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ORIGINAL PAPER

Applying Technology to Visually Support Language and Communication in Individuals with Autism Spectrum Disorders

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Abstract The burgeoning role of technology in society has provided opportunities for the development of new means of communication for individuals with Autism Spectrum Disorders (ASD). This paper offers an organizational framework for describing traditional and emerging augmentative and alternative communication (AAC) technology, and highlights how tools within this framework can support a visual approach to everyday communication and improve language instruction. The growing adoption of handheld media devices along with applications acquired via a consumer-oriented delivery model suggests a potential paradigm shift in AAC for people with ASD.

Keywords Applying technology · Computer based instruction

Introduction

Augmentative and alternative communication (AAC) strategies began to be explored for individuals with autism spectrum disorders (ASD) in the 1980s and early 1990s. Since that time, developments in technology have played a crucial role in improving the quality, affordability and accessibility of AAC strategies for members of this population. Currently, we are in the midst of a potential paradigm shift in AAC for people with ASD, in large part due to the growing adoption of handheld media devices along with applications acquired via a consumer-oriented delivery model that are not only affordable but also transportable, socially acceptable and ubiquitous. These new tools support implementation of a visual approach to everyday communication and language instruction in ways that were impossible prior to the digital technology revolution by enabling both access to visual content and creation of better instructional materials.

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The Evolution of Technology Used in AAC Applications for Individuals with ASD

AAC originally developed from a challenge to provide expressive communication tools for persons with little or no functional speech and/or insufficient manual dexterity to write or manipulate a keyboard. Such difficulties are generally associated with neuromotor disorders such as cerebral palsy (Zangari et al. 1994). In the 1980s and early 1990s, the use of AAC for persons with ASD began to be explored. Since that time, a wide variety of strategies and tools have been developed, and AAC users within this population now have a plethora of low-tech tools, special and general purpose hardware, and special and general purpose software at their disposal that may be combined as needed to help meet their communication requirements.

The first strategies used with the ASD population were *no-tech* in nature, focusing primarily on the use of manual signs in the context of total communication training (e.g., Carr et al. 1978). Following the early adoption of manual signs for individuals with ASD, forms of *low-tech* special-purpose AAC tools emerged. These low-tech special-purpose AAC tools do not involve an integrated circuit (Quist and Lloyd 1997) and have been developed exclusively as AAC systems to enhance communication. They include non-electronic communication boards and graphic symbols (Mirenda and Iacono 1988; Wendt 2009). The technology involved in the use of these tools can be either pointing-based (i.e., individual points to a symbol in order to communicate) or exchange-based (i.e., individual hands over a graphic symbol in exchange for an object or activity delivered by the communication partner) (Sigafoos et al. 2007). The popularity of an exchange-based approach, the so-called Picture Exchange Communication System (PECS) (Bondy and Frost 1998; Frost and Bondy 1994, 2002), led to further increased acceptance of low-tech AAC approaches with this population.

Building upon this increased acceptance of AAC approaches with individuals with ASD, the application of *high-tech* special-purpose AAC hardware and software emerged for adoption. These tools were used primarily for expressive communication purposes (Mirenda and Iacono 2009; Zangari et al. 1994). They use an integrated circuit (Quist and Lloyd 1997) and were developed for the special needs population. Among these were portable speech generating devices (SGDs) that produce synthetic and/or digitized speech; the use of these tools increased communication options for individuals with ASD in new and unprecedented ways (Schlosser and Blischak 2001; Schlosser and Sigafoos 2008; Schlosser et al. 2009).

SGDs can be grouped into two classes: dynamic-display devices (e.g., *Dynavox V*) and static-display devices (e.g., *GoTalk*). Although static-display devices were initially the norm, both types are currently available. These devices typically use specialized software (e.g., *Boardmaker with Speaking Dynamically Pro®*, *Viking*), have considerable expansion capability, can be text and/or symbol-based, and often can incorporate multimedia content.

Furthermore, as the use of AAC for persons with ASD became more widespread, it expanded beyond simply its traditional use for expressive communication alone, and was used to augment comprehension (Drager et al. 2006) and to provide organization of time and sequences—a framework outlined in Shane and Weiss-Kapp (2008).

Despite these advances, the AAC systems described above are often expensive, cumbersome, and time-consuming to program and personalize. Often, they serve to stigmatize the user. These barriers may prevent many individuals from using their systems on a regular basis, leading to impoverished input and lost opportunities for language learning and natural interaction. More recently, however, the relatively expensive, dedicated hardware platforms and software programs described above have been subject to competition from less costly, consumer-level tools developed for the general market. For some individuals, communication needs can be met by using consumer-level hardware (e.g., personal laptop computer, tablet computer) to run special-purpose software designed to support communication.[1] For others, special-purpose software is not necessary, and communication needs can be met through a combination of consumer-level hardware and general-purpose software.[2] Low-cost, widely available peripheral devices (e.g., cameras, camcorders, DVD players) offer even more opportunities for AAC users to create, edit, store and present content in ways that do not rely on expensive, dedicated tools. Thus, relatively affordable, consumer-level hardware, software and peripherals now afford opportunities for greater flexibility in selection and design of AAC systems for users with ASD.

With the current widespread availability of general-purpose portable hardware (e.g., Apple *iPad*™, Google *Android*™) running specialized AAC "apps", new opportunities now exist for AAC users with ASD. In fact, the adoption of the new portable hardware and software may suggest a significant paradigm shift in AAC: what is now available to consumers is a device that is small, low cost, easy to obtain and transport, readily available, and socially acceptable. Many of the apps designed for these devices (e.g., *Proloquo2go, MyTalk*) may serve as full AAC systems, similar in many ways to the dedicated SGDs described above, while others (e.g., *Steps, First-Then, MyChoiceBoard, PicCalendar)* may also provide support for organization and enhance the efficiency of simple functions such as choice-making. Apps are often easily obtainable, affordable, customizable, and user-friendly. For further information regarding the technology outlined in this section, the reader is referred to Appendix.

Importantly, some of these new technologies are beginning to be evaluated as tools to be used in intervention studies (e.g., Van der Meer et al., in press). Despite these innovative opportunities, however, caution must continue to be exercised to ensure that the dazzle of this impressive technology does not replace a methodical, clinical process that matches a person with communication assistance needs with the optimal communication technology available—a process that has come to be known as "clinical feature matching" (e.g., Blischak and Ho 2000; Shane and Bashir 1980). Furthermore, even technology that has been carefully selected for an individual based on this

[1] Examples of consumer-level hardware running special-purpose software include personal laptop computers with *Speaking Dynamically Pro®*, tablet computers running *Clickit! and* personal laptops with *Pogo Boards*.

[2] Examples of consumer-level hardware running general-purpose software include tablet computers running *Microsoft Word* and personal desktop or laptop computers running *Microsoft Powerpoint* to present dynamic displays.

feature-matching process does not itself enhance communication unless combined with an appropriate instructional approach. The remainder of this paper will describe one such approach developed at Children's Hospital Boston for learners with ASD, and will outline ways in which current technology has helped to make implementation of this approach a reality.

Application of Technology Within a Visual Communication Approach for Learners with ASD

One clinical approach that makes significant use of AAC is the *Visual Immersion Program* (VIP) (Shane et al. 2009a). The VIP has developed in response to research findings and clinical observations suggesting that learners with ASD have relative natural strengths in visual processing (Althaus et al. 1996) and tend to be highly interested in visual content delivered via electronic screen (Shane and Albert 2008). The VIP is built upon several core principles. First, learners should be immersed in a visually symbol-rich environment across home, school, and community. Spoken language acquisition relies on constant exposure to rich linguistic input by native speakers along with frequent opportunities for use; individuals with ASD should similarly be provided with these same opportunities for language development although "spoken" language is supplemented with a rich visual linguistic environment. Second, visuals should support both comprehension and expression. Third, there should be a focus on multiple communicative functions beyond protesting and requesting (e.g., directing, questioning, commenting). Adherence to these principles requires tools that allow for quick, convenient creation and presentation of visual content on an almost constant basis in order to facilitate effortless everyday communicative exchanges. It also requires tools that allow mentors and learners to use visual content in unique ways that enhance language learning. The following discussion outlines ways in which the VIP takes advantage of current technology to create and present visual materials that accomplish both of these goals, thereby making the principles of the VIP a reality in ways that were impossible prior to the digital technology revolution.

Using Technology to Facilitate Effortless Everyday Communicative Exchanges

Successful implementation of the VIP begins with the recognition that not all learners with ASD are yet able to communicate using spoken language. Their linguistic deficits, both in terms of form and content, often result in difficulties with comprehension and expression of directives, comments, questions, and other communicative functions, and make it difficult for learners to participate in daily exchanges. For many of these individuals, visual scenes can be used to represent complex ideas in a way that bypasses the need for aural language processing. Because these scenes offer a means of delivering symbolic content that is simultaneously interesting and meaningful, scene-based visual supports hold great potential for improving the effectiveness of everyday interactions when used frequently (Light and Drager 2007). The VIP uses visual scene cues in two different forms. *Dynamic* scene cues are full-motion video clips that depict an entire scene, event or concept that unfolds over time. Each scene is a perceptually integrated whole that illustrates not only objects and spatial relationships, but change over time. *Static* scene cues are photographs that capture a single prototypical moment in the scene event or depiction of a concept (refer to Fig. 1).

Often, static scene cues are introduced after the learner is familiar with the corresponding dynamic scene cue. Together, these tools can offer an effective means of communication for learners with ASD who are not yet able to separate language elements from the scene as a whole.

Prior to the introduction of mobile smartphone technology, regular use of scene cues to enhance the effectiveness of everyday communicative exchanges was extremely difficult. Use of dynamic scene cues was largely limited to the tabletop environment where they were presented on high-tech, general-purpose hardware platforms (e.g., personal desktop, laptop, tablet computers) that were difficult to transport. Static scene cues offered greater potential for use in the natural environment, as they were not bound to hardware platforms that could display animation, but they required a time-consuming process of printing, laminating, and organizing that frequently proved to be difficult for families and clinicians alike, and therefore impractical as a reliable means of supporting

Fig. 1 Static scene cue

communication during everyday exchanges. Currently, however, the availability of consumer-level, handheld alternatives (e.g., *iPhone*™, *Blackberry Storm*™, *Android*™, *iPod touch*™, *iPad*™) has made regular use of scene cues more of a reality. These small, portable devices can store, organize and present large numbers of images, including both static images and videos. This reduces the need to limit communication opportunities to the tabletop environment or to keep track of cumbersome low-tech materials, and increases the ability of mentors and learners alike to quickly access scene cues "just in time" to take full advantage of each communication opportunity. In many cases, the devices themselves can also capture images for on-the-spot creation of materials. These tools have allowed clinicians, parents, teachers, and other mentors to use both dynamic and static scene cues with greater frequency and across multiple contexts, bringing creation of a visually immersive environment closer to a reality for individuals with ASD.

Using Technology to Improve Language Instruction

Communicating via dynamic and static scene cues is a momentous achievement, but a transition from scene cues to the elements of language is the ultimate goal. Within a visual communication approach, language elements are represented by visual element cues (see Fig. 2). These are graphic symbols or photographs that represent each of the individual linguistic components that comprise a sentence (e.g., noun, verb, preposition, adjective, and object) (Shane et al. 2009a). These element cues may be displayed in low-tech form or on most hardware platforms using either special-purpose or general-purpose software.

Within the VIP, element cues form the building blocks of generative language. Once learners understand the symbolic meaning of individual symbols and the rules governing their syntactic configurations, they have the capacity to both comprehend and generate novel utterances (Light et al. 2003). Clinical experience indicates that children with mild-to-severe autism often have little difficulty learning that these graphic elements can correspond to the grammatical notions of "subjects" (Dave) and

Fig. 2 Language element cue

"direct objects" (water), but these same learners often seem to have great difficulty understanding the graphic symbols used for the more abstract depiction of verbs (e.g., pour), prepositions (e.g., in front of), and adjectives (e.g., cold). In addition, combining element cues in a way that demands an understanding of abstract configurational rules for forming grammatical sentences is often difficult for those with ASD. Thus, instruction in use of element cues within the VIP is a twofold process involving first the learning of individual language concepts and their graphic representations, and second the learning of rules governing element cue combination (i.e., syntax). As described in the following sections, the VIP takes advantage of technological innovations whenever possible to maximize the effectiveness of instruction in both of these domains.

Using Technology to Improve Graphic Representations of Difficult Concepts

Language elements are represented in the VIP, as they are in most aided systems, by graphic symbols; accordingly, effective use of the system relies on knowledge of the individual concept represented and recognition of the graphic that represents it. Some researchers have argued that nouns are easiest to understand via graphics whereas verbs and prepositions are more difficult to understand (Schlosser and Sigafoos 2002). Yet, if AAC systems are to support multiple communicative functions, as the VIP strives to do, learners must be able to comprehend more than noun symbols. Actions involve movement and this change may be particularly difficult to represent through static symbols. Although some limited sets of animated symbols have been available for many years (Zangari et al. 1994), they have received limited usage and there has been no investigation of their efficacy conducted until recently. In a recent study, Mineo et al. (2008) reported that non-disabled preschoolers identified symbols for actions better when they were animated rather than static. Recently, Schlosser et al. (2010) completed a study with nondisabled preschoolers across three age groups to determine the effects of animation on guessing, naming, and identifying graphic symbols for verbs and prepositions. Results indicated that (a) animated symbols were more guessable than their static counterparts; (b) animated verbs were named more accurately than static verbs but there was no difference for the prepositions; and (c) older children were more effective than younger children in terms of guessing, naming, and identifying symbols. Whether these results will replicate with children with ASD is currently being investigated (Schlosser et al., 2010).

Based on clinical observation, some learners with ASD can only comprehend the meaning of a symbol when represented in animated form. Accordingly, a set of animated symbols for over 110 verbs and prepositions (*ALP Animated Graphics)* was developed by the Center for Communication Enhancement of Children's Hospital Boston and incorporated into the *VIP-TLC* software (see below).[3] Obviously only a high-tech system can portray an animated or dynamic representation. Using a hi-tech system appears to be opposite to how instruction is traditionally delivered. Typically, in clinical practice, low-tech methods are introduced first and eventually hi-tech devices and approaches are utilized. Because some individuals with ASD require dynamic images in order to comprehend meaning, beginning intervention with static images may not be effective. In addition to use of animated graphics during tabletop instruction for concepts, the widespread availability of consumer-level mobile technology now enables use of animated graphics in the natural environment. Additionally, once meaning of a dynamic symbol is recognized, it can be faded and replaced by its static image (Shane et al. 2009b). Mobile devices may also be used to store and organize static images.

Using Technology to Improve Concept Knowledge Within the Context of Various Syntactic Structures

A central tenet of the VIP, as in language development for typically developing children, is that knowledge of difficult language concepts is most effectively acquired when the learner is provided with multiple, varied opportunities to experience the concept within meaningful exchanges. Children's Hospital at Boston has developed a special-purpose software program that enables learners to experience difficult concepts such as verbs and prepositions within various syntactic constructions. The program uses visual scenes to make language more interesting and accessible to the learner in order to facilitate not only development of concept knowledge, but acquisition of syntactic knowledge as well. This *Visual Immersion Program (VIP)—Teaching Language Concepts (TLC)* software presents learners with color-coded language elements arranged in a left-to-right orientation (See Fig. 3). Learners are encouraged to combine elements creatively to generate sentences in order to demonstrate how sequential placement of specific language elements can result in the activation of a video that depicts a created sentence. With repeated explorations, learners can often come to understand the meaning of the individual symbols and begin to internalize the abstract rules for generating meaningful, grammatically correct sentences.

[3] These authors are involved in the design and creation of the described software project but do not receive royalties for these activities.

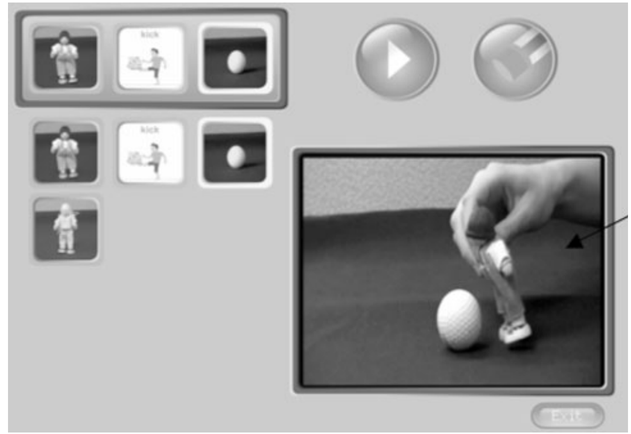

Fig. 3 Visual immersion program (VIP) teaching language concepts (TLC) software

TLC is perhaps the most streamlined in a collection of many software programs (e.g., *Microsoft PowerPoint, Boardmaker with Speaking Dynamically Pro®, Viking)* that can be used to create personalized materials for language instruction. This speaks to yet another benefit of consumer-level, high-end technology, which is the ability to easily customize content and program software to improve the language learning experience.

Using Personalization to Enhance Language Instruction

Traditionally, the libraries of visual symbols available for AAC purposes have consisted of generic sets and systems of static graphic images (Fuller et al. 1992; Lloyd et al. 1997). Based on clinical observations, many young children with moderate to severe ASD often have difficulty understanding the meaning of many of the graphics within these symbol sets and systems. In fact, many individuals with ASD need instruction on the fundamental symbolic nature of visual images; i.e., that an image stands for something other than itself (Kozleski 1991). The use of highly iconic images (e.g., video clips, digital photographs) of familiar people and objects can usually improve comprehension of symbol as well as help maintain attention and interest. Research has shown support for the hypothesis that symbols that look more like what they represent are more guessable and if they are not guessable more easily learned (for reviews see Fuller and Lloyd 1990; Stephenson 2009).

A noteworthy trend in AAC is the ease with which non-technical individuals can now create personalized content that can be applied to both AAC systems and in language instruction software. An important outcome of such ready access to low cost, easy-to-use consumer electronics, mainstream software, and free access to large inventories of visual content is the opportunity to introduce more motivating and meaningful content. For example, digital cameras are now commonplace in most households; they provide a straightforward way to create visual content representing people, places, and things. Photographs often provide a more concrete and iconic means of representing information related to organization and transitions for learners who have difficulty interpreting more abstract visuals (e.g., black and white line drawings, colored picture symbols) (Kozleski 1991; Mirenda and Locke 1989). In addition, general-purpose photo-editing programs (e.g., *iPhoto*, *Picassa*) can be used to store, organize and modify personalized visual supports, making them easier to customize and maintain. Similarly, general-purpose video recording equipment (e.g., camcorders, smartphones) allow the relatively effortless recording of videos that can in turn be used as part of video modeling instruction to teach both behavioral and language skills (see below). These videos can be edited with software that is usually bundled with home computers (e.g., *Windows Moviemaker*, Apple *iMovie*), and played on simple free video players (e.g., *Windows Media Player*, *QuickTime Player*). Finally, there now exist vast online inventories of videos, photographs graphics (e.g., *YouTube, Google Images*) that offer free, quick and easy access to a multitude of video content that can be downloaded and used to represent common objects, activities, events, and language concepts.

It is interesting to note that the creation of visual content, once considered low-tech (e.g., graphics printed on paper), is now typically the product of a high-tech production process; individuals now start with a process that includes either creating or downloading digital content, editing it, then displaying it on a digital device. Only after the last step—printing—does the high tech process produce a low-tech product—a paper graphic.

Thus, instruction for language form and content within the VIP has been vastly improved through use of both consumer-level, general-purpose hardware and special-purpose software that, in combination, allow for creation and easy presentation of more effective visual supports. Although the VIP emphasizes use of visual content to support knowledge and improve instruction in the form and content of language, as described above, attention is also given to language use (e.g., social pragmatic skills), behavioral management, and daily living skills. A growing body of literature suggests that instruction within these domains may be advanced through use of video modeling (Bellini and Akullian 2007; Shukla-Mehta et al. 2010); accordingly, the VIP attempts to maximize the effectiveness of this strategy by taking advantage of current technology.

Using Technology to Enable Video Modeling

Video modeling (a method that traditionally falls under what is known as observational learning; Bandura 1977) is a form of learning that results from imitation of observed behaviors. A growing body of literature reveals that persons with ASD not only effectively imitate a model's behaviors after observing them on a screen, but also generalize these behaviors across models and settings (Bellini and Akullian 2007; Shukla-Mehta et al. 2010). Based on this body of literature, there appear to be five instructional domains for which video modeling is well suited. The first of these domains is language concepts, which, as described above, is of primary interest within the VIP. The others include (2) social pragmatics, (3) activities of daily living, (4) life skills, and (5) behavior management. Clearly, the ease with which video content can now be created or located (see personalization above) has stimulated the expansion of this instructional technique into an effective, mainstream learning strategy. While it is the case that video modeling examples can be played on any number of general-purpose computer media players, the instructional requirements of logical segmenting, highlighting, and replay could be improved. Accordingly, this process has been streamlined in a special-purpose software application, called the *Visual Immersion Program (VIP)—Video Observational Learning (VOL)*.[4] In this application, an instructional video can be quickly and intuitively divided into logical segments, with each segment representing a step in a multi-step routine. In addition, static scene cues representing each of the video segments can be easily created and then shown with or without its accompanying video. Video segments can be played in a continuous fashion, or step-by-step depending on learning needs. The major benefit of this tool is that practitioners can now readily create lessons to teach language concepts by incorporating highly motivating video content that includes familiar people, settings, objects, favorite activities, etc. Additionally, videos may be segmented as needed to more effectively highlight behavioral skills, social pragmatic skills, or activities of daily living and life skills.

Conclusions

In this paper we overviewed several categories of communication hardware and software as well as described current trends in communication technology as it applies to individuals with ASD. While in the past most technologies for persons with special needs were developed by companies and organizations focused exclusively on such populations, the contemporary landscape is quite different as hardware and software created for mainstream markets are

[4] These authors are involved in the design and creation of the described software project but do not receive royalties for these activities.

readily adaptable to special needs populations. As a result, new possibilities exist for use of technology to effectively support and improve everyday communicative exchanges for learners with ASD and their communication partners; additionally, technological developments are leading to the creation and more widespread use of innovative teaching tools that may be more effective for language instruction than their predecessors. The widespread uses of innovative technology across every segment of society bodes well for persons with ASD.

Appendix: Referenced Technology

Hardware

GoTalk: Special Purpose Hardware by Attainment Company
DynaVox V: Special Purpose Hardware by DynaVox Mayer-Johnson.

Software

Boardmaker with Speaking Dynamically Pro: Special Purpose software produced by DynaVox Mayer-Johnson.
Clickit!: Software produced by IntelliTools®, inc.
First-Then: Special Purpose application by Good Karma Applications, Inc.
Google Images: General Purpose software by Google, available at http://images.google.com/
iMovie: General Purpose Software produced by Apple Inc.
iPad AAC software applications: http://www.miasapps.com/icomm.html
iPhoto: General Purpose software produced by Apple Inc.
Microsoft PowerPoint: General Purpose software produced by Microsoft
Microsoft Word: General Purpose software produced by Microsoft
My Choice Board: Special Purpose application: Good Karma Applications, Inc.
MyTalk: Special Purpose application: 2nd Half Enterprises LLC, available at http://www.mytalktools.com/pDownloadMyTalk.htm
PicCalendar: Special Purpose application by INZENYR LLC
PogoBoards: Special Purpose software produced by Talk To Me Technologies, LLC, available from: http://www.pogoboards.com
Proloquo2Go: Special Purpose application: AssistiveWare, available at http://www.proloquo2go.com/
Picassa: General Purpose software produced by Google
QuickTime Player: General Purpose software produced by Apple, Inc
Steps: Special Purpose application by Adastrasoft
Windows Movie Maker: General Purpose software produced by Microsoft
Windows Media Player: General Purpose software produced by Microsoft
Viking: Special Purpose software produced by Viking Software
Visual Immersion Program (VIP)—ALP Animated Graphics (AAG): Special Purpose software produced by Children's Hospital Boston
Visual Immersion Program (VIP)—Teaching Language Concepts (TLC): Special Purpose software produced by Children's Hospital Boston
Visual Immersion Program (VIP)—Video Observational Learning (VOL): Special Purpose software produced by Children's Hospital Boston
YouTube: General Purpose software by Google Inc., available at http://www.youtube.com

Mobile Media Devices

Android: Smartphone currently owned by Open Handset Alliance (OHA)
Blackberry Storm: Smartphone developed by Research In Motion (RIM)
iPhone: Smartphone produced by Apple Inc.
iPad: Handheld media device by Apple Inc.

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