Augmentative and Alternative Communication

ISSN: 0743-4618 (Print) 1477-3848 (Online) Journal homepage: https://www.tandfonline.com/loi/iaac20

New and emerging AAC technology supports for children with complex communication needs and their communication partners: State of the science and future research directions

Janice Light, David McNaughton & Jessica Caron

To cite this article: Janice Light, David McNaughton & Jessica Caron (2019): New and emerging AAC technology supports for children with complex communication needs and their communication partners: State of the science and future research directions, Augmentative and Alternative Communication, DOI: 10.1080/07434618.2018.1557251

To link to this article: https://doi.org/10.1080/07434618.2018.1557251

Published online: 16 Jan 2019.

AUGMENTATIVE AND ALTERNATIVE COMMUNICATION
https://doi.org/10.1080/07434618.2018.1557251

RESEARCH ARTICLE

New and emerging AAC technology supports for children with complex communication needs and their communication partners: State of the science and future research directions

Janice Light[a], David McNaughton[b] and Jessica Caron[a]

[a]Department of Communication Sciences and Disorders, The Pennsylvania State University, University Park, PA, USA; [b]Department of Educational Psychology, Counseling, and Special Education, The Pennsylvania State University, University Park, PA, USA

ABSTRACT
This paper discusses recent research and development with a specific focus on selected new and emerging research-based augmentative and alternative communication (AAC) technologies that are developmentally appropriate and responsive to the individual interests, needs, and skills of children with developmental disabilities, their families, peers, and other communication partners. Specifically, this paper reviews the state of the science and future directions related to recent research and development of AAC technologies as supports to (a) enhance language learning, (b) facilitate social interaction, (c) improve literacy skills, (d) increase participation in society, and (e) teach interaction strategies to communication partners.

ARTICLE HISTORY
Received 2 June 2018
Revised 13 August 2018
Accepted 30 August 2018

KEYWORDS
AAC; children; developmental disabilities; parents; communication partners; technology; visual scene displays; video visual scene displays

Approximately 97 million individuals worldwide have significant disabilities that impede or preclude the development of functional speech (extrapolated from Beukelman & Mirenda, 2013; United Nations, 2017). This population includes children[1] with cerebral palsy, Down syndrome, intellectual developmental disabilities (IDD), autism spectrum disorder (ASD), and other developmental disabilities. Without access to functional speech, these children are severely restricted in their current and future participation in education, employment, healthcare, family life, and community activities; they are at risk in all aspects of development (Light, 1997). Unless children who have complex communication needs are provided with effective intervention, the negative effects of disability are compounded even further by missed opportunities for interaction and learning (Romski & Sevcik, 2005).

Augmentative and alternative communication (e.g., signs, communication boards, speech- generating devices, mobile technology with AAC apps) offers significant promise to enhance the communication of children with complex communication needs. Ultimately, the goal of AAC intervention is to enhance communicative competence. The development of communicative competence is impacted by numerous factors, including those related to the child, the environment, and the communication partners, as well as the AAC system (Light & McNaughton, 2014).

There is certainly evidence that AAC technologies have significant positive benefits for children with complex communication needs with a range of developmental disabilities, including gains in turn taking, requesting, commenting, receptive and expressive vocabulary, and mean length of message (e.g., Ganz et al., 2011; Ganz & Simpson, 2018; Kasari et al., 2014; O'Neill, Light, & Pope, 2018; Romski et al., 2010); as well as decreases in challenging behaviours (Walker & Snell, 2013). Despite the positive benefits of these traditional AAC technologies, there is substantial room for improved designs. Even with extensive technological developments taking place within society, the field continues to rely primarily on AAC technologies that reflect the designs of early communication boards from the 1980s (Light & McNaughton, 2012).

AAC system characteristics are a major factor in the success (or failure) of AAC intervention (Johnson, Inglebret, Jones, & Ray, 2006). There is an urgent need to better understand the development of children with complex communication needs over time (i.e., motor, cognitive, sensory perceptual, linguistic, social development), in order to design more effective, developmentally-appropriate, research-based AAC technologies (Light & McNaughton, 2013). The design of AAC technologies has a significant impact on performance

CONTACT Janice Light JCL4@PSU.EDU Department of Communication Sciences and Disorders, Penn State University, 308 Ford Building, University Park, PA 16802, USA

[1]This paper focuses on children with complex communication needs, including infants, toddlers, preschoolers, school-aged children, and adolescents; however, many of the challenges and AAC technology supports may also be relevant to adults with severe developmental disabilities that are beginning communicators.

(Light, Wilkinson, Thiessen, Beukelman, & Fager, 2019). Improving the design of AAC technologies is definitely an important consideration; furthermore, it is a component of AAC intervention that is relatively easy to change.

McNaughton and Light (2013) challenged the AAC field to capitalize on the potential offered by mobile and other innovative technologies for greater functionality, integration, and interconnectivity to enhance the communication and participation of individuals with complex communication needs and their partners. As part of the special issue of *Augmentative and Alternative Communication* on the state of the science, this paper focuses on examples of recent research and development that capitalize on these advances, with a specific focus on new and emerging AAC technologies that are developmentally appropriate; research-based; and responsive to the individual interests, needs, and skills of children with complex communication needs, their families, peers, and other communication partners. Traditionally, the AAC field has focused on applications of technologies to support individuals with complex communication needs to the neglect of the needs of parents, service providers, peers, and other communication partners. Yet it is well recognized that successful communication depends on both participants (Kent-Walsh, Murza, Malani, & Binger, 2015). Therefore, this paper also explores ways to harness the power of AAC technologies to support parents, service providers, and other partners. The goals are to review the state of the science (i.e., the research evidence to date) and define future research directions related to new and emerging AAC technologies as supports for children with complex communication needs and their communication partners. Specifically, we focus on AAC supports to: (a) enhance language learning, (b) facilitate social interaction, (c) improve literacy skills, (d) increase participation in society, and (e) teach partner interaction strategies. Table 1 outlines goals for AAC intervention and examples of effective AAC technology supports for target groups of children with complex communication needs. Table 2 provides examples of intervention goals and AAC technology supports for parents and other communication partners.

AAC technologies to support children's language learning

Trevor[2] is 16 months old. He has Down syndrome and lives at home with his parents, his older brother, and their dog. Trevor enjoys playing outdoors and he loves his dog. He has no functional speech and produces a limited range of sounds. He uses a few signs (i.e., DOG, BANANA, MORE) to communicate. He has a very limited expressive vocabulary and communicates primarily to express needs and wants. How can we design AAC supports to enhance Trevor's language learning?

The challenge

For young children like Trevor, who are at the "first words" stage of language learning, it is critical that intervention focuses on the development of language skills, including the acquisition of a wide range of vocabulary concepts to express a range of communicative functions. Often, AAC interventions for beginning communicators focus primarily on teaching requests for objects or activities to the neglect of social closeness and commenting/exchanging information; they introduce a limited range of vocabulary concepts (Beukelman & Mirenda, 2013). In contrast, Light and Drager (2007) argued that AAC technologies should be designed to better support young children in *learning* a wide range of new language concepts to express a wide range of semantic relations and communicative functions. In typical development, young children learn language concepts within the contexts of their daily interactions during meaningful and motivating activities (Light, 1997). Within their daily interactions, they are exposed to a wide range of spoken language concepts: Children demonstrate interest in people, objects, activities, and other relations; communication partners respond to them and provide models of relevant words; children are able to choose words of interest to them from the input provided and then try them out immediately in context; their partners provide feedback, allowing the children to fine tune their understanding and use of these new vocabulary concepts (Warren & Brady, 2007).

Traditionally, it has been difficult to support children's language-learning processes via AAC. Many AAC technologies utilize AAC symbols that may not be readily understood by beginning communicators (McCarthy, Benigno, Broach, Boster, & Wright, 2018); the symbols are decontextualized and presented in isolation in a grid layout of rows and columns. Research by Trudeau, Sutton, and Morford (2014) demonstrated that young children with typical development have significant difficulty understanding and expressing even basic messages via these AAC graphic symbols, despite well-developed underlying language skills, suggesting that these AAC systems pose substantial learning demands that may limit, rather than facilitate, language learning for beginning communicators.

Challenges for partners programming vocabulary

In addition to the learning demands for children, it is often time consuming and difficult for parents and professionals to programme many AAC technologies with relevant vocabulary, so they may only add vocabulary infrequently. Sometimes, to circumvent programming demands, professionals recommend teaching core vocabulary (i.e., a small set of words—such as I, you, no—reported to be frequently used[3] by individuals without disabilities; Beukelman & Mirenda,

[2]The cases represent composites based on the authors' clinical and research experiences. All personally identifying information has been removed to protect confidentiality.

[3]Despite the common belief that core vocabulary represents words that are used frequently, in reality, these lists are typically defined as words that occur at a frequency of at least 0.5 per 1,000 (or 1 per 2,000 words). In other words, many of the words on core vocabulary lists actually do *not* occur frequently. Some core lists are defined by words that are used commonly across individuals, but these lists typically include words that are only used by as few as 50% of the participants, suggesting that many of the words on these lists are actually *not* that common either. In fact, there is substantial

Table 1. Target groups of children with complex communication needs, intervention goals, and evidence-based AAC technology supports.

Target group of children	Goals for AAC intervention	AAC technology supports
Beginning communicators at the early stages of semantic development	• Support language development • Increase communicative turns • Foster acquisition of a wide range of semantic concepts • Encourage expression of early semantic relations (i.e., 2–3 word combinations)	AAC technologies with visual scene displays (VSDs) that support just-in-time (JIT) programming of VSDs and relevant vocabulary during meaningful and motivating activities
Beginning communicators that have difficulty with joint attention	• Reduce joint attention demands • Support social interaction • Increase engagement • Increase communicative turns	VSDs of preferred books or other favourite activities; video visual scene displays (i.e., VSDs embedded within preferred videos)
Early communicators that have difficulty with displaced talk (i.e., talk about events outside the here and now)	• Provide contextual support for displaced talk • Increase communicative turns • Support social interaction and information exchange	Video VSDs (VSDs embedded within videos that capture child's experiences)
Individuals who require AAC who are preliterate	• Support learning of single word reading skills for relevant vocabulary • Introduce to literacy learning	VSD or grid-based AAC apps with transition to literacy (T2L) supports (i.e., dynamic text paired with speech output upon selection of a hotspot)
Individuals who require AAC who are learning new tasks and communication requirements to participate in educational, vocational, healthcare, and/or community environments	• Teach skills to independently complete educational, vocational, healthcare, and or community activities • Fulfill successfully the communication demands within these tasks	Video VSDs that integrate video modelling to learn new tasks with VSDs to support communication

Note: In order to build communicative competence, children with complex communication needs require instruction in linguistic, operational, social, and strategic skills as well as access to effective AAC supports.

Table 2. AAC technology supports for parents, professionals, and other communication partners of children with complex communication needs.

Target group of communication partners	Goals for partners	AAC technology supports
Parents and professionals who are responsible for adding vocabulary and supporting the child's language development	• Reduce time and effort required to programme new vocabulary • Allow partners to add VSDs and vocabulary just-in-time during interactions • Support partner responsivity to child interests • Allow partners to capitalize on teachable moments	AAC technologies with just-in-time (JIT) programming
Parents, professionals, and other communication partners who have difficulty understanding the child's communication	• Provide contextual support for interaction with child • Provide topic cues to support partner's understanding • Support social interaction and information exchange	AAC technologies with visual scene displays (VSD) or video VSDs
Parents, professionals, and other communication partners who are learning interaction strategies to support the child's communication	• Teach partners interaction strategies • Provide JIT training to support interaction with child	AAC technologies with video VSDs that integrate video modelling of interaction strategies

2013). However, this core vocabulary does not carry the main meaning of the message; these words are not developmentally appropriate at the early stages of language development. As Mirenda (2014) noted, there is no published research that supports the effectiveness of teaching core vocabulary as a means to enhance language learning with children who use AAC, despite its widespread use clinically. If diverse vocabulary representing a range of concepts is not added to AAC technologies as frequently as required, this lack of vocabulary will serve as an external constraint on the language learning and conceptual development of young children with complex communication needs. Vocabulary use at an early age is a strong predictor of the development of cognitive skills, literacy learning, and educational achievement (e.g., Hart & Risley, 2003). Children require access to a large and varied vocabulary to support language development and communication (e.g., people, actions, descriptors, social words, nouns such as names of animals, toys, places, vehicles, etc.; Fenson et al., 2007; Hart & Risley, 2003; Rowe, 2012).

Because of operational demands, when new vocabulary is added to AAC technologies, the programming typically occurs offline, away from the interactions where young children learn language. Parents and other partners often struggle to accurately anticipate their children's needs and interests outside of meaningful interactions so that often the vocabulary added may not reflect the developmental needs and interests of the children. As a result, it is difficult for parents and other partners to respond to children's interests and needs in the moment during daily interactions; they are not able to capitalize on many of the naturally-occurring opportunities for language learning. The research clearly shows that partner responsivity is a critical component of language learning (Warren & Brady, 2007). Unfortunately, traditional AAC technologies with multi-step programming demands may not support partner responsivity.

individual variation in vocabulary use, especially in the early stages of development.

Figure 1. An example of a VSD for a young child to communicate about getting kisses from the family dog. He might select hotspots of: (a) his own face to say "*me*" (or his name); (b) his dog's head to say "*doggie*" (or the dog's name) with the sound effect of a dog barking; or (c) their noses to say "*kissing*" with the sound effect of kissing.

Challenges for children participating in vocabulary selection

Current AAC technologies are not designed to empower young children with complex communication needs in their vocabulary acquisition. Programming traditional AAC technologies is a complex, multi-step process that requires well developed meta-linguistic skills, precluding the involvement of children at the early stages of language development. Usually, vocabulary is selected by professionals or parents, and communication displays are preprogrammed by others with little input from the beginning communicator. In contrast, "… typically developing children are able to choose, store, and retrieve new words while they are actively responding to and manipulating their environments" (Sturm & Clendon, 2004; p.78).

Visual scene displays and just-in-time programming to support language learning

Visual scene displays (VSDs)

Light and colleagues proposed the use of VSDs[4] to support language learning by young children and older beginning communicators with complex communication needs, specifically to support early semantic development (Light & Drager, 2007; Light & McNaughton, 2012). VSDs are photographs of meaningful and motivating events within the communicator's life. Figure 1 provides an example of a VSD that might be used by a child to communicate about the family's dog. The language concepts that are typically used within the activity are embedded within the scene as hotspots. The child selects the hotspot and the word or phrase is spoken out. (See Light, Wilkinson et al. (2019) for a discussion of research on the design of AAC displays to reduce visual cognitive processing demands and enhance performance.)

VSDs may offer a number of potential advantages for beginning communicators who are at the early stages of symbolic development (i.e., those that are learning first words and developing early semantic relations). They capture the social interactions that are the contexts in which young children learn language and communication skills and they replicate these contexts within AAC systems, thus providing visual contextual supports for the children's language learning and use (Light & McNaughton, 2012). VSDs preserve functional as well as visual relationships (i.e., proportional size, location) between people and objects as they are experienced in the real world, thus providing greater support for young children's comprehension and use. They may support access to language concepts via episodic, not just semantic, memory because they capture events actually experienced by the children. VSDs also offer visual processing advantages as they exploit the human capacity for rapid visual processing of naturalistic scenes (Light & McNaughton, 2012; Light, Wilkinson et al., 2019).

In order to serve as effective supports for language learning, VSDs must provide access to developmentally appropriate, meaningful, and motivating vocabulary. It is important to note that the process of vocabulary selection is independent of decisions about organization/layout within AAC displays; grid displays or VSDs may or may not include appropriate vocabulary for beginning communicators depending on the decisions made by service providers and parents. Although there is nothing inherent within a VSD that guarantees appropriate vocabulary selection, the research clearly demonstrates that VSDs drive visual attention to the key concepts within the interaction (i.e., concepts related to familiar people and shared activities; Wilkinson & Light, 2014). These are the early emerging concepts typically acquired by young children, thus supporting developmentally appropriate vocabulary selection.

Just-in-time (JIT) programming

Recent research and development have led to the development of AAC apps on mobile technologies that support quick and easy programming of VSDs and hotspots so that new vocabulary can be provided on the fly or "just-in-time" during daily interactions (i.e., as the need and interest arise; Jakobs, 2009), in keeping with how beginning communicators learn new concepts. Schlosser et al. (2016) discussed a range of JIT supports for individuals with developmental disabilities, including prompts or reminders. The current paper focuses only on VSD apps that support JIT programming[5] of vocabulary to enhance language learning. These apps allow parents and professionals to (a) take photos or videos (using an onboard camera) to capture events or experiences within

[4]There are many AAC apps that support the use of visual scene displays (VSDs), available from a wide range of AAC manufacturers/app developers. If AAC apps are to effectively support just- in-time (JIT) programming, adding new VSDs, hotspots, and vocabulary must require only a minimal number of steps.

[5]In theory, JIT programming could be achieved with any AAC technology, including grid displays, but only if it is very quick and easy to add a new vocabulary concept; in practice, many current AAC technologies require numerous steps to programme even a single concept. This paper focuses specifically on VSD apps that support JIT programming because it is these apps that have been researched to date.

a child's life as they occur; (b) import these photos quickly into the AAC app as VSDs during the interaction; (c) add hotspots quickly by drawing on the screen using a finger or stylus; and (d) record speech output for these hotspots providing access to new vocabulary immediately as it is required. JIT programming capability is intended to ensure that parents and professionals can easily respond to a child's interests by adding relevant vocabulary, thereby capitalizing on the teachable moments that occur during interactions with him or her throughout the day.

The research evidence

Research has investigated the effects of VSDs with and without JIT programming. This research supports the benefits of VSDs to enhance comprehension, expression, and language learning. It should be noted that this research has investigated VSDs that have varied in terms of their design and composition (e.g., line drawings or photos, personalized or non-personalized). Recent research has established empirically based clinical guidelines for designing VSDs for children with complex communication needs (see Light, Wilkinson et al., 2019, for these guidelines).

The research has demonstrated that young children (24–27 months) are able to learn to use VSDs successfully with relatively few instructional opportunities (Olin, Reichle, Johnson, & Monn, 2010). Furthermore, young children with typical development (29–35 months) are more accurate using VSDs to locate vocabulary concepts than using traditional AAC technologies with grid displays (Drager, Light, Curran-Speltz, Fallon, & Jeffries, 2003). Gevarter et al. (2014) found that two 3-year-old children with ASD demonstrated more rapid and consistent acquisition of requests for objects using photo VSDs compared to traditional AAC symbols, and a third demonstrated no difference across the different display types. Gevarter et al. (2018) extended this research and compared the effects of a taxonomic grid display to a schematic VSD or hybrid display with four children with ASD (aged 4–8). Three of the participants reached mastery making requests with the schematic, but not the taxonomic, display; the fourth met criterion with both displays but only demonstrated generalization with the schematic VSD. Ganz, Hong, Gilliland, Morin, and Svenkerud (2015) compared communication with VSDs to exchange-based communication with two 5-year-old children with ASD: One of the participants did not demonstrate any of the target communicative behaviours in either condition, but the other quickly learned to use VSDs to communicate and was much more apt to use this system throughout the intervention to comment spontaneously and to respond to questions. Schlosser et al. (2013) found that VSDs/video VSDs were effective means to supplement spoken language input to support the comprehension of directives by children with ASD.

VSDs with JIT programming and children's language learning

Light et al. (2016) investigated the effects of a VSD app with JIT programming using a multiple baseline across participants design with five children with complex communication needs (aged 15–33 months) in home and daycare settings with their primary caregivers. The participants (who had diagnoses of Down syndrome, motor impairment, or ASD) all demonstrated significant increases in the frequency of their communication from means of 0–17 turns in 15-min interactions at baseline to means of 23–47 turns during intervention with the VSD app with JIT programming (gains of +22 to +43 turns across participants). The intervention was found to be highly effective for four of the five participants (percentage of non-overlapping data, PND, of 100%) and effective for the fifth (PND = 89%), despite this participant's multiple health problems and hospitalization during the intervention. All of the children also increased significantly the number of unique concepts that they expressed from means of only two to six unique concepts at baseline to means of 13–21 unique concepts during intervention using the VSD app with JIT programming (gains of +9 to +21 unique concepts per 15-min interaction). The intervention was found to be highly effective at increasing the number of unique vocabulary concepts expressed by all of the participants (PND = 100%). Moreover, they communicated to express a greater range of functions, including comments and social expressions as well as requests. Parents and daycare staff had no difficulty learning to programme the app and were able to extend implementation of the app and maintain its positive effects at least 1–2 months post-intervention. On average, parents and daycare staff added ∼ 1–5 new concepts per day for the participants, who continued to acquire unique language concepts ($M = 17$–40 unique concepts expressed in 15-min probes 3–7 weeks post-intervention). The technology seemed to have a good contextual fit (cf., Granlund, Björck- Åkesson, Wilder, & Ylvén, 2008) with families and daycares, resulting in uptake and sustained use after intervention formally ended. The successful uptake may have resulted, in part, from the similarities between the VSD app and social media apps: the parents and caregivers quickly grasped the concept of using photos of meaningful activities tagged with relevant vocabulary as a platform to support communication.

A preliminary study by Light et al. (2012) highlighted the importance of JIT programming specifically to support language learning during daily interactions. Using a single case alternating treatment design, they compared the effects of AAC technologies with VSDs, with and without JIT programming, across three participants with developmental disabilities and complex communication needs (aged 3–5 years). All of the children took significantly more communicative turns using the VSD app with JIT programming in 15 min interactions ($M = 19$–29 turns) compared to the traditional app that did not support JIT programming ($M = 10$–18 turns).

Similar positive effects have been observed with older beginning communicators (e.g., Drager et al., 2017; Holyfield, Caron, Drager, & Light, 2018). For example, Holyfield et al. investigated the effects of an AAC app with VSDs, speech output, and JIT programming with beginning communicators with severe disabilities (aged 9–18 years). All of the participants demonstrated an increase in the number of communication turns they expressed after the VSD technology with JIT programming was introduced (i.e., mean gains of +13 to +26 turns across participants in 15-min interactions, with PND of 100% for all participants, indicating that the intervention was highly effective). The participants were able to learn to use VSDs appropriately in interactions with minimal intervention (i.e., only five intervention sessions). Drager et al. found similar results in another single case study involving nine beginning communicators with severe developmental disabilities (aged 8–20 years), all of whom demonstrated increases in the expression of symbolic communicative turns following introduction of AAC technology with VSDs and JIT programming.

Effects of JIT programming on communication partners

Research by Caron, Light, Davidoff, and Drager (2017) demonstrated that adults were able to quickly learn to programme AAC apps using JIT programming with minimal instruction. On average, they required 1 min to programme a new VSD with two hotspots, suggesting that they would be able to add five new VSDs with 10 new vocabulary concepts in ~ 5 min. These adults expressed strong preference for these apps, which were quick and easy to programme, compared to others with more detailed, multi-step programming demands. Furthermore, speech-language pathologists were able to quickly learn to utilize JIT programming successfully during interactions with young children to respond to their needs and interests and add new VSDs and vocabulary on the fly (Caron, Light, & Drager, 2016).

JIT programming and children's engagement in vocabulary selection

One of the key benefits of VSD apps with JIT programming is the capacity to provide quick access to relevant vocabulary in the moment in response to a child's needs and interests. Given that VSDs capture meaningful events in children's lives, they provide a concrete means for young children to indicate their interest in concepts by selecting areas of the VSD. Ideally, JIT programming of vocabulary would be so simple and intuitive that children could participate in this process even at the early stages of language development, thus empowering them in their vocabulary acquisition (Light, 1997). Holyfield, Drager, Light, and Caron (2017) explored the demands of JIT programming from a developmental standpoint with young children with typical development (aged 10–24 months). All were able to participate successfully in some aspects of JIT programming. As was expected, the oldest (aged 20–22 months) were more successful than the youngest (aged 10–13 months), even though there was individual variation across children. Despite the greater success of the older participants, it is important to note that even infants (less than a year old) successfully participated in some of the programming steps (drawing on the VSD, taking a photo as a VSD). Future research is required to identify the factors that contribute to successful participation and to design AAC technologies that better support children's involvement. If children with complex communication needs are able to participate successfully in JIT programming of their AAC systems, this involvement could bolster their language learning significantly by empowering the children to grab the contexts and vocabulary concepts of interest to them in the moment, and allowing them to use new concepts immediately to communicate (Holyfield et al., 2017).

Light et al. (2012) found that young children with complex communication needs were highly engaged in the process of JIT programming, even though they were not able to independently programme vocabulary: They actively attended to the partner and/or the AAC technology 97% of the time that new VSDs were being added and 95% of the time that new hotspots and vocabulary were being added. The interactions between the participants and their adult partners, surrounding the JIT programming of VSDs and relevant vocabulary, served as rich supports for language learning. They provided opportunities for repetition of key language concepts associated with the experience, and for focused stimulation around the new concepts programmed as hotspots.

Future directions

Results of research to date are tantalizing, for they suggest that, by re-designing AAC technologies, it may be possible to bootstrap not only the expressive communication of children with complex communication needs, but also their language learning. AAC apps with VSDs, speech output, and JIT programming provide a rich context to support early semantic development during daily interactions. They also provide a means for children to independently explore new vocabulary concepts because the VSDs provide strong visual contextual supports for learning. Light et al. (2016) reported that the participants frequently played with their AAC technologies independently or with a sibling or peer, selecting hotspots from the VSDs to retrieve new concepts. Future research is required to further investigate the effects of VSD technologies with a wider range of beginning communicators with complex communication needs and their typical partners in natural settings and compare these effects to those of AAC technologies utilizing traditional grid displays. As children develop language skills over time, they think about the world in very different ways and require different types of AAC technologies to meet their needs, skills, and interests. There is a need to investigate which technology designs work best for which children at which stages of development and in which contexts. Ultimately this work will support *precision AAC*, that is, the customization of decision-making, intervention, and technologies to maximize outcomes for each individual with complex communication needs (see Beukelman, 2016). VSDs represent just one approach to AAC displays; future research is required to investigate the effects of other approaches to the vocabulary, representation, organization, and layout of language for children with complex communication needs to support their development over time, including innovative approaches, not yet imagined, that depart from current practice. Future research and development must be driven by the needs and skills of children with complex communication and by what is known about language learning.

Future research and development is also required to enhance AAC technology supports for parents and service providers. The development of AAC apps that support JIT programming is one example of technology design that has substantially reduced the time and effort required of parents and professionals to implement AAC; in this case, to programme vocabulary. Future research should explore other ways that AAC technologies can be designed to reduce the burden on partners during interactions. For example, a recent meta-analysis by O'Neill et al. (2018) found that use of aided AAC input by partners was highly effective in supporting language development (both comprehension and expression) across participants with complex communication needs of various ages, disabilities, and language skills. Despite the benefits of aided AAC input, in practice, it can be challenging for partners to regularly implement this strategy in daily interactions (O'Neill et al., 2018). Future research and development should consider ways to utilize AAC technologies to provide a rich and more complete model of AAC input, thus easing the burden on communication partners. One possible solution would be the utilization of dynamic JIT translation of partner speech into written text, graphic symbols, or signs (depending on the needs and skills of the individual with complex communication needs). Future work should also explore applications of machine learning to provide *smart supports* to guide service providers and parents in supporting their children's language learning. For example, AAC technology might track the vocabulary concepts available, compare these concepts to those acquired early in development, note imbalances in the range of concepts programmed, and suggest new concepts (e.g., verbs) that should be added to support language development in beginning communicators.

AAC supports to facilitate social interaction

Re-designing AAC technologies can serve to support not only vocabulary acquisition and language learning but also social interaction by (a) reducing joint attention demands and providing a shared context for young children and their partners, and (b) supporting the transition to displaced talk for children with complex communication needs.

Reducing joint attention demands and providing a shared context for interaction

> Ella is 4 years-old and has a diagnosis of autism spectrum disorder. She lives at home with her parents and her younger brother. She likes to play with magnetic letters and she loves to look at books. She attends an inclusive preschool in the mornings with children with and without disabilities. She uses a few sign approximations to communicate and exchanges photos of familiar objects and activities to make requests. She has been introduced to AAC technology, but she has difficulty attending to the technology, the activity, and her partner. How can we design AAC supports to reduce these attentional demands and better support Ella's communication with familiar adults and peers?

The challenge

At the early stages of language development, young children like Ella, and older beginning communicators, often have difficulty with joint attention (i.e., shifting attention from a partner to a shared activity and back) and, as result, struggle to participate in communicative interaction. In typical development, infants first learn to attend to a single focus—either their partner or an object (Brady et al., 2012). For example, they learn to play peek-a-boo games or participate in "bye-bye" routines where their attention is focused on their partner, or to focus on an interesting object or activity (e.g., a toy). Later, they learn to coordinate joint attention between their partner and a shared activity. The development of joint attention marks a pivotal point in language development for young children; it provides the foundation for language learning as children follow their partner's attention and map language onto objects and actions accordingly. The research suggests that the development of joint attention may be challenging for some young children with developmental disabilities (e.g., Schertz, Odom, Baggett, & Sideris, 2013). The challenges of joint attention are further magnified for young children who use aided AAC because they must learn to coordinate attention among the partner, the shared activity, *and* the AAC system (Smith, McCarthy, & Benigno, 2009). If children struggle to coordinate attention across all three of these foci, they will have difficulty learning the associations between referents, spoken words, and their AAC symbols.

VSD supports to reduce joint attention demands in social interaction

Light (1997) suggested that one way to reduce the increased joint attention demands for beginning communicators who use aided AAC is by infusing the shared activity into the AAC technology. For example, books can be added to AAC technologies as VSDs and relevant vocabulary can be added as hotspots. Young children with typical development talk as they interact with their environment. Utilizing VSDs may provide a mechanism to infuse the environment into AAC technologies, reducing joint attention demands and providing children with something to communicate about.

Infusing a shared activity (e.g., preferred book or video) into AAC technologies may also facilitate interaction for communication partners. Often parents, peers, and other communication partners struggle to determine motivating and meaningful opportunities for communication with children with complex communication needs. They may experience challenges understanding the children's communicative attempts and may have difficulty knowing what to talk about. VSDs may provide a shared context to support successful interaction for not only the individual with complex communication needs, but also his or her partner. Photo VSDs naturally provide partners with something to talk about and they establish a shared referent, thus increasing the likelihood of successful interaction. In fact, photographs (and videos) are ubiquitous in social media and serve as powerful supports for social interaction for everyone.

The research evidence

Therrien and Light (2018) investigated the effects of AAC technologies on interactions between five preschoolers with ASD and their typical peers. The technologies included VSDs of preferred children's books with relevant vocabulary embedded as hotspots within the VSDs, thus integrating a shared activity and a means of communication, and reducing joint attention demands for the participants. As a result of intervention (including introduction of the AAC technology and instruction in turn taking for each dyad), four of the five participants with ASD demonstrated increased turn taking in interactions with their typical peers; the fifth demonstrated gains in instruction but not in the probes, perhaps because instruction had to be terminated early due to the end of the school year. The peers also benefitted from the intervention: all demonstrated increased turn taking with the children with ASD as a result of intervention. Average joint engagement increased for all dyads as well, although there was variation across sessions. The AAC technologies provided a shared context that supported not only the communication of the children with complex communication needs but also the peers without disabilities. Specifically, the technology provided the participants with something to do together and something to say, thus supporting their engagement and interaction. Unlike prior studies that have focused on training peer partners as instructors, Therrien and Light utilized AAC technologies as universal designs to support all of the participants in more equal, shared interaction.

Video VSDs to reduce joint attention demands in social interaction

Although books are powerful shared activities to facilitate social interaction, videos provide a highly preferred activity for many children with developmental disabilities and may serve as an effective context to promote communication as well. There are, of course, many technologies that support videos; however, typically they involve passive viewing and do not integrate AAC supports. Recently, Light, McNaughton, and Jakobs (2014) proposed redesigning AAC apps to integrate VSDs into videos as communication supports (see https://tinyurl.com/rerc-on-aac-vVSD for a demonstration of video VSDs[6]). Essentially, these technologies support (a) capturing video of motivating activities or downloading preferred videos; (b) pausing the video at key junctures, automatically creating VSDs; and (c) adding hotspots to the VSDs with relevant vocabulary to support communication about the video, just in time, in response to the child's interests. The use of videos with embedded VSDs appears promising for several reasons. First, the videos capitalize on preferred interests. Second, they reduce joint attention demands for children with complex communication needs because the AAC supports are integrated seamlessly into the video so there is no need for the child to shift attention between the video and a separate AAC system/app. Third, video VSDs preserve dynamic relationships and capture both the spatial and temporal cues found in the real world. Fourth, the motion within the video may serve to engage children with complex communication needs because motion is a powerful attractor of visual attention (cf. Jagaroo & Wilkinson, 2008). Finally, automatic pausing of the video at key points explicitly marks the appropriate opportunity for communication and provides the necessary vocabulary within the VSD. When video VSD apps support JIT programming, these apps offer the added advantage of supporting the child's engagement in vocabulary selection and programming and the partner's responsivity to the child's interests.

The research evidence

Results of two preliminary studies support the effectiveness of video VSDs as a means to support social interactions. Caron, Laubscher, Light, and McNaughton (2018) implemented a single case experimental design to investigate the effects of video VSDs on the contingent communication turns of five participants with moderate-to-severe ASD and limited speech (aged 10–18) during interactions focused on preferred YouTube videos. At baseline, the participants took few communicative turns ($M = 0–28$ across participants). When video VSDs were introduced (with vocabulary reflecting the individual interests of the participants), they all demonstrated significant increases in the frequency of their communication turns ($M = 24–82$). Video VSDs were highly effective at increasing turn taking (Tau U of 0.93–1.00).

Chapin, McNaughton, Light, McCoy, and Caron (2018) investigated the effects of video VSDs on the communication of four preschoolers with ASD (aged 3–5 years) while viewing preferred videos. The preschoolers took few, if any, communication turns during baseline while watching the videos ($M = 0–13$); after introduction of the videos with embedded VSDs and hotspots, the participants all increased their communication turns ($M = 3–25$). Video VSDs were again found to be highly effective at supporting social interactions, this time for young children with ASD (Tau U of 0.92–1.00 across participants). Future research should investigate the effects of both photo VSDs and video VSDs on social interactions between children with complex communication needs and their communication partners, across a greater range of ages, activities, and environments.

Facilitating displaced talk by children with complex communication needs

VSDs and video VSDs can serve to facilitate social interaction by not only infusing shared activities (e.g., favourite books, videos, or TV shows) into AAC technologies but also facilitating the transition to displaced talk.

> Charlie is 9 years old and has a diagnosis of severe autism spectrum disorder. He attends a specialized school programme for children with ASD; he lives at home with his parents. He loves

[6]Video VSDs were initially developed under the Rehabilitation Engineering Research Center on Augmentative and Alternative Communication (RERC on AAC) by InvoTek, Inc., 1026 Riverview Dr., Alma, AR 72921, USA; www.invotek.org. An app that supports video VSDs, GoVisualTM, is available from Attainment Company, 504 Commerce Parkway, Verona, WI 53593, USA; www.attainmentcompany.com/govisual

to ride his bike and go to the park to feed the fish. With prompting, he uses ~ 20 speech approximations and ~ 10 sign approximations. He understands one step directions and simple wh-questions. However, he has significant difficulty participating in displaced talk about past (or future) events. How can we design AAC technologies to support Charlie in learning to engage in displaced talk?

The challenge

As young children with typical development learn language, they are initially tied to the immediate environment in which they are communicating; their use of language is context-bound (Adamson & Bakeman, 2006). Over time, they gradually learn to engage in displaced talk and communicate about objects, people, and events outside the here and now. This transition to displaced talk marks an important shift in language development that opens up many new learning opportunities and prepares children for school, where learning requires the understanding and use of displaced talk. Unfortunately, many children with developmental disabilities, like Charlie, may struggle to participate in displaced talk.

Video VSDs to support displaced talk

AAC technologies with video VSDs can be used to support displaced talk by capturing videos of meaningful experiences, pausing the video at any point to create a VSD, and adding appropriate vocabulary to support the child's communication about the experience. Video is highly transparent and serves to bring the past event to the here and now and make it more accessible for beginning communicators. This contextual support may function as a bridge to assist individuals with complex communication needs in displaced talk about past events.

The research evidence

Caron, Holyfield, Light, and McNaughton (2018) explored the effects of video VSDs as a means to support displaced talk in a single case pilot study with a 9-year-old boy with severe ASD during interactions about his school day focused on the question, "What have you been doing?" At baseline, with access to his typical means of communication (i.e., ~ 20 speech approximations, signs, and conventional yes/no gestures), he struggled to participate in displaced talk about the events of the day ($M = 0.3$ turns per minute). After the introduction of the video VSD app to capture key events in the day, he demonstrated significant increases in his communication turns per minute ($M = 2.6$)—a gain of +2.3 turns per minute. With increased communication, he was able to sustain longer social interactions.

Future directions

These preliminary results are promising; however, it is important to note that this study did not have experimental control. Future research is required to further investigate the effects of video VSDs as supports for displaced talk. This research should consider the effects not only on individuals with complex communication needs, but also on their partners who may also benefit from contextual support to enhance their understanding. For example, VSDs and video VSDs may provide powerful contextual or topic cues that may enhance partners' understanding of the communication of children with severe speech impairments. Future research is also required to explore the effects of partners capturing their own experiences through photo and video VSDs to share these events with beginning communicators with complex communication needs. Using video or photos in this way would serve as concrete visual supports to enhance comprehension of displaced talk by beginning communicators (e.g., a mother might capture video of her plane trip and share it with her preschooler, thereby establishing a shared context for communication as well as supports for her daughter to ask questions and extend her language learning).

AAC supports for literacy learning

Sara is 14 years old and has a diagnosis of Down syndrome. She lives at home with her parents and sisters and attends a special education programme at school. She loves the World Wrestling Federation (WWF). She uses speech as her primary means of communication, but her speech is highly unintelligible to unfamiliar partners. She did not receive adapted literacy instruction in school; she recognizes fewer than 10 sight words and knows approximately five letter sounds. Her family recognizes that literacy skills will provide an important tool for Sara to support her future participation in employment, healthcare, and community living. How can we design AAC technologies to support Sara's expressive communication and her acquisition of literacy skills?

The challenge

Given the importance of literacy skills in society, it is concerning that the majority of individuals with complex communication needs reach adulthood without functional literacy skills (Foley & Wolter, 2010). There are numerous intrinsic and extrinsic factors that contribute to poor literacy outcomes, but one significant factor is the design of many AAC technologies. Most children with complex communication needs utilize AAC technologies/apps with visual scene displays (VSDs) or with grids of picture symbols; these technologies/apps do not support the transition from photographs or pictures to traditional orthography. VSDs for children typically do not provide access to written words. In the case of traditional grid displays, written words are often provided above the picture symbols and may appear in the message bar when the symbol is selected. However, the written words above the symbols are small and static and those in the message bar are displaced from the graphic symbols that are their referents. This design does not drive attention to the written orthography or support the acquisition of sight-word vocabulary.

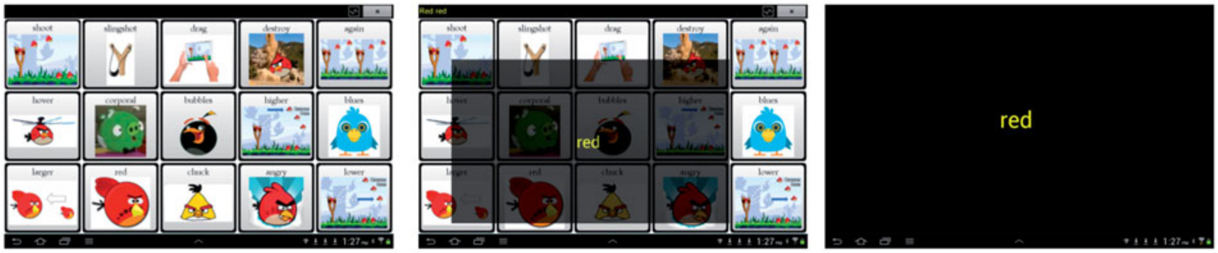

Figure 2. An example of the dynamic text (T2L; transition to literacy) feature on a grid display (reprinted from Caron, Light, Holyfield, & McNaughton, 2018). Upon selection of the graphic symbol with a static text label (image on left), the text alone zooms out from the graphic symbol (image in the middle); the text then fills the screen for 3 s and the word is spoken (image on the right) before the text fades back into the graphic symbol. See https://tinyurl.com/rerc-on-aac-T2L for videos demonstrating the T2L feature with VSD and grid displays.

AAC technology features to support literacy learning

It is possible to re-design AAC technologies to better support literacy learning by individuals with complex communication needs. Recently, Light, McNaughton, Jakobs, and Hershberger (2014) proposed a new feature, for both VSDs and grid-based systems, to support the transition to literacy (T2L). To date, development efforts have focused on a T2L feature to support reading of single words: (a) upon selection of a graphic symbol from the AAC display, the written text appears using dynamic smooth animation of the written word to draw visual attention to the text and support orthographic processing; (b) the text originates from the graphic symbol to support the association of the symbol and the text; (c) the written text gradually increases in size and ultimately replaces the graphic symbol on the display for 3 s to make the word salient; and, (d) when the written word appears on the screen, it is paired with speech output of the word to support phonological processing of the text (Light, McNaughton, Jakobs, & Hershberger, 2014). The exposure to traditional orthography is infused into the individual's AAC system, thus ensuring that literacy learning is driven by the individual's interests and communication needs. (See Figure 2; visit https://tinyurl.com/rerc-on-aac-T2L for video examples of the T2L feature[7] within VSD and grid AAC apps.).

The research evidence

To date, a series of four experimental studies, all utilizing a single case multiple probe across participants designs, have been completed to investigate the effects of the T2L feature (incorporated into VSD or grid-based AAC apps) on the acquisition of sight words, and several additional studies are in progress. Caron, Light, Holyfield, and McNaughton (2018) introduced the grid-based T2L AAC app to five school-aged students with ASD (aged 6–14 years) in structured one-on-one sessions targeting 12 words. At baseline, the participants performed at low levels of accuracy in reading the words (measured by matching the words to the correct picture symbol from a field of four); after five to eight intervention sessions involving use of the T2L grid-based app alone (without literacy instruction), all five acquired the target words (range = 75–92%) and demonstrated generalization to functional use of the words to communicate using a grid display with written words only. Tau U was 1.00 for all participants, demonstrating a very large intervention effect. On average, the students required 20–32 presentations of the dynamic text (3 s exposure for each presentation) to acquire the sight words (i.e., $M = 1–1.5$ min of exposure in total per word for learning).

Mandak, Light, and McNaughton (2018) investigated the effects of the VSD T2L app, targeting 10 sight words, during shared reading of a storybook with three preliterate preschoolers with ASD (aged 3–4 years). All participants demonstrated successful acquisition of the target sight words (77–100% accuracy across participants). Tau U was 0.41, suggesting a moderate effect of the VSD T2L app, for one participant; Tau Us were 0.63 and 0.76, suggesting large effects, for the other two. The preschoolers required an average of 24 presentations (3 s each) within the shared book reading to acquire each sight word (less than 2 min of total exposure per word), suggesting the powerful effects of motion on visual attention to the orthographic text.

Boyle (2018) extended this research and investigated the effects of the T2L VSD app on the acquisition of 10 sight words during a shared book reading activity with six preliterate preschoolers with developmental delays or Down syndrome in small groups with their peers without disabilities; all participants demonstrated positive gains in reading 10 target sight words as a result of the intervention with the T2L VSD app. Tau U was 0.84–1.00 across the six participants, indicating very large effects of the T2L app. On average, the participants with developmental disabilities required 2–7 min of exposure per word for acquisition within the small group activities.

Holyfield, Light, McNaughton et al. (2018) investigated the effects of the VSD T2L app with six non-literate adults with severe intellectual developmental disabilities (aged 22–55 years). This study targeted 10 sight words for high preference activities (e.g., bowling), and the T2L VSD app was introduced in the context of social interaction about these preferred activities. Results of the study were mixed. Three of the six participants did not demonstrate increases in their

[7]The transition to literacy (T2L) feature for VSD apps was initially developed under the RERC on AAC by InvoTek, Inc., 1026 Riverview Dr. Alma, AR 72921, USA; www.invotek.org. Commercially available AAC apps that support VSDs with the T2L feature include: GoVisualTM available from Attainment Company, 504 Commerce Parkway, Verona, WI 53593, USA; www.attainmentcompany.com/govisual; and Snap Scene available from Tobii Dynavox, 2100 Wharton St., Suite 400, Pittsburgh, PA 15203, USA; www.tobiidynavox.com/en-US/software/iPad-apps/snap-scene/. The transition to literacy (T2L) feature for grid-based apps was developed by, and is available from, Saltillo, 2143 Township Rd. 112, Millersburg, OH 44654, USA; https://saltillo.com/

sight-word reading with exposure to the T2L VSD app alone; however, the other three demonstrated positive gains, maintained these gains at least a month after intervention had ended, and generalized learning to novel stimuli (i.e., novel photo representations of the words). These positive results are of note, given the severity of the participants' disabilities, their previous lack of success with literacy instruction, the relatively short time they were exposed to the app, and the simplicity of the intervention (i.e., exposure to the T2L feature built into the app).

It is important to emphasize that the T2L feature is intended to complement, not replace, evidence-based literacy instruction. In order to isolate the effects of the T2L feature on single word reading, in these studies, the participants did not receive any literacy instruction or feedback; the observed gains resulted solely from the exposure to the dynamic text, paired with speech output, within the AAC apps, suggesting the potential power of this technology design. In fact, the participants in these studies increased their sight-word reading skills with only limited exposure to the written words.

Future directions

These studies suggest the potential promise of harnessing AAC technologies not just to support expressive communication, but also to support literacy learning. However, future research is required to replicate the results of these studies with other individuals with complex communication needs of different ages and disabilities. Research is also required to investigate whether the T2L feature works best when used only during specific activities or when integrated into communication throughout the day. Moreover, research is required to investigate the effects of the T2L feature on communicative interaction, including the perception and performance of the individual with complex communication needs and those of the communication partner. Clearly, literacy skills must extend well beyond acquiring a set of sight words. Future research and development is also required with regard to designing AAC technologies to support learning other literacy skills beyond single-word reading (e.g., phonological awareness, letter sound correspondences, decoding skills, reading comprehension, writing skills).

AAC supports for participation in educational, vocational, and community activities

> James is a 17-year old student with severe ASD. He lives in a rural area and is very interested in farm equipment. He understands simple questions and follows simple directions. He has no functional speech and communicates primarily through yes/no responses to partner questions. He is currently participating in a vocational training program and works in the school library. His responsibilities include checking books in and out, re-shelving them, and making dye cuts. Each of these tasks involves numerous steps and communication demands. Despite instruction, he remains very dependent on his job coach to assist him in completing his work tasks, and he rarely communicates. How can we design AAC technologies to support James' independent participation and communication in his job?

The challenge

If individuals with complex communication needs are to participate successfully in educational, vocational, family, healthcare, and community environments, they need to acquire a wide range of skills, including the ability to complete typical tasks as well as meet the communication demands within these activities. AAC technologies offer the potential to not only support expressive communication but also provide instructional supports to foster other educational, vocational, and community skills. There is robust research literature that demonstrates the effectiveness of video modelling as a means to teach children and adults to complete the necessary steps in a wide range of tasks (Bellini & Akullian, 2007). Unfortunately, video modelling apps do not provide supports for communication for those that require AAC, which means individuals with complex communication needs must manage separately the video models and their AAC supports, substantially increasing demands.

Video VSDs to support participation

As noted earlier, Light, McNaughton, and Jakobs (2014) conceptualized a new AAC technology utilizing video VSDs. This technology can be used not only to support social interaction (as described earlier) but also to integrate AAC supports and video modelling. Essentially, the app allows a partner to capture video of successful completion of target educational, vocational, healthcare, daily living, or community activities (e.g., taking the bus to work, buying groceries, checking in books at the library), using an onboard camera or via wireless transfer from another source. The video is then paused following each step of the task, providing the opportunity for the learner to complete that step. Each time the video is paused, hotspots can be added to the VSD, providing the vocabulary required to meet the communication demands of the situation (e.g., greeting the bus driver).

The research evidence

Preliminary research by O'Neill, Light, and McNaughton (2017) and by Babb, Gormley, McNaughton, and Light (2018) suggests that video VSDs are an effective means to increase the independent communication and participation of adolescents and young adults with complex communication needs in vocational and community activities. For example, in a pilot case study, O'Neill et al. (2017) explored video VSDs to teach an adolescent with ASD to independently complete three vocational and community tasks (i.e., completing a shredding job, working in a print shop, riding the bus). The participant quickly learned to use the video VSD app and demonstrated gains in the percentage of task steps and communication opportunities completed accurately and independently across the three tasks while using the video VSD app: Her performance at her job at the print shop increased from 15% at baseline to 75% after only three intervention sessions; her performance taking public transportation increased from 22% at baseline to 100% after eight sessions; and her performance at her shredding job increased from 10% at baseline to 100% after five sessions. These results are promising but should be interpreted cautiously as the case report did not establish experimental control.

Babb et al. (2018) extended this preliminary research and investigated the effects of the video VSD app with an adult with ASD and no speech in three vocational tasks using a multiple probe across behaviours experimental design (i.e., checking in books at the library, sorting library books for re-shelving, completing dye cuts). At baseline, the participant completed, on average, 8%, 5%, and 15% of the steps in these tasks independently. After minimal intervention with the video VSD app (i.e., three to six sessions across the three tasks), he attained mastery (> 90% successful independent completion of all task and communication requirements) in all three tasks. He maintained mastery in probes conducted 1, 3, and 5 weeks post-intervention. Furthermore, he generalized use of the video VSD app to support his participation and communication in a completely new task (i.e., a shredding job) without any instruction, demonstrating an immediate increase in successful independent participation.

Future directions

Ultimately, video VSD technology could reduce dependence on professionals (e.g., teachers, job coaches, paraprofessionals) and create increased opportunities for employment and independent participation in meaningful community activities for individuals with complex communication needs. Future research is required to replicate these preliminary results and to extend these studies to investigate the use of video VSDs as a means to increase communication and participation for individuals who require AAC of various ages and disabilities across a wide range of contexts (e.g., educational, vocational, healthcare, daily care, social, community living).

Supports to teach communication partners knowledge and skills

Successful communication depends on both participants in the interaction. Therefore, AAC intervention must consider not just the needs of individuals that require AAC, but also those of their communication partners. To date, researchers and developers of AAC technologies have focused primarily on providing supports for individuals with complex communication needs (McNaughton & Light, 2015). However, it is challenging for parents and other partners to interact effectively with children with complex communication needs, especially with those that are beginning communicators and require significant scaffolding support. AAC technologies offer the potential to provide supports not only for children with complex communication needs, but also for parents, professionals, and peers.

> Brianne attends middle school and volunteers 3 times a week in a class for students with severe multiple disabilities. She and her friends try to plan social activities with the students with multiple disabilities, but they have difficulty understanding the students' communicative attempts. Many of the students with multiple disabilities are presymbolic and use non-conventional means to communicate. Brianne and her friends have trouble knowing what the students are communicating and responding consistently to these attempts. How can we design AAC technologies to support Brianne and her friends in recognizing and responding consistently to the communicative behaviours of their peers with multiple disabilities?

The challenge

Peers (like Brianne), parents, and other communication partners may require instruction to learn effective interaction strategies (e.g., modelling AAC use, waiting, and allowing time for communication, recognizing, and responding to communication attempts). Kent-Walsh et al. (2015) completed a meta-analysis of the effects of partner instruction on the communication of individuals with complex communication needs. They concluded that partner instruction was highly effective and efficient: With only minimal instruction, communication partners learned to use targeted interaction strategies successfully and the changes in partner strategies resulted in gains across various outcomes (pragmatic, semantic, syntactic/morphological) for individuals with complex communication needs. In these studies, partner instruction was typically implemented in one-on-one sessions by a trained researcher. Unfortunately, this type of training is not always a key component of typical practice due to service delivery and funding constraints. Furthermore, training is not available to partners "just in time" as required to support interactions. Rather, it is dependent on the availability of a professional who is knowledgeable and skilled in partner instruction. As a result, many parents, peers, and other partners may not have access to the training they need when they need it (McNaughton et al., 2019).

Video VSDs to teach partners knowledge and skills

Video VSD technology may offer an alternative medium to teach partners appropriate interaction strategies to support the communication of individuals with complex communication needs. Just as video VSD technology is an effective means to teach new skills to individuals who use AAC, so too may it prove to be an effective way to teach interaction strategies to communication partners. Furthermore, if these video supports for partner training are infused into the AAC technologies used by children with complex communication needs, they will be available to partners as required during naturally-occurring interactions. Incorporating partner training into AAC technologies offers a number of potential advantages compared to traditional partner training formats that typically involve one-on-one (or small group) instruction of partners by the AAC team: (a) instruction is readily available to a wide range of partners at any time for practice or review; (b) it can be accessed "just in time" should the need arise during interaction with the individual with complex communication needs; (c) it can be delivered in the moment in short bursts, thus minimizing time demands for partners; and (d) it is easily customizable to meet the needs of the individual who uses AAC using onboard cameras and other tools.

The research evidence

Holyfield, Light, Drager, McNaughton, and Gormley (2018) utilized video VSDs to teach middle school peers to recognize and interpret correctly the presymbolic communication behaviours of students with severe multiple disabilities. They collected videos of the students with multiple disabilities during their daily interactions at school; each time the student produced a communicative behaviour, the video was paused to create a VSD and add a hotspot that labelled the behaviour with the appropriate linguistic map (e.g., "unhappy", "funny'', "want it") to help partners respond to the behaviours consistently. The study utilized a pre-test–post-test control group design to evaluate the impact of the training (using video VSDs) on the performance of 24 peers interpreting specific communicative and non-communicative behaviours of the three middle-school students with multiple disabilities. Prior to training, the peers in both the experimental and control groups were inconsistent in their interpretations of the behaviours of the students with multiple disabilities, with means of only 33% and 31% accuracy across the experimental and control groups, respectively. After training, the peers in the experimental group demonstrated significant improvements in accuracy ($M = 86\%$) compared to peers in the control group, who received no training and demonstrated no gains ($M = 28\%$).

Future directions

Future research is required to explore the effects of video VSDs as a training media with a range of stakeholders (e.g., parents, siblings, peers, teachers, paraprofessionals, personal care attendants, medical professionals) in their interactions with a range of individuals who use AAC across a range of real world contexts. Future research and development is also required to determine effective user interfaces to integrate AAC supports for individuals with complex communication needs and JIT training supports for communication partners. Finally, it will be important to evaluate the relative effectiveness of this approach compared to more traditional face-to-face partner training.

Conclusion

The AAC technologies described in this paper represent new and emerging, research-based, developmentally appropriate approaches to (a) support children with complex communication needs in language learning, social interaction, literacy acquisition, and participation in society; and (b) provide interaction and instructional supports for their parents, service providers, peers, and other communication partners. AAC interventions that utilize VSD or video VSD technologies also have an important collateral effect: Since they are designed to capture authentic life events, they focus intervention on communication and participation during meaningful activities within the lives of individuals with complex communication needs. Historically, AAC interventions with children have seldom actually targeted real-life circumstances within families (Granlund et al., 2008). In their review of 20 years of communication intervention research with individuals with severe intellectual and developmental disabilities, Snell et al. (2010) reported that, in almost half of the studies, intervention was delivered in decontextualized settings, removed from the natural environment and in more than 50% of the studies, the intervention was delivered by a researcher, not a natural communication partner. Utilizing AAC technologies with VSDs or video VSDs drives AAC intervention away from segregated clinic rooms and into real life interactions. This approach focuses intervention on supporting the communication and participation of individuals with complex communication needs across a wide range of meaningful real-world contexts: home, school, work, healthcare, and community (Light & McNaughton, 2015). It also ensures greater contextual fit with the lives of children with complex communication needs, their families, and other communication partners, including those from diverse cultural backgrounds, as the experiences captured in VSDs and video VSDs reflect the authentic experiences of these individuals.

Despite the advances in AAC to date, the work of developing effective AAC supports and interventions for children with complex communication needs and their communication partners is still in its infancy. Future research and development is required around other technological innovations (e.g., sensing technologies, GPS and context recognition, augmented reality, machine learning/artificial intelligence) that might improve AAC technology solutions for children with developmental disabilities and their communication partners (see Light, McNaughton et al., 2019). It is absolutely critical that this future research and development is driven not by the technology, but rather by the needs and skills of the primary end users: individuals with complex communication needs and their partners. Research is urgently required to advance understanding of the cognitive, motor, sensory-perceptual, linguistic, and social processes of children with complex communication needs and their partners at different stages of development to ensure that AAC technologies are developmentally appropriate, impose minimal learning demands, are motivating and appealing, and accommodate changes in needs and skills seamlessly over time. Despite the important role of AAC technologies, these supports alone are not enough; rather children with complex communication needs also require evidence-based instruction to learn the linguistic, operational, social, and strategic skills required to develop communicative competence.

It is essential that we ensure the effective translation of evidence-based AAC technologies and intervention to practice. Unfortunately, there remains a substantial gap between what the research has demonstrated is possible and what is most likely to occur in the lives of children with complex disabilities who require AAC. There is an urgent need for more effective technology transfer, research dissemination, and training to build capacity in the field across stakeholders and support the effective diffusion of innovation. Also required is a deep commitment to the fundamental right of *all* children to have the opportunity to participate fully in society and attain their full potential.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The contents of this paper were developed under a grant to the Rehabilitation Engineering Research Center on Augmentative and Alternative Communication (The RERC on AAC) from the US Department of Health and Human Services, National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR) grant # 90RE5017. The contents do not necessarily represent the policy of the funding agency, and endorsement by the federal government should not be assumed.

This paper is part of a special issue of the *AAC* Journal on the State of the Science.

ORCID

Janice Light http://orcid.org/0000-0003-4449-798X
David McNaughton http://orcid.org/0000-0001-5979-3859
Jessica Caron http://orcid.org/0000-0001-8036-9921

References

Adamson, L.B., & Bakeman, R. (2006). Development of displaced speech in early mother–child conversations. *Child Development*, *77*, 186–200. doi:10.1111/j.1467-8624.2006.00864.x

Babb, S., Gormley, J., McNaughton, D., & Light, J. (2018). Enhancing independent participation within vocational activities for an adolescent with ASD using AAC video visual scene displays. *Special Education Technology*. Advance online publication. doi:10.1177/0162643418795842

Bellini, S., & Akullian, J. (2007). A meta-analysis of video modeling and video self-modeling interventions for children and adolescents with autism spectrum disorders. *Exceptional Children*, *73*, 264–287. doi:10.1177/001440290707300301

Beukelman, D.R. (2016). Precision intervention research for adults with complex communication needs from acquired medical conditions. *Augmentative and Alternative Communication*, *32*, 233–235. doi:10.1080/07434618.2016.1252947

Beukelman, D., & Mirenda, P. (2013) *Augmentative and alternative communication: Supporting children and adults with complex communication needs*. Baltimore, MD: Paul H. Brookes Publishing.

Boyle, A. (2018). The effects of digital texts with Transition to Literacy features on the sight word recognition skills of young children with disabilities and their peers without disabilities. Unpublished doctoral dissertation, The Pennsylvania State University.

Brady, N., Fleming, K., Thiemann-Bourque, K., Olswang, L., Dowden, P., Saunders, M., & Marquis, J. (2012). Development of the Communication Complexity Scale. *American Journal of Speech Language Pathology*, *21*, 16–28. doi:10.1044/1058-0360(2011/10-0099)

Caron, J., Holyfield, C., Light, J., & McNaughton, D. (2018). "What have you been doing?": Supporting displaced talk through AAC video VSD technology. *Perspectives on Augmentative and Alternative Communication*, *3*, 123–135. doi:10.1044/persp3.SIG12.123

Caron, J., Laubscher, E., Light, J., & McNaughton, D. (2018). Effect of video VSDs on communicative turns of individuals with autism spectrum disorder and complex communication needs. Manuscript submitted for publication.

Caron, J., Light, J., Davidoff, B., & Drager, K. (2017). Comparison of the effects of mobile technology AAC apps on programming VSDs. *Augmentative and Alternative Communication*, *33*, 239–248. doi:10.1080/07434618.2017.1388836

Caron, J., Light, J., & Drager, K. (2016). Operational demands of AAC mobile technology applications on programming vocabulary and engagement during professional and child interactions. *Augmentative and Alternative Communication*, *32*, 12–24. doi:10.3109/07434618.2015.1126636

Caron, J., Light, J., Holyfield, C., & McNaughton, D. (2018). Effects of dynamic text and speech output in an AAC app with graphic symbols on single-word reading for individuals with autism spectrum disorder. *Augmentative and Alternative Communication*, *34*, 143–154. doi:10.1080/07434618.2018.1457715

Chapin, S.E., McNaughton, D., Light, J., McCoy, A., & Caron, J. (2018, July). Effects of video visual scene display technology on the symbolic communicative turns taken by preschoolers with ASD during a shared activity. Paper presented at the Annual Conference of the Rehabilitation Engineering and Assistive Technology Society of North America, Arlington, VA.

Drager, K., Light, J., Currall, J., Muttiah, N., Smith, V., Kreis, D., … Wiscount, J. (2017). AAC technologies with visual scene displays and "just-in-time" programming and symbolic communication turns expressed by students with severe disability. *Journal of Intellectual & Developmental Disability*. Advance online publication. doi:10.3109/13668250.2017.1326585

Drager, K., Light, J., Curran-Speltz, J., Fallon, K., & Jeffries, L. (2003). The performance of typically developing 2 ½-year-olds on dynamic display AAC technologies with different system layouts and language organizations. *Journal of Speech, Language and Hearing Research*, *46*, 298–312. doi:10.1044/1092-4388(2003/024)

Fenson, L., Marchman, V.A., Thal, D., Dale, P.S., Reznick, J., & Bates, E. (2007). *MacArthur-Bates Communication Development Inventories: User's guide and technical manual*. Baltimore, MD: Paul H. Brookes.

Foley, B.E., & Wolter, J. (2010). Literacy intervention for transition-aged youth: What is and what could be. In McNaughton, D., & Beukelman, D. (Eds.). *Transition strategies for adolescents and young adults who use AAC* (pp. 35–68). Baltimore, MD: Paul H. Brookes.

Ganz, J.B., Earles-Vollrath, T.L., Mason, R.A., Rispoli, M.J., Heath, A.K., & Parker, R.I. (2011). An aggregate study of single-case research involving aided AAC: Participant characteristics of individuals with autism spectrum disorders. *Research in Autism Spectrum Disorders*, *5*, 1500–1509. doi:10.1016/j.rasd.2011.02.011

Ganz, J., Hong, E.R., Gilliland, W., Morin, K., & Svenkerud, N. (2015). Comparison between visual scene displays and exchange-based communication in augmentative and alternative communication for children with ASD. *Research in Autism Spectrum Disorders*, *11*, 27–41. doi:10.1016/j.rasd.2014.11.005

Ganz, J., & Simpson, R. (2018). *Interventions for individuals with autism spectrum disorder and complex communication needs*. Baltimore, MD: Paul H. Brookes.

Gevarter, C., O'Reilly, M., Rojeski, J., Sammarco, N., Sigafoos, J., Lancioni, G., & Lang, R. (2014). Comparing acquisition of AAC-based mands in three young children with autism spectrum disorder using iPad© applications with different display and design elements. *Journal of Autism and Developmental Disabilities*, *44*, 2464–2474. doi:10.1007/s10803-014-2115-9

Gevarter, C., O'Reilly, M., Sammarco, N., Watkins, L., Kuhn, M., & Sigafoos, J. (2018). Comparison of schematic and taxonomic speech generating devices for children with ASD. *Education and Training in Autism and Developmental Disabilities*, *53*, 222–238.

Granlund, M., Björck- Åkesson, E., Wilder, J., & Ylvén, R. (2008). AAC interventions for children in a family environment: Implementing evidence in practice. *Augmentative and Alternative Communication*, *24*, 207–219. doi:10.1080/08990220802387935

Hart, B., & Risley, T. (2003). The early catastrophe: The 30 million word gap. *American Educator*, *27*, 4–9.

Holyfield, C., Caron, J.G., Drager, K., & Light, J. (2018). Effect of mobile technology featuring visual scene displays and "just-in-time" programming on communication turns by pre-adolescent and adolescent beginning communicators. *International Journal of Speech Language Pathology*. Advance online publication. doi:10.1080/17549507.2018.1441440

Holyfield, C., Drager, K., Light, J., & Caron, J.G. (2017). Typical toddlers' participation in "just- in-time" programming of vocabulary for visual scene display augmentative and alternative communication apps on mobile technology. *American Journal of Speech Language Pathology*, *26*, 737–749. doi:10.1044/2017_AJSLP-15-0197

Holyfield, C., Light, J., Drager, K., McNaughton, D., & Gormley, J. (2018). Effect of an AAC peer training on interpreting idiosyncratic behaviors from students with multiple disabilities. *Augmentative and Alternative Communication*. Advance online publication. doi:10.1080/07434618.2018.1508306

Holyfield, C., Light, J., McNaughton, D., Caron, J., Drager, K., & Pope, L. (2018). *Effect of AAC featuring VSDs with dynamic text on the single word reading of adults with intellectual developmental disabilities and limited speech*. Manuscript submitted for publication.

Jagaroo, V., & Wilkinson, K. (2008). Further considerations of visual cognitive neuroscience in aided AAC: The potential role of motion perception systems in maximizing design display. *Augmentative and Alternative Communication*, *24*, 29–42. doi:10.1080/07434610701390673

Jakobs, T. (2009). PlayTalk communication software for children with complex communication needs. Grant (R43 HD60312-01A1) funded by the National Institute on Child and Human Development (September 2009 – August 2010).

Johnson, J.M., Inglebret, E., Jones, C., & Ray, J. (2006). Perspectives of speech language pathologists regarding success versus abandonment of AAC. *Augmentative and Alternative Communication*, *22*, 85–99. doi:10.1080/07434610500483588

Kasari, C., Kaiser, A., Goods, K., Nietfeld, J., Mathy, P., Landa, R., … Almirall, D. (2014). Communication interventions for minimally verbal children with autism: A sequential multiple assignment randomized trial. *Journal of the American Academy of Child and Adolescent Psychiatry*, *53*, 635–646. doi:10.1016/j.jaac.2014.01.019

Kent-Walsh, J., Murza, K., Malani, M., & Binger, C. (2015). Effects of communication partner instruction on the communication of individuals using AAC: A meta-analysis. *Augmentative and Alternative Communication*, *31*, 271–284. doi:10.3109/07434618.2015.1052153

Light, J. (1997). "Let's go star fishing": Reflections on the contexts of language learning for children who use aided AAC. *Augmentative and Alternative Communication*, *13*, 158–171. doi:10.1080/07434619712331277978

Light, J., Caron, J., Currall, J., Knudtson, C., Ekman, M., Holyfield, C., … Drager, K. (2016, August). *Just-in-time programming of AAC apps for children with complex communication needs*. Seminar presented at the biennial conference of the International Society for Augmentative and Alternative Communication, Toronto, Canada.

Light, J., & Drager, K. (2007). AAC technologies for young children with complex communication needs: State of the science and future research directions. *Augmentative and Alternative Communication*, *23*, 204–216. doi:10.1080/07434610701553635

Light, J., Drager, K., Chew, K., Guthrie, S., Mellman, L., & Riley, K. (2012, August). *The effects of AAC technologies with "just-in-time" programming for children with complex communication needs*. Poster presented at the biennial conference of the International Society for Augmentative and Alternative Communication, Pittsburgh, PA.

Light, J., & McNaughton, D. (2012). Supporting the communication, language, and literacy development of children with complex communication needs: State of the science and future research priorities. *Assistive Technology*, *24*, 34–44. doi:10.1080/10400435.2011.648717

Light, J., & McNaughton, D. (2013). Putting people first: Re-thinking the role of technology in AAC intervention. *Augmentative and Alternative Communication*, *29*, 299–309. doi:10.3109/07434618.2013.848935

Light, J., & McNaughton, D. (2014). Communicative competence for individuals who require augmentative and alternative communication: A new definition for a new era of communication. *Augmentative and Alternative Communication*, *30*, 1–18. doi:10.3109/07434618.2014.885080

Light, J., & McNaughton, D. (2015). Designing AAC research and intervention to improve outcomes for individuals with complex communication needs. *Augmentative and Alternative Communication*, *31*, 85–96. doi:10.3109/07434618.2015.1036458

Light, J., McNaughton, D., Beukelman, D., Fager, S., Fried-Oken, M., Jakobs, T., & Jakobs, E. (2019). Challenges and opportunities in augmentative and alternative communication: Research and technology development to enhance communication and participation for individuals with complex communication needs [Special Issue]. *Augmentative and Alternative Communication*, *35*(1).

Light, J., McNaughton, D., & Jakobs, T. (2014). Developing AAC technology to support interactive video visual scene displays. RERC on AAC: Rehabilitation Engineering Research Center on Augmentative and Alternative Communication. Retrieved from https://tinyurl.com/rerc-on-aac-vVSD

Light, J., McNaughton, D., Jakobs, T., & Hershberger, D. (2014). Investigating AAC technologies to support the transition from graphic symbols to literacy. RERC on AAC: Rehabilitation Engineering Research Center on Augmentative and Alternative Communication. Retrieved from https://tinyurl.com/rerc-on-aac-T2L

Light, J., Wilkinson, K., Thiessen, A., Beukelman, D., & Fager, S. (2019). Designing effective AAC displays for individuals with developmental or acquired disabilities: State of the science and future research directions [Special Issue]. *Augmentative and Alternative Communication*, *35*(1).

Mandak, K., Light, J., & McNaughton, D. (2018). Digital books with dynamic text and speech output: Effects on sight word reading for preschoolers with autism spectrum disorder. *Journal of Autism and Developmental Disabilities*. Advance online publication. doi:10.1007/s10803-018-3817-1

McCarthy, J., Benigno, J., Broach, J., Boster, J., & Wright, B. (2018). Identification and drawing of early concepts in children with autism spectrum disorder and children without disability. *Augmentative and Alternative Communication*, *34*, 155–165. doi:10.1080/07434618.2018.1457716

McNaughton, D., & Light, J. (2013). The iPad© and mobile technologies revolution: Benefits and challenges for individuals who require augmentative and alternative communication. *Augmentative and Alternative Communication*, *29*, 107–116. doi:10.3109/07434618.2013.784930

McNaughton, D., & Light, J. (2015). What we write about when we write about AAC: The past 30 years of research and future directions. *Augmentative and Alternative Communication*, *31*, 261–270. doi:10.3109/07434618.2015.1099736

McNaughton, D., Light, J., Beukelman, D., Klein, C., Nieder, D., & Nazareth, G. (2019). Building capacity in AAC: A person-centered approach to supporting participation by people with complex communication needs [Special Issue]. *Augmentative and Alternative Communication*, *35*(1).

Mirenda, P. (2014). Revisiting the mosaic of supports required for including people with severe intellectual or developmental disabilities in their communities. *Augmentative and Alternative Communication*, *30*, 19–27. doi:10.3109/07434618.2013.875590

Olin, A.R., Reichle, J., Johnson, L., & Monn, E. (2010). Examining dynamic visual scene displays: Implications for arranging and teaching symbol selection. *American Journal of Speech Language Pathology*, *19*, 284–297. doi:10.1044/1058-0360(2010/09-0001)

O'Neill, T., Light, J., & McNaughton, D. (2017). Videos with integrated AAC visual scene displays to enhance participation in community and vocational activities: Pilot case study of an adolescent with autism spectrum disorder. *Perspectives on Augmentative and Alternative Communication*, *2*, 55–69. doi:10.1044/persp2.sig12.55

O'Neill, T., Light, J., & Pope, L. (2018). Effects of interventions that include aided AAC input on the communication of individuals with complex communication needs: A meta-analysis. *Journal of Speech Language and Hearing Research*, *61*, 1743–1765. doi:10.1044/2018_jslhr-l-17-0132

Romski, M.A., & Sevcik, R.A. (2005). Augmentative communication and early intervention: Myths and realities. *Infants & Young Children*, *18*, 174–185. doi:10.1097/00001163-200507000-00002

Romski, M.A., Sevcik, R.A., Adamson, L.B., Cheslock, M., Smith, A., Barker, R.M., & Bakeman, R. (2010). Randomized comparison of augmented and nonaugmented language interventions for toddlers with developmental delays and their parents. *Journal of Speech, Language, and Hearing Research*, *53*, 350–364. doi:10.1044/1092-4388(2009/08-0156)

Rowe, M. (2012). A longitudinal investigation of the role of quantity and quality of child-directed speech in vocabulary development. *Child Development*, *83*, 1762–1774. doi:10.1111/j.1467-8624.2012.01805.x

Schertz, H.H., Odom, S.L., Baggett, K.M., & Sideris, J.H. (2013). Effects of joint attention mediated learning for toddlers with autism spectrum disorders: An initial randomized control study. *Early Childhood Research Quarterly*, *28*, 249–258. doi:10.1016/j.ecresq.2012.06.006

Schlosser, R.W., Laubscher, E., Sorce, J., Koul, R., Flynn, S., Hotz, L., … Shane, H. (2013). Implementing directives that involve prepositions with children with autism: A comparison of spoken cues with two types of augmented input. *Augmentative and Alternative Communication*, *29*, 132–145. doi:10.3109/07434618.2013.784928

Schlosser, R., Shane, H., Allen, A., Abramson, J., Laubscher, E., & Dimery, K. (2016). Just-in-time supports in augmentative and alternative communication. *Journal of Developmental and Physical Disabilities*, *28*, 177–193. doi:10.1007/s10882-015-9452-2

Smith, J.L., McCarthy, J.W., & Benigno, J.P. (2009). The effect of high-tech AAC system position on the joint attention of infants without disabilities. *Augmentative and Alternative Communication*, *25*, 165–175. doi:10.1080/07434610902972410

Snell, M.E., Brady, N., McLean, L., Ogletree, B.T., Siegel, E., Sylvester, L., … Sevcik, R. (2010). Twenty years of communication intervention research with individuals who have severe intellectual and developmental disabilities. *American Journal on Intellectual and Developmental Disabilities*, *115*, 364–380. doi:10.1352/1944-7558-115-5.364

Sturm, J., & Clendon, S. (2004). Augmentative and alternative communication, language, and literacy: Fostering the relationship. *Topics in Language Disorders*, *24*, 76–91. doi:10.1097/00011363-200401000-00008

Therrien, M., & Light, J. (2018). Promoting peer interaction for preschool children with complex communication needs and autism spectrum disorders. *American Journal of Speech Language Pathology*, *27*, 201–221. doi:10.1044/2017_AJSLP-17-0104

Trudeau, N., Sutton, A., & Morford, J. (2014). A study of developmental changes in interpretation and construction of graphic AAC symbol sequences through systematic combination of input and output modalities. *Augmentative and Alternative Communication*, *30*, 187–199. doi:10.3109/07434618.2014.940465

United Nations, Department of Economic and Social Affairs, Population Division. (2017). World population prospects: The 2017 revision, key findings and advance tables. Working Paper No. ESA/P/WP/248. Retrieved from https://esa.un.org/unpd/wpp/publications/Files/WPP2017_KeyFindings.pdf

Walker, V.L., & Snell, M.E. (2013). Effects of augmentative and alternative communication on challenging behavior: A meta-analysis. *Augmentative and Alternative Communication*, *29*, 117–131. doi:10.3109/07434618.2013.785020

Warren, S.F., & Brady, N.C. (2007). The role of maternal responsivity in the development of children with intellectual disabilities. *Mental Retardation and Developmental Disabilities Research Reviews*, *13*, 330–338. doi:10.1002/mrdd.20177

Wilkinson, K., & Light, J. (2014). Preliminary study of gaze towards humans in photographs in individuals with autism, Down syndrome, and other intellectual disabilities: Implications for design of visual scene displays. *Augmentative and Alternative Communication*, *30*, 130–146. doi:10.3109/07434618.2014.904434