases the chances of targets being missed, which would impact calibration accuracy. If both of these methods fail, some systems can be calibrated by another individual (e.g., teacher or clinician) prior to use by the child. Children may be more accurate when communication targets are relatively large and limited in number.

2.1.4. Limitations

While eye tracking is a potentially powerful component of an AAC system for children with CCN and severe physical impairments, the various contexts and positions children are in throughout the day can also make eye tracking access difficult and limit access to communication technologies. For example, many eye tracking systems do not perform well in natural light or when the user is positioned near a window. Additionally, it is difficult to use eye tracking while being transported from one environment to another. As a result, children require additional access options to SGDs, other communication technologies, and low-tech AAC approaches (e.g., switch scanning or partner-dependent scanning using a communication board) to ensure communication access across all settings and tasks.

2.1.5. Case illustration-eye tracking

MA is a 10-year-old girl with a medical diagnosis of a rare muscle fiber myopathy, which caused slow degeneration of her physical abilities. She is fully integrated into a 5th grade classroom with her peers. During an initial evaluation for an SGD, she demonstrated adequate control of eye movement and very slight and effortful finger movement. MA was already using finger movement to control a sensitive wheelchair joystick for independent mobility. Although some children demonstrate difficulty achieving calibration, MA was immediately successful and thus, an excellent candidate for eye tracking technology. MA participated in a two-month trial evaluation period. During that trial period, MA, her parents, and school staff participated in extensive training on mounting, positioning, and using the eye tracking SGD in various communication environments throughout the day. The team recommended eye tracking as her primary access method to an SGD so as to lessen fatigue and preserve finger movement for mobility access.

After a successful trial period, the team recommended that MA receive an eye tracking SGD system and that she, her family, and teachers receive training when it arrived. MA learned to use her SGD using eye tracking to support face-to-face communication, generate written text for academic assignments, surf the internet for academic and recreational needs, email friends, family, and teaching staff, communicate with distant friends and family via Skype, and send/receive text messages for social closeness with friends as well as communication with family when outside of the home.

2.2. *Head tracking*

Head tracking technologies can translate the natural movements of the head into mouse/ cursor movements on the display screen of an SGD or computer monitor. The cursor follows the child's head movements and the child makes selections by either using a preset dwell time (i.e., the cursor must remain on the target for a set amount of time to activate it) or by activating an external switch to speak the message out loud.

Head tracking technologies use infrared cameras that track a reflective dot or configuration of dots placed on the child's forehead, glasses, brim of a hat, or the individual's hand or finger. Single reflective dot tracking systems include the HeadMouse Extreme by Origin Instruments,[5] SmartNav by NaturalPoint,[6] and TrackerPro by Madentec.[7] Some of these systems require no additional user interface software. The AccuPoint by Invotek, Inc.[8] is a cluster-dot system that can be worn on the forehead or brim of a hat. This cluster-dot technology allows the system to be more sensitive to decreased or minimal range of head movement.

Another difference between available technologies is related to the relative and absolute head tracking abilities that each employ. Single reflective dot systems are relative tracking systems (e.g., HeadMouse Extreme) and require the user to recalibrate the system during use by moving the cursor to the extreme edges of the SGD or computer screen. Because the cursor requires recalibration in relative systems, individuals using this technology need to have extensive range of head/neck movements. In contrast, systems like the AccuPoint and SmartNav are absolute head tracking systems. Once set up, AccuPoint maintains its calibration during use. The SmartNav has an absolute mode that decreases the need to recalibrate while in use. Additionally, AccuPoint incorporates a scaling feature. This feature allows an individual with minimal range of head movement full control of the cursor by increasing the sensitivity of the system to movement. Understanding these unique features can help clinicians recommend the appropriate head tracking technology for children with severe physical impairments. Unfortunately, there are limited reports of the clinical-decision making process for head tracking use by children with severe physical impairments.

2.2.1. *Clinical decision-making*

In making clinical decisions about head tracking for children, there are several considerations: (1) the range and control of the child's head movement (2) the amount of training and practice required to use head tracking technology, and (3) the short and long-term costs of using head tracking to the individual.

2.2.2. *Range of head movement and control*

Some children have very limited head movement, while others have more movement with limited control. Advances in head tracking technologies make these devices a viable access method for many children. For example, new head tracking technologies can accommodate a range of head movement capability. The AccuPoint's scaling capabilities allow children with minimal head movements to control the cursor across the entire computer monitor or screen of the SGD. For children with limited control or extraneous head movements (e.g., spastic CP), the absolute modes of the SmartNav and AccuPoint allow them to maintain calibration.

2.2.3. *Training time and practice*

For very young children or for those with cognitive impairment, head tracking may not be a transparent process. Children may not understand or immediately recognize that their head movements cause a cursor to move to make a selection on a computer or SGD interface. Simple low-tech strategies, such as attaching a reflective dot to the end of a head stick, may help some children make the connection between their head movements and the movement of the cursor on the computer screen. To date, researchers have not yet tested specific training strategies to help children learn how to use head tracking technologies.

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[5]Origin Instruments Corporation, 854 Greenview Drive, Grand Prairie, TX 75050-2438, 1-972-606-8740, http://orin.com.

[6]NaturalPoint, P.O. Box 2317, Corvallis, OR 97339, 1-541-753-6645, www.naturalpoint.com.

[7]Madentec, 99 Street, Edmonton, Alberta, Canada T6E 5H5, 1-780-450-8926, www.madentec.com.

[8]Invotek, Inc., 1026 Riverview Drive, Alma, AR 72921, 1-479-632-4166, www.invotek.org.

2.2.4. *Limitations and costs of using head tracking technology*

Research suggests that individuals with disabilities are at risk for repetitive stress injuries (RSI) [4,5,17]. However, little is know about the impact of head pointing technologies on children with severe physical impairments. Clinical observations of children using head pointing demonstrate increases in tone and, for some children, the extensive head movements required to maintain calibration in relative tracking systems (i.e., TrackerPro, HeadMouse Extreme) may cause pain with extended use. Technologies that employ absolute head tracking (i.e., AccuPoint and SmartNav) help the user maintain calibration, limiting the amount of extensive head movements required and reducing the risk of RSI that may develop with prolonged use. Intervention teams need to monitor the use of head control technologies over time, with different head tracking options (relative versus absolute), to ensure that children can safely and efficiently communicate across environments. As children with severe physical impairments and CCN are facing a lifetime of access technology use, there is a need for research that examines the physical impact of these methods to ensure that clinical interventionists are making access decisions that are healthy and efficient.

2.2.5. *Case illustration*

BC is a 10-year-old with cerebral palsy and spastic quadriparesis. He demonstrated low muscle tone throughout his trunk and increased tone (spasticity) throughout his arms and legs. He had the most reliable control over his head movements. His team suggested he try using a head tracking system that was built into an SGD. With time and practice, he was successful in using head tracking access to support face-to-face communication and to use email and the Internet.

However, while this method was effective, the range of head/neck movement required to use the technology over time (due to the need to re-calibrate with use, as this was a relative tracking system) was a potential concern for the intervention team. Additionally, some activities required a low or light tech option in order for BC to engage in the activity (i.e., playing a board game). Alternative strategies (i.e., using a safe laser pointer mounted to a headband) were also implemented to give BC the needed break from using head tracking and to increase his level of engagement across communication opportunities with his friends and family.

3. Advances in scanning techniques

Scanning is another method for accessing SGDs and computers. Unlike a direct access technique like eye and head tracking, scanning requires the child to activate a switch to control a cursor that moves from one target to the next. When the target message is highlighted, the child activates the switch and a message can be spoken out loud or inserted into a line of text. There are different scan patterns (step scanning, row-column scanning, and block scanning), and individuals may choose to use one or more switches. One can find websites that demonstrate various scan patterns (e.g., the University of Washington, Department of Speech & Hearing Sciences, Tele-Collaboration Project: http://depts.washington.edu/tcollab), as well as a variety of video illustrations on YouTube.

While scanning methods have remained the same over the years, the switches that children use to control scanning technologies have changed. For example, sensitive EMG switches, such as the Impulse Switch by AbleNet,[9] provide switch access with minimal voluntary muscle contractions anywhere on a child's body. A variety of wireless switch options are also readily available (e.g., Wireless Gumball Switch by Enabling Devices,[10] Big Beamer switch by AbleNet). These significantly decrease the number of cords connected to an SGD or computer and allow for freedom of movement from one device to another. Voice and sound switches available from Saltillo[11] enable children with volitional control of their voice to activate a scanning array by vocalizing. These new switch options make multi-modal access approaches for children with CCN and severe physical disabilities more accessible. They can be used with minimal movements (i.e., voluntary muscle twitch) or with emerging abilities (i.e., voicing or sound), along with other access methods (i.e., head or eye tracking).

3.1. *Clinical decision-making*

While a variety of switches are now available to children, there are several issues related to switch scanning that require consideration when making clinical deci-

[9] AbleNet, Inc., 2808 Fairview Ave. N, Roseville, MN, 55113-1308, 1-800-322-0956, www.ablenteinc.com.

[10] Enabling Devices, 50 Broadway, Hawthorne, NY, 10532, 1-914-747-3070, http://enabling devices.com.

[11] Saltillo Corporation, 2143 Township Rd. #112, Millersburg, OH, 44654, 1-800-382-8622, www.saltillo.com.

sions: (1) the cognitive and motor difficulties associated with switch scanning, (2) how to modify scanning to increase successful use for children, and (3) how switch scanning supports a multimodal access system.

3.2. Cognitive and motor difficulties related to switch-scanning

Research suggests that scanning can be difficult for children to learn due to the sensory, perceptual, motor, and cognitive demands [22,23,27,33]. Compared to other access methods (e.g., direct selection of an item with hand or finger), children with no neurological impairment perform more slowly and make more errors when using switch scanning access methods [33]. Switch scanning requires cognitive and motor processes that children with CCN and severe physical impairments find challenging. For example, switch scanning requires attention and concentration to follow the scan pattern. This is especially challenging in distracting environments (e.g., classroom or lunchroom). Switch scanning also requires children to time their movements precisely and hit the switch as soon as a desired communication target is highlighted. Children with motor planning deficits may find this particularly challenging and frustrating.

Two-switch scanning is a method in which children use one switch to advance the scan from item to item and another switch to select the desired item. Children must have the motor ability to control two switches in order to take advantage of this kind of scanning.

3.3. Modifying scanning to increase success

Researchers are beginning to investigate how to redesign scanning arrays to reduce learning demands. For example, research has shown that visual and auditory feedback features are important considerations when teaching children to use scanning [20,21]. Suggested strategies include changing how targets are visually scanned, adding auditory cues, such as a rising intonation to indicate that the scanned item is being offered as a choice, and changing the auditory/visual feedback given upon selection. Today, clinicians can adjust multiple scanning parameters to manipulate speed, direction, pattern, and feedback in ways that support efficient access.

3.4. Switches and scanning as part of a multimodal system

Switch scanning provides an alternative to other access methods, particularly those that are difficult to use in some contexts. For example, when eye tracking is not successful (e.g., outside, on a school bus), the ability to use scanning may provide continuous communication for children. Additionally, children can use switches in conjunction with head or eye tracking to select or create messages on an SGD. In the following example, the child uses eye tracking to reach the desired communication target on an SGD, and then selects a message by activating a switch with a muscle movement or sound.

3.5. Case illustration

MG is a two-year-old with Spinal Muscular Atrophy Type 2. After a recent bout with pneumonia, MG lost upper extremity control. Prior to her recent setback, she communicated at home by pointing to pictures and symbols on low-tech communication boards with her hands. Because MG was unable to use her hands, the intervention team explored alternative pointing options, including eye gaze. After several trials with the technology, which included changing the calibration targets to child-appropriate pictures (i.e., favorite cartoon character), MG achieved successful calibration and, when optimally positioned (e.g., in wheelchair with adequate support), she could use an eye tracking SGD to play games, indicate basic emotional and physical states (happy, sad, grumpy, want hug, nap), and make activity choices. While MG was in her wheelchair, she had an access method to support communication.

However, when she was in bed, on the floor, or sitting on her parent's laps, she was unable to use eye gaze technology with her SGD. Using the same SGD, her intervention team programmed MG's communication pages so she could also use switch-activated scanning. A facilitator simply selected a button on the interface to change the mode. Then, using a light touch switch mounted below her left index finger, MG could use scanning when out of her wheelchair to communicate with her family and caregivers.

4. Advances in access to mainstream methods of communication

In the present technological age, children engage in all forms of communication with a wide range of technologies: talking on cell phones, texting, email, communicating via social networking sites, using Skype and other video chat software options, online gaming communities, etc. Current advances in SGD technology are making steps toward increasing participation in these kinds of communication opportunities for children with CCN and severe physical impairments. First, many SGDs are also fully functional computers that can access the Internet. Many have built-in wireless capabilities or USB ports that can manage wireless adaptors. Second, AAC software enables children to perform computer functions (e.g., web page navigation) that are optimized for eye or head tracking by providing larger buttons, simplified displays, large onscreen keyboards for text entry, etc. Additionally, pages for instant messaging are now available on many SGDs and some work with certain cell phone carriers, providing children with severe physical disabilities a way to make and receive cell phone calls, increasing their safety and independence. While these advances are helping children with CCN and severe physical impairments engage in communication opportunities similar to their peers, many challenges still remain. For example, SGD manufacturers still struggle to provide cell phone access and families are left with very limited options in selecting the type of phone and service carrier they can use. Additionally, some tools, such as ebook readers, work with a limited number of providers or Internet sites. It is anticipated that as the demand for these features increases, SGD manufacturers will begin to more seamlessly integrate access to a wider variety of these communication tools.

4.1. Case illustration

BT is a 14-year-old adolescent with severe athetoid cerebral palsy. As a young child, he used scanning to access an SGD. With the advances in eye gaze technology, BT was recently evaluated and received an eye gaze SGD. During the evaluation, BT and his family expressed a strong desire for cell phone and texting access so that BT could engage in communication opportunities similar to his peers, and could begin to attend school and social events more independently, without sacrificing safety. The device BT chose utilized a sim card from a cell phone. Although the family had to change cell phone carriers, they considered the inconvenience worthwhile. With BT's new SGD and cell phone access, he could independently attend weekly youth group meetings at the local YMCA and take the bus to meet a small group of friends at the movies without having his parents with him. He also engaged in a common form of social communication (texting) with his middle school friends. Additionally, due to his increased ease of access using eye gaze, BT is beginning to spend more time using his SGD for other forms of communication, such as email, and his friends are currently helping him to develop his own Facebook profile.

5. Future advances in access technology

5.1. Speech recognition for dysarthria

For children who have severe physical impairments but clear speech, automatic speech recognition (ASR) is a viable method of computer access. In addition to ASR software that can be installed on a computer, ASR apps (e.g., Dragon) for mobile devices like the iPod Touch, iPhone, and iPad by Apple[12] present interesting and potentially powerful options to support written communication. However, mainstream ASR has considerable difficulty recognizing dysarthric speech [9,13,19, 29,30]. Additionally, current mainstream ASR requires the user to generate strings of continuous speech, and children with respiratory, phonatory, and/or articulator deficits may be unable to successfully train for and use this technology.

Extensive research is underway to develop ASR technology that recognizes dysarthric speech [6,14,15,18, 25,26,28,31,34]. These investigations focus on the use of speech as the sole input method rather than as a component of a multi-modal access approach. Preliminary work on a Supplemented Speech Recognition program has been completed [8]. This unique technology combines first letter cues, ASR optimized for dysarthria, and word prediction. Deng and colleagues [7] have investigated the use of ASR technology along with surface electromyography (sEMG) signals from the facial musculature as a method to improve recognition accuracy of dysarthric speech. While these new and emerging technologies offer exciting potential for individuals with dysarthria, the use of this technology with children is yet to be explored.

5.2. Brain-computer interface

The field of brain-computer interface is emerging with technology from implantable electrodes to external EEG monitoring devices [2,3,32] that individuals can use to control computer functions. While this tech-

[12] Apple, www.apple.com.

nology holds promise for individuals with severe disabilities, it is not available or approved for widespread use, and has not been used with children. However, as researchers develop less invasive methods and clinical applications for children, the technology may offer additional access opportunities for children with severe physical abilities.

5.3. Access to handheld and mobile technologies

The iPod Touch, iPhone, and iPad by Apple, as well as the myriad of smart phones and tablets now available, have generated considerable interest within the assistive technology field [24]. Much of this technology primarily serves the needs of individuals who have adequate hand control. However, developers are beginning to explore software apps and features that improve accessibility. For example, some applications enable users to access small onscreen keyboards available on smartphone technology by passing through the letters of a target word, versus tapping out each letter. Many smart phones incorporate voice control and screen reading programs to increase accessibility for those with fine motor and/or visual and literacy deficits. For children with severe physical disabilities, switch scanning access is beginning to emerge. Head or eye tracking access methods are not yet possible on these devices. Given the tremendous interest this technology has generated, more sophisticated accessibility options are likely to become available in the future.

6. Conclusion

Eye and head tracking, new switch options, and greater opportunities for interoperability with mainstream technology have expanded opportunities for communication for children with severe physical impairments and CCN, and many promising technologies are on the horizon. While clinical information regarding the use of these technologies is emerging, numerous opportunities for research exist. Documenting the training and practice needs of children using eye and head tracking technologies is required to guide clinical intervention. As children with severe physical impairments and CCN face a lifetime of technology use to support communication, there is a need for research that identifies which access options are the most efficient and safest for children to use over time. Additionally, there is a need for research that documents how access modalities to communication change over time and across contexts as children grow and develop. Access is a fundamental component to successful communication and participation. Understanding the clinical decision-making process and long-term outcomes of these access decisions is essential to ensure that children with severe physical impairments and CCN continue to communicate to the fullest extent possible for life participation.

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Conflict of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

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