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New Car, Same Principles: Using Language Development Theories to Drive the Design of Supportive Augmentative and Alternative Communication System Interfaces

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Abstract

Innovations in technology have resulted in increased use of tablets, mobile devices, and applications as augmentative and alternative communication (AAC) systems for children with complex communication needs (CCN). Although research has been conducted on the specific characteristics of AAC technologies, many interfaces remain replications of prior communication devices with little consideration of the features of newer platforms. A greater concern is that these interfaces may not be based on empirical evidence or derived from key developmental language theories. As such, these interfaces may place additional demands on children with CCN instead of supporting their development of language content, form, and use. The purpose of this paper is to discuss potential interface supports for AAC systems that capitalize on current technologies and draw upon key tenets of developmental theory.

Reflection From First Author

If you were anything like me at 16, there was nothing you anticipated more than passing the test for your driver's license. I diligently studied the Department of Motor Vehicles' handbook and begged my parents to take me driving. No matter the car we took, the basic principles were the same: gas to go, brake to stop, signal to turn, and so on. After passing the test, I was granted the almighty license to drive and free to choose my first car. Now, how does this comparison relate to language development and augmentative and alternative communication (AAC) interfaces? When I first got my license, my car required a key to start; my new car, on the other, hand simply requires me to have my keys somewhere on my person and press a button next to the steering wheel. My new car also has many features that solve problems my older car could not (e.g., the backup camera that prevents me from embarrassing incidences with mailboxes). Although the principles of driving have remained, new technologies have introduced innovative features. We have also seen many new advances in the realm of AAC technologies. A variety of new devices, platforms, and features have been integrated to solve problems identified by research and feedback from key stakeholders. New technologies also can facilitate the growth of skills and strategies. I'd like to think that I am now a much better driver than I was at 16 and that some of my skills (such as parallel parking) have been supported by changes in technology (again, my new car's cameras). The advance of technology in AAC offers an opportunity to use new features to support the development of language skills for children with complex communication needs (CCN). The principles of AAC remain and the overarching goal is to provide a means for supporting communication for individuals with CCN. For children who use AAC, this means integrating what we know about language development and applying it to the design of new technologies that continue to enter the field.

Introduction

The design of high-tech augmentative and alternative communication (AAC) system interfaces has received much attention from researchers in the field of speech-language pathology. Research has focused on specific features of AAC interfaces including color (Thistle & Wilkinson, 2009; Wilkinson & Snell, 2011), arrangement of symbols (Drager et al., 2004; Drager, Light, Speltz, Fallon, & Jeffries, 2003; Fallon, Light, & Achenbach, 2003; Light, Drager, & Nemser, 2004; Wilkinson & Light, 2014), use of animation (Jagaroo & Wilkinson, 2008; Kearns & McCarthy, 2012; Mineo, Peischl, & Pennington, 2008; Schlosser et al., 2012), appeal to children (Light, Drager, & Nemser, 2004; Light, Paige, Curran, & Pitkin, 2007), symbolic representations (Lund, Miller, Herman, Hinds, & Light, 1998; Namy, Campbell, & Tomasello, 2004; Schlosser & Sigafoos, 2002; Stephenson, 2009; Worah, McNaughton, Light & Benedek-Wood, 2015) and programming demands (Caron, Light, & Drager, 2016). Much of this research has been afforded and supported by the advances made in technology. The purpose of this paper is to discuss potential avenues for developing AAC interface supports across the primary domains of language (content, form, use) that are theoretically and empirically grounded in the core tenets of developmental literature.

The innovation and enhancement of tablets, mobile devices, and applications have led to increased opportunities to create new and improved interface designs to support children and adults with CCN (Light & McNaughton, 2012a, b). The Apple iPad® alone has increased mainstream awareness and social acceptance of AAC (McNaughton & Light, 2013). These mobile devices are often small, affordable, and easy to obtain relative to some high-tech dedicated devices (McNaughton & Light, 2013). It is likely that many devices will continue to improve with new updates and innovative features. However, it is important to consider that in the realm of speech-language pathology, technology should be viewed as a tool that supports the primary goal of achieving successful communication (Light & McNaughton, 2013).

With communication in mind, it is important to engineer AAC applications that emerge from a strong theoretical base. New technologies have the potential to provide support and scaffold language learning for children with CCN; however, many AAC apps on the market are not necessarily based on research evidence (Light & McNaughton, 2013). Further, the development of these technologies is often strongly influenced by preferences of the population as a whole without consideration for the specific needs and skills of individuals with CCN (Beukelman, 2012). Many of the AAC apps currently available are replications of traditional AAC interfaces developed in the past (Light & McNaughton, 2012a) and do not integrate features of new platforms. For example, the iPad's touchscreen provides a range of features related to sensing movements and responding to gestures. Many of these technologies also serve multiple functions and offer capabilities beyond communication, including access to education, social media, entertainment, gaming, and the internet (Light & McNaughton, 2012a). In order to best capitalize on advances in technology and develop interfaces with the end goal of communication in mind, it becomes necessary to consider the theories of language development. Shane et al. (2016) asserted that visual supports should be introduced in a systematic and developmentally appropriate manner. Such supports should also align with a child's symbolic understanding at each stage in their development (Shane et al., 2016). In a recent paper, Smith (2015) specifically addressed language development for individuals who require AAC by summarizing past research literature and proposing directions for assessment, intervention, and future research. Smith discussed the specific challenges children with CCN face in developing language form, content, and use. This paper will further explore how the challenges discussed by Smith (2015) may be mitigated by technologies that support language learning in developmentally appropriate manners.

Language Development Theories and AAC

Children with CCN face a myriad of challenges in developing language (Smith, 2015). These challenges may be due to cognitive impairments as well as motor limitations that restrict their ability to naturally explore and manipulate the environment (Light, 1997). It is important to consider how AAC interfaces can align with language development theory, as providing children with technology that deviates from the typical progression may impose additional learning demands for children with disabilities.

Theories of language acquisition provide frameworks for understanding how children come to develop competency across the primary domains of language content, form, and use. There are multiple viewpoints regarding how children without disabilities acquire and refine their expressive and receptive language abilities. These key milestones should serve as a guide for children with CCN as well. Theorists such as Piaget, Vygotsky, and Tomasello proposed several key processes to consider in understanding how children learn language (Piaget 1923/1965; Tomasello 1999; Vygotsky, 1978). Many of the core tenets of their theories can be used to inform the design of AAC technologies. Components from Piaget's cognitive theory support AAC interfaces that facilitate the development of schemas and creation of opportunities for active participation with the environment (1923/1965). Vygotsky's social interaction theory can inform interface supports that make connections to others (1978). Tomasello's social learning theories would also inform AAC interfaces that support key developmental processes such as joint engagement and understanding communicative intent (Tomasello, 1999).

In addition to developing language, children with CCN face the unique challenge of also using symbols to communicate. This results in an input-output asymmetry for individuals with CCN in that their language input is typically made up of spoken language while their expected output is often symbolic (Smith & Grove, 2003). According to Goldin-Meadow (2014), language learning is often resilient to variations in how linguistic input is processed. With this unique characteristic in mind, it is further necessary to consider information gleaned from the theories that discuss the development of symbolism and representational skills for young children. These theoretical frameworks and empirical studies are each rich in concepts that can be realized in a variety of ways with AAC interfaces. Because of the unique challenges children with CCN face, it is important to consider how both language development and representational theories can be integrated with AAC interfaces and support understanding of language content, form, and use.

The following sections will discuss potential built-in supports to AAC interfaces across the three major domains of language with support from relevant theory. See Table 1 as a reference for key concepts to be discussed according to each domain of language (i.e. content, form, and use) and specific examples of potential interface supports. In developing such supports, it is important to consider current and heavily used mainstream technologies that may be underutilized in AAC. See Table 2 for an exploration of technologies (videos, animation) to be discussed and potential roles they may serve in supporting language learning for children who use AAC. For example, videos can be used in a number of ways (potential roles) and can be integrated using games (interface integration).

Table 1. AAC Interface Supports According to Language Domain and Key Concepts.

Domain	Concept	Example
Content	Joint Attention	The AAC interface flashes symbols for food items and verbs a caregiver is using while preparing dinner. The child receives input from the caregiver and AAC device.
	Symbolic Representations	The AAC interface shows a symbol for ball followed by a video of the ball rolling during a play activity between the child and caregiver.
	Organizational Schemas	The AAC interface presents an item that the child can pair with other items and receive feedback on how they interact. Selecting a balloon and a pin leads to a pop; selecting the balloon and clown leads to a balloon animal.
	Context	The AAC interface provides contexts for language learning in the form of a zoo activity. Children travel through a zoo and access animals, sounds, and view animations of actions (e.g., the zookeeper feeding a monkey a banana).
Form	Morphemes	Morphemes are populated based on the touch screen gesture used. Pressing the button for dog twice would populate the plural DOGS. Activating a verb followed by a swiping motion from right to left changes the verb to past tense.
	Combining Words	The AAC interface provides built-in prompting to expand an utterance. The child selects BALL and the interface adds I WANT THE for a total utterance of I WANT THE BALL.
Use	Age-appropriate language	Speech recognition provides relevant topical vocabulary according to a situation the child is a part of with their peers (e.g., when playing dress up clothing items are populated)

Table 2. Exploration of Heavily Used Mainstream Technologies, Potential Roles and Integrations.

Technology	Potential Roles	Interface Integrations
Videos	Contextual Support Word Learning Feedback Sharing	Visual Scenes Games Playbacks following utterance Video Capture Options
Animation	Contextual Support	Visual Scenes Animated Symbols
	Appeal Feedback	Custom Animations Emphasize Selections
Speech Recognition	Contextual Support	Vocabulary displayed based on context of utterances
	Word Learning Feedback	Real-time models and Recasts Highlight words used on interface
	Word Prediction	Populate utterances Expansions
Location Services	Contextual Support	Populate relevant vocabulary based on location

Developing Interfaces to Support Development of Language Content

Key components to consider in designing future AAC interfaces to support development of language content include facilitating joint attention, developing appropriate representations for language concepts, and providing supportive contexts for word learning (see Table 1). Research has been conducted in AAC with regards to each of these, and additional support can be extracted from developmental theories. Aligning the findings from each can potentially inform interfaces that reduce barriers in language learning for children with CCN.

Supports for Facilitating Joint Attention

The ability to both establish and maintain joint attention has been identified as a critical skill to support language learning and is especially relevant to word learning (Tomasello & Farrar, 1986). According to Tomasello (1999), joint attention is the ability to jointly follow, initiate, and maintain attention towards others, objects, or events in the physical environment. In order for joint attention to be meaningful, a child must understand others' intentions as part of the interactions. Joint attention itself is often viewed as the first use of intention and provides a foundation for language development. Children must be able to discern others' intentions in order to engage with them. In typical development, children first attend to people's intentions and then imitate their communicative actions to learn about language (Tomasello, 1999; Tomasello & Moll, 2010). Intentionality is an important foundational skill for children with CCN that should be considered when introducing appropriate visual supports (Shane et al., 2016). For children with CCN who require aided AAC, there is an additional component to consider. Not only does the child need to attend to their communication partner and a referent, but also the AAC device. This consideration has led to studies examining how joint attention with an AAC device can be facilitated (Adamson, Bakeman, & Deckner, 2004; Benigno & McCarthy, 2012; Smith, McCarthy, & Benigno, 2009). For example, Smith et al. (2009) examined how the position of the AAC device during shared storybook reading impacted young children's joint attention. However, exploration into how the interface itself can be adapted has just begun.

Just-in-Time (JIT) programming is a newly proposed method of providing contexts for language learning and other supports as they occur in real time for individuals who use AAC using interfaces that capture and integrate technologies such as photo and video (Caron et al., 2016; Schlosser et al., 2016). JIT supports can be used for a variety of purposes including delivering items (i.e., prompts, reminders, rewards), supporting independence in new settings, providing more efficient storage and retrieval of information, and facilitating multiple information delivery formats (Schlosser et al., 2016). Although many of these functions extend beyond the level of a beginning communicator, such supports also could cue young children to attend to items in the context of interactions with a caregiver. JIT supports also can capitalize on a variety of new technological advances including speech and voice recognition, localization, and screen sharing. For example, a JIT prompt on an AAC interface using voice recognition may occur while a caregiver holds up a bottle asking, "Do you want your bottle?" During the utterance, the symbol for bottle may appear on the screen. The caregiver also may capitalize on the situation at hand to capture a photograph of the bottle or kitchen scene and program messages in the moment with ease to provide the vocabulary a child may use in that context. While the child with CCN must still coordinate their gaze with the parent, object, and AAC system, the device now provides relevant information from the environment that could potentially support word learning.

Additional cues that may elicit joint attention could include sounds or lights emitted from the interface that attract a child's attention, voice recognition that responds to the caregiver a child is attending to in the moment, or even cues for a caregiver to attend to something a child is focusing on at the time. Research in child language development has shown infants have a preference for child-directed/infant-directed speech (CDS/IDS), a slower, higher pitch tone of speaking (Cooper & Aslin, 1990; Fernald, 1985; Pegg, Werker, & McLeod, 1992). This manner of speaking is often exaggerated and can call a child's attention to language. Speech recognition could potentially capitalize on this exaggerated vocal feature to identify what content to use for populating images to show to a child via their AAC interface. In fact, new technologies allow for multiple forms for cues such as the use of spoken language (Allen & Shane, 2014; Shane et al., 2012), environmental sounds (Harmon et al., 2014), visual representations and vibrations (Schlosser et al., 2016). As an example of this potential support, while a caregiver is giving their child a bath or reading a bedtime story, speech recognition may be used on an AAC interface to highlight language items as they are spoken. Such a feature may reduce demands for the caregiver and also provide a means to address the input-output asymmetry (Smith & Grove, 2003) that is inherent for children with CCN. Such supports may also facilitate a child's representational skills. Such immediate supports also would allow communication partners to follow a child's lead in a new way (Schlosser et al., 2016). While attending to a separate device may still place greater demands on a child with CCN, wearable technologies may provide new ways of providing additional input and supporting joint attention.

Wearable technologies such as the Apple Watch® are becoming increasingly more capable of supporting a variety of functions. Many wearable devices also incorporate feedback in the form of vibrations and sounds. These devices could potentially function as a provider of JIT support for children with CCN. In the same scenario outlined above, perhaps the young child is wearing a small device and when the caregiver asks about the bottle, the watch vibrates and shows the child a symbol for bottle. These supports in conjunction with partner instruction could make inclusion of a device within an interaction more fluid or deliberate. These supports also can be provided in context.

Providing Contexts for Language Learning

A child's environment plays a large role in their development and the importance of context for word learning appears across language development theories (Piaget, 1923/1965; Vygotsky, 1978; Tomasello, 1999). According to Piaget (1923/1965), it is important for children to actively participate in language learning in their environment. For Piaget (1923/1965), language develops through active participation of the child and their imitation of sounds and association with specific actions. These acts of imitation and association support the development of language content. As children interact with their environment, they acquire word meanings. Vygotsky and Tomasello stressed the importance of word learning in the context of social interactions. According to Vygotsky (1978), learning and development processes that are internal to the child only begin to operate when the child is interacting with people in their environment and during cooperation with their peers. For Vygotsky (1962, 1978), language is first a means for a child to communicate with others in their environment, and as it is internalized by the child, it transitions to a means by which children are able to perform mental functions and think with language. This also creates the frame for Vygotsky's zone of proximal development, which is defined as the distance between a child's actual development level in independent problem solving and the level of potential development when problem solving occurs in collaboration with a more capable peer or an adult. For a more thorough description of Vygotsky's principle of the zone of proximal development and its relation to AAC, see Bedrosian (1997). In addition, see Light (1997, 2003) and Smith (2015) for discussions of the application of Vygotsky's theory the language learning of children with CCN. According to these theories, children actively learn language from others in the environment. This is an important consideration to keep in mind when designing AAC interfaces to support word learning for children with CCN.

Light (1997) discussed the interrelated contexts for language learning with specific consideration given to children with CCN, which included physical, functional, language, social, and cultural contexts. Each of these plays an important role in language acquisition but requires special attention when considering children with CCN. For example, these children often have physical impairments that restrict their ability to experience a variety of environments; this impacts their physical contexts for language learning. Additionally, children with CCN spend more time in daily care routines (Light & Kelford-Smith, 1993). This may reduce the time caregivers may facilitate play, reading and other activities, which support language learning (Light, 1997). Due to the challenges children with CCN may face in interacting in a variety of contexts, it is important to consider supports to incorporate into an AAC interface that may potentially reduce these limitations. The use of visual scene displays, videos, animations, and interactive games may present opportunities to capitalize on new technology and support language learning contexts.

Visual scene displays. Visual scene displays (VSDs) are interfaces that embed representations of language concepts into integrated scenes (Light, Drager, McCarthy, et al., 2004). Unlike grid displays that present concepts in columns and rows, VSDs display language concepts using hot spots created by outlining an item's shape in a photograph or drawing (Light, Drager, McCarthy, et al., 2004). VSDs can include a range of vocabulary items like grid displays; for example, a VSD for a photograph of a child's bedroom may include concrete items such as bed, pillow, nightlight, as well as abstract vocabulary such as sleep, read, and tired. Research suggests that VSDs are easier for children without disabilities as young as 2.5 years of age to use and learn compared to grid displays (Drager et al., 2004; Fallon et al., 2003). Visual scenes have been found to be beneficial for children ages 3 to 5 as well (Drager et al., 2004; Light, Drager, McCarthy, et al., 2004); however, results have shown that older children performed well despite the layout. These findings suggest that providing context is particularly necessary for young language learners. Because VSDs rely on photographs for providing context, the increased inclusion of cameras in mobile technologies is a feature to continue to capitalize on and explore. As discussed previously, the concept of JIT programming (Caron et al., 2016) is being actively explored to support provision of context during activities.

Videos, animations, and interactive scenes. Features such as videos or interactive scenes may provide another means to increase exposure to environments a child may not regularly access. For example, some popular video games and apps are attached to a context (e.g., cities, natural environments) and children control characters to move through these environments. While interactive scenes have not been explicitly explored in the research literature, there is evidence to suggest that videos can support word learning for children. According to a study conducted by Mineo and colleagues (2008), videos of verbs resulted in higher accuracies compared to static symbols. Positive effects of video and animation have also been reported for individuals with autism spectrum disorder (ASD) for representation of verbs and prepositions (Shane et al., 2012). In focus groups by Boster and McCarthy (2017), parents and speech-language pathologists (SLPs) viewed example interface designs featuring video and game options. Both groups were in favor of such interfaces for teaching and language learning purposes. Although a child may not have access to a context, technology may provide a means for substituting to support language acquisitions. For example, a child with CCN may not be able to experience playing at a park, but providing an interactive game with a variety of animations, videos, and sounds from that context could potentially offer experience with concepts they may otherwise not be provided. This is not to say that the solution to providing contexts for language learning is solely providing children with increased interactions with technology; however, it is a potential area to explore to examine whether or not such features could provide additional support for language learning.

Supports for Representing Content

For children with CCN who must use symbols to communicate it is crucial to support their development of representational skills. Joint attention and intention reading continue to remain important for young children and aid in their understanding of symbols. Shane et al. (2016) indicated that visual supports for establishing symbolic communication include focusing on joint imitation and cause and effect. These skills build the framework for understanding others intent behind symbolic communication. According to Tomasello (1999), to understand a symbol, you must understand what someone intends to communicate by using it. Additional investigations also assessed the impact of symbol iconicity (the degree to which a symbol resembles its referent) at different stages of development (Preissler & Carey, 2004; Stephenson, 2009) and with varying forms of representation (Worah et al., 2015). Preissler and Carey (2004) found that children aged 18–24 months demonstrated the ability to learn words from association with pictures. This finding supports the belief that as parents often name objects and provide information to children, they can relate this to objects in the real world. Worah and colleagues (2015) developed a symbol system designed to be developmentally appropriate for children. The symbols were created based on results of young children's conceptualizations of frequently occurring vocabulary items (Lund et al., 1998). The symbols developed by Worah et al. (2015) included whole people and objects, familiar activities, contexts, and rich colors as informed by work by Light and colleagues (Light & Drager, 2002, 2007; Light et al., 2007). These symbols were compared to Picture Communication Symbols©, a commonly used set of symbols developed by Mayer Johnson® that represent vocabulary using colored line drawings. These symbols typically do not include whole people or contexts and frequently include abstract elements such as arrows, bars, and circles to represent concepts (i.e., *is* represented by an equal (=) sign). Compared to Picture Communication Symbols, the developmentally appropriate symbol set resulted in greater accuracies in identification by participants.

Shane et al. (2016) also recently outlined a developmental framework of six phases of progressing from concrete to increasingly abstract visual graphic learning for children with ASD. According to Shane et al., the first stage of visual supports should build foundational skills for symbolic communication (i.e., joint attention), followed by introduction of concrete symbols (object proxies, 3D photographs, videos), context-based symbols (photographs, VSDs, animated graphic symbols), abstract symbols (graphic symbols), abstract symbols (topic displays), and finally generative symbols (schedules). These supports would not only be used to support language development but also to provide instructional and organizational supports that many children with ASD use successfully.

Many AAC interfaces currently provide a variety of options related to representations and symbol sets; future designs should be tailored to the child's current level of development and their representational skills. Considerations include built-in supports that enable caregivers to personalize symbols sets such as menu options that allow colors and features of symbols to be changed quickly and easily. As children become older they may also become interested in participating in customizing their symbols sets. In a focus group with SLPs and parents of children with ASD, parents were interested in features such as symbol sets that could grow with their children (Boster & McCarthy, 2017). Although the iconicity of representation remains an area to explore, there are additional features to consider, such as learners' experiences with symbols, comprehension of spoken language, and the ability to perceive communicative intent (Stephenson, 2009).

In addition to iconicity, mediums of representation in new technologies are providing increasingly more options for capturing and displaying videos and animations. For example, the recent iOS update for Apple iPhones introduced the ability to send animated GIFs (Graphic Image Files) as text messages. Such features may also have merit in future AAC interfaces, but investigations exploring such features have yielded mixed results. When video was used to represent actions, children identified concepts with greater accuracy compared to static symbols and performed more accurately as age increased (Mineo et al., 2008). SLPs and parents of children with ASD also viewed the use of videos and animations as desirable features in a focus group conducted by Boster and McCarthy (2017). Videos and animations can potentially support language development for children with CCN by incorporating these into a game interface available to children to help represent abstract concepts such as verbs and prepositions. A potential support may be a space on an AAC interface in which children can combine symbols and then view a video of their utterance. These potential tools may now be realized with the increased ease of importing videos and creating animations with new technologies. However, such supports may only be valuable after children have developed a certain level of representational skill (Stephenson, 2009).

Organization

Typically, interfaces are organized and programmed by adults (Blackstone, 1993); this may make it difficult for children to locate items on their display. A series of studies with typically developing children ranging in age from 2.5–5 also demonstrated that organization of vocabulary items impacted the ability to locate and use items up to a certain stage in development (Drager et al., 2003; Drager et al., 2004; Light, Drager, McCarthy, et al., 2004). For children ages 4 to 5, the language organization, whether organized according to an event schema or categories, no longer resulted in differences (Light, Drager, McCarthy, et al., 2004). Work by Fallon et al. (2003) demonstrated that children organize language concepts according to an event schema. Schemas according to Piaget (1923/1965) begin developing during the sensorimotor stage. Schemas refer to a child's mental representations about what objects in their environment are and how they can be used. As children grow, they actively explore items and develop schemas through their actions on objects in their environment. For example, a child may develop a schema for their cup and associate different actions with it. The cup is something provided to them to drink from, and it can hold a variety of different liquids such as milk or juice. The child may also experiment with the cup to further develop their schema, when knocked to the floor; the same cup may also serve as a means to gain their parent's attention.

Due to motor, sensory, or intellectual impairments, children with CCN may rely more on others to facilitate their formation of schemas. Their access to actively acting on objects, events, and people in their environment may be limited; therefore, it is necessary to explore ways to increase their interactions with such items to support language learning (Light, 1997). Consequently, creating a means for AAC interfaces to support schemas for young children with CCN should be considered, especially for those younger than age 5. For AAC interfaces, vocabulary items could be organized according to such schemas. As an example, an interface may represent vocabulary for items such as *Oh no!, Cup, Mommy, spill,* within a VSD versus across several different pages. Interface supports could include designs that offer opportunities for children to play with language, participate in symbolic play routines, and organize the content as developmentally appropriate (i.e., page of symbols children can activate to hear words, watch videos, combine words to explore content).

Interactive games may also be explored to offer opportunities for children to select items and view animations, sounds, or videos as feedback. Games or functions that elicit actions from a parent or caregiver may also be explored. Virtual reality and simulated experiences open possibilities in providing young children new ways to act on and explore items in their environment. Although some current interfaces rely on a specific organization, children may benefit from grouping items and taking greater control in organizing their displays in ways that are personally meaningful to them. It also may be beneficial to explore new ways for children to move through their vocabulary items. For example, during a focus group Boster and McCarthy (2017) introduced SLPs and parents of children with ASD to an interface in which children could swipe through clouds with vocabulary items on a touchscreen display. Participants in the focus group felt the design would be appealing to children; however, they were concerned about a lack of organization and SLPs expressed concerns regarding motor planning. Advances in word prediction and speech recognition features could potentially reduce such concerns in interfaces such as the one described. As technologies continue to develop, it is necessary to consider how such devices can be integrated with what is known from language development theory in terms of how children acquire words.

Developing Interfaces to Support Development of Language Form

Children with CCN face the unique challenge of learning to construct utterances using symbolic systems that are not true languages (Light, 1997). As such, it can be difficult to teach children with CCN how to create appropriate utterances that go beyond one or two words. Creating more complex utterances provides a means to communicate more specific ideas and provide more detail in interactions (Tomasello, 1999). In regard to language form, there are two essential skills to consider to support the early linguistic constructions of children with CCN– the acquisition of morphological markers and combining words (see Table 1).

Supporting Morphology

Brown's morphemes (1973) are often used as a marker of language development for children without disabilities. Although AAC interventions have been successful in teaching children with CCN how to use grammatical structures (Binger, Maguire-Marshall, & Kent-Walsh, 2011), AAC interfaces may limit children to one form of a verb or require an additional selection for the addition of a morpheme. Future interfaces should facilitate access to developmentally appropriate morphemes (e.g., present progressive –ing, and plural –s). For children who use direct selection, AAC interface gestures may offer a means to quickly add grammatical morphemes. For example, in order to use the plural form of a word a child could activate a symbol more than once (e.g., DOG + DOG = DOGS). To indicate a present progressive form, a gesture involving selection of the icon with a swiping motion from right to left could change the form of the word (e.g., activating SWIM combined with the gesture = SWIMMING). Options for 3D touch are also now a standard feature for iPhones, which allow different actions to be performed based on the pressure applied to a button (i.e., pressing the phone button harder results in speed dial options); such features may soon be incorporated into tablets and could be explored as additional means to facilitate morpheme use. Boster and McCarthy (2017) found that SLPs and parents of children with ASD were interested in using gestures on mobile devices more in future interface designs.

Supporting Word Combinations

Though two to three word combinations emerge around 18 months (Owens, 2001), children with CCN often struggle to move beyond one- and two-word utterances (Smith & Grove, 2003). The work of Tomasello (1999) may provide insight into how children come to expand their constructions. According to Tomasello, children first produce holophrases, which are single-word units capable of carrying the meaning of an entire speech act (*more* for *I want more* or *want* for *I want that*). For many children who use AAC, one symbol may represent multiple concepts and removes the need to combine additional symbols (Smith, 1996). Further, communication partners frequently only require one-word utterances from children, offering them fewer opportunities to experiment with word combinations (Light, Binger, & Kelford-Smith, 1994).

According to Tomasello (1999), following holophrases, children then move to verb island constructions, where they produce utterances with a verb then add in variables, which can change (*Want milk, Want juice, Want ball*). AAC interfaces could potentially facilitate these constructions by providing children with possible variable items following the selection of a verb. As children continue to develop, additional "slots" can be added to support the combination of two and three symbol constructions (e.g., *I want ball*, *You throw ball*) and abstract constructions such as imperatives, transitives, locatives, and passives. Word prediction and population options for text could also potentially be used to help children expand their utterances and to facilitate faster rates of communication. For example, if a child selects "juice" a populated option may be "please."

Vygotsky's zone of proximal development (1978) can also inform age-appropriate features to be incorporated into the AAC interface and the appropriate level of support needed for the child to advance. Providing age-appropriate models from more capable peers and adults can be particularly beneficial. Providing models and recasts are effective in supporting multisymbol utterances (Binger & Light, 2007; Goossens, 1989; Romski & Sevcik, 1996); however, this can place additional demand on caregivers. With this in mind, it may be beneficial to explore ways in which technology assume the role of modeling. Speech recognition software continues to develop and may be a feature to incorporate into future designs to facilitate real-time models for language. For example, as a caregiver is speaking to their child, the interface may highlight icons or show the utterance as it is created with all the appropriate grammatical features. Such an interface may offer supports based on the child's current needs and then be turned off later as the skill is acquired.

Developing Interfaces to Support Development of Language Use

Many individuals who use AAC are now expected to participate in a wide range of environments including their family, school, work, and community (McNaughton & Kennedy, 2010). Therefore, interfaces should promote communication in a variety of settings from an early age. Support for participation and language use may be built-in to AAC interfaces or be facilitated with the provision of additional technologies outside of the AAC system.

Providing Built-In Supports

Potential built-in interface supports for language use should include tools to provide cues to communication partners, tools to increase interactions with peers, and features that allow children to change topic quickly to engage in age-appropriate play (see Table 1). According to Piaget (1923/1965), young children use egocentric speech because they are focused primarily on their own actions and not their peers. Because AAC devices are typically programmed by adults, there may be an unfair bias to include messages that are not consistent with the utterances of a child's same age peer. Young children also may shift between topics and play activities quickly and in a way that a caregiver cannot anticipate. As such, a child with CCN may be left with an AAC interface that does not support the egocentric, unpredictable aspects of play that characterizes their interactions with their peers. Speech recognition may serve as a means to provide relevant vocabulary from peers in a play activity; location services also may support the provision of necessary vocabulary. Although it is often fast-paced and constantly shifting, many play activities offer opportunities contexts for language learning. For example, when a child moves to the swing set on a playground their vocabulary shifts to be appropriate for the activity of swinging. This is another example of how JIT programming features may be useful in future interface designs.

Provision of External Supports

Mobile technologies including iPads, mobile cameras, and Bluetooth switch technologies, can potentially support participation for children with CCN despite limitations in expressive language. Recently, Therrien and Light (2016) implemented a turn-taking intervention featuring an iPad. Pairs of children learned to use the iPad to participate in a shared storybook reading activity. The number of turns increased when the books were presented to the children on the iPad and they had received instruction on using it to take turns. Photography activities using the iPod Touch also have been explored as a means to increase participation for children with CCN (Boster & McCarthy, 2016). Such findings indicate the need to further explore how technology can be used to create opportunities for communication for children with CCN and their peers. Engaging in age-appropriate play can provide a means for developing strategic and social competencies in AAC.

Conclusions

Language development theories suggest that children acquire language in multiple ways and AAC can be a powerful tool for children with CCN. Looking ahead, advances in technology will lead to new and exciting opportunities in AAC, including rethinking, revisiting, and refining current approaches and interfaces. However, it is necessary to consider why we would use these features and ensure that technology remains a useful tool to support language learning not only for today, but also tomorrow. A benefit of technology is that new opportunities are continuously introduced for a variety of different learning purposes and can accommodate variability in individual learning profiles. Moving forward, it is important to be sensitive to the fact that technologies and integrations such as those discussed here can play a number of roles in supporting language learning across the different domains of language content, form, and use. While at times these decisions may be overwhelming, it helps again to think of the car you are licensed to drive. New models will continue to arrive, yet you are licensed to drive all of them. As an SLP, you also possess the knowledge to align new technologies to the foundational theories of our field. We must decide which models serve our needs most efficiently and across time.

As with all new technologies, it is important to consider which advances are appropriate to pursue. Many of the proposed interfaces to be explored have overlapping benefits in terms of supporting the development of language content, form, and use. While such benefits provide promising avenues of exploration, the focus must remain on developing integrations that facilitate successful communication as the end goal. As AAC applications continue to be produced by individuals with varying levels of knowledge of language development theory and science, there should be increased awareness and critique to ensure best outcomes for children with CCN. As specialists in the area of language, SLPs should feel empowered to advocate for the inclusion of features that support communication. Exercising such power and remaining focused on the central theories of language development can help all SLPs to feel confident in the driver's seat when it comes to tackling the world of AAC for children with CCN.

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