

Evaluating Augmented Reality to Complete a Chain Task for Elementary Students With Autism

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Abstract

The purpose of this study was to examine the effects of augmented reality to teach a chain task to three elementary-age students with autism spectrum disorders (ASDs). Augmented reality blends digital information within the real world. This study used a marker-based augmented reality picture prompt to trigger a video model clip of a student brushing her teeth. All students learned how to brush their teeth independently and maintained the skill 9 weeks later with the introduction of augmented reality. Theoretical and teacher implications are discussed in the context of using new technologies to teach students with ASDs.

Keywords

elementary school, age/grade level, autism, exceptionality, small *N*/single subject design, methodologies, instructional technology, technology perspectives, mobile devices, technology perspectives

According to *The Diagnostic and Statistical Manual of Mental Disorders* (fifth edition; DSM-5; American Psychiatric Association, 2013), individuals with autism spectrum disorders (ASDs) demonstrate qualitative impairments in social communication and social interaction across multiple contexts. Other common characteristics for individuals with ASD include difficulty with verbal reasoning, short-term memory, and performing daily living skills, which may continue into adulthood (Carpentieri & Morgan, 1996). These difficulties present both pragmatic and pedagogic challenges in teaching students with ASD through traditional methods such as verbal instruction and memorization tasks (Quill, 1997). Conversely, means of instruction that incorporate visual supports (e.g., pictures, in vivo modeling, video modeling [VM]) for students with ASD are recognized as evidenced-based practices that capitalize on the strengths of students with ASD (Ayres & Langone, 2005; Bryan & Gast, 2000; Hine & Wolery, 2006; Mechling, 2007, 2011; Mechling, Ayres, Bryant, & Foster, 2014; Mechling, Ayres, Foster, & Bryant, 2014; Rayner, Denholm, & Sigafos, 2009).

Recent literature continues to support the efficacy of visual strategies for teaching tasks to individuals with ASD. Such visual strategies include picture prompts (Cihak, 2011; Cihak, Alberto, Kessler, & Taber, 2004; Ingvarsson & Le, 2012), video prompting (Mechling, Ayres, Foster, & Bryant, 2013; Yanardag, Akmanoglu, & Yilmaz, 2013), and VM (Bellini & Akullian, 2007; Cardon, 2012; Charlop-Christy, Dennis, Carpenter, & Greenberg, 2010; Cihak, Fahrenkrog, Ayres, & Smith, 2010). Mechling, Gast, and Seid (2009) taught cooking

tasks to three individuals with autism using self-prompting on a personal digital assistant (PDA). The participants selected the prompt level necessary to complete each step of the task analysis (i.e., picture, picture + auditory, and video + auditory). All three participants were successful at completing the chain task and acquiring the cooking skills with prompting on the PDA. Mechling (2008) suggested that more studies regarding the use of portable devices to deliver picture-based or video-based instruction in real settings is needed. Typically, these different strategies have generally been used in isolation. Students may use picture prompts or video prompts and/or VM, but usually do not use these strategies collectively or in chronological proximity in real-world settings. New developments in augmented reality technology allow for a new approach that fuses picture prompting and VM in real-world settings.

Attention and VM

While VM is designated as an evidence-based practice for teaching tasks to students with ASD (Bellini & Akullian,

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2007), it is not without problems. One common problem is that students with ASD have difficulty acquiring and maintaining attention to a video model (McPartland, Webb, Keehn, & Dawson, 2011). To address this issue, a key theoretical framework behind VM is Bandura's social learning theory (SLT).

SLT (Bandura, 1977) refers to learning that occurs through observation of a model demonstrating a skill, which the student retains and mimics when properly motivated. While this theory was originally practiced as an *in vivo* approach, VM offers more efficient and effective means of actualizing SLT (Charlop-Christy et al., 2010; Gena, Couloura, & Kymissis, 2005; Wilson, 2012). In application, Bandura's theory provides a phase-based model for observational (social) learning, the first phase of which requires the learner to attend mentally and physically to the model.

Previous research established that VM is an evidence-based practice that generally is effective for students with ASD. However, due to potential difficulties in attending, which are prevalent among individuals with ASD, VM may not be as generally effective as its evidence-based practices designation may suggest. Although some literature suggests the superiority of VM over static picture prompts (e.g., Chang & Wang, 2010; Mechling et al., 2013), other studies demonstrated that specific learner profiles and needs dictate which of these practices is more effective (Alberto, Cihak, & Gama, 2005). In cases wherein individuals with ASD struggle significantly to acquire and maintain attention, VM may be ineffective compared to picture prompts, which do not require constant attention. Augmented reality has the potential to offer both VM and individualized supports to promote attention.

Augmented Reality

Augmented reality overlays digital information (e.g., text, picture, and video) on the physical world, effectively supplementing or augmenting real-time reality (Craig, 2013). Carmigniani and Furht (2011) defined augmented reality as "a real-time direct or indirect view of the real world environment that has been enhanced/augmented by adding virtual computer-generated information to it. Augmented reality is interactive by combining real and virtual objects" (p. 3). One form of augmented reality is marker-based augmented reality, which uses a physical marker to trigger a display of digital information. Figure 1 illustrates the use of augmented reality. A physical marker can be a picture or object (e.g., Boardmaker picture). The marker is then paired with a video, picture, and/or audio prompt. Using a mobile device with an augmented reality app, the marker triggers prerecorded digital information created by the user. In this context, augmented reality allows for picture prompts and VM to be used in tandem in real-world settings.

Few studies have been conducted involving the use of augmented reality in classroom or instructional settings for teaching content (e.g., vocabulary) and tasks. Among those studies, the use of augmented reality reported positive outcomes in content mastery (Liu, 2009; McMahan, Cihak, Wright, & Bell,

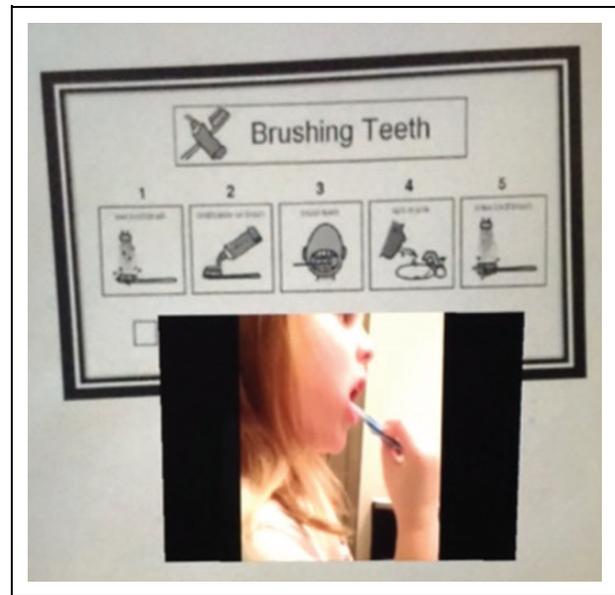


Figure 1. Example of augmented reality using a Boardmaker picture as a trigger that initiates a video clip of how to brush your teeth.

2016; Vilkoniene, 2009) and motivation: an important component for social learning (Di Serio, Ibáñez, & Kloos, 2013; Hsiao, Chen, & Huang, 2013). For example, McMahan et al. examined the effects of augmented reality instruction to teach science vocabulary words to four college students with intellectual disabilities who attended a postsecondary education (PSE) program. Students were given a printed booklet of vocabulary words, a tablet device with augmented reality app, and instructed to scan the words to trigger digital content that included a video clip of the definition and the application of the vocabulary word on a visual diagram. All students readily acquired the vocabulary word and were able to label each word on the corresponding diagram following the augmented reality intervention. Additionally, the students reported high levels of enjoyment from the ability to control their own learning, access the information independently, and from use of the augmented reality application overall. In another study, McMahan, Cihak, Gibbons, Fussell, and Mathison (2013) evaluated the effects of using an augmented reality application to identify potential food allergens for seven college students with autism and intellectual disability who attended a PSE program. The participants were provided instruction on using the augmented reality application to scan food product bar codes and determine whether or not the item contained specified ingredients, to which a person might be allergic. Results demonstrated an immediate improvement in the students' abilities to identify foods with possible allergens when using the augmented reality application. Further, the students demonstrated mastery of the skills related to using the augmented reality application with minimal initial training, and these skills were maintained 6 weeks following the study. These two studies indicate positive outcomes of using augmented reality technology and mobile devices to increase access to digital information and improve

the functional capabilities of individuals with autism and intellectual disability.

No published research exists regarding the use of augmented reality technology as a means to teach chain tasks or life skills to students with intellectual disabilities or ASD. However, given the relative effectiveness that VM and picture prompting demonstrate, and the unique challenges (e.g., difficulty attending and difficulty memorizing) prevalent among children with ASD, augmented reality interventions should be explored. Augmented reality combines the strengths of both picture prompting and VM and might mitigate the challenge of attention for students with ASD while simultaneously providing support for the completion of tasks that otherwise require procedural memory.

Augmented Reality, Social Learning, and Universal Design for Learning (UDL)

A theoretical basis to frame the potential of augmented reality as an effective means of teaching tasks and skills to students with ASD may be established using both SLT and UDL (Rose & Gravel, 2010). SLT already provides a theoretical basis for the effectiveness of VM. Inasmuch as VM may continue to be used as a component of augmented reality (as it is in this study), the theoretical basis of SLT carries over. However, issues of attention, a key component for social learning, may be ameliorated through the additional interactive aspects of augmented reality compared to VM, as noted in the prior section. Such a hypothesis may be understood through the UDL framework.

Augmented reality and UDL. UDL is “a framework for teaching and learning that often capitalizes on the power and flexibility of modern technologies to address the needs of the broadest possible range of students” (Rose & Gravel, 2010, p. 119). This multifaceted framework invokes brain network research to inform best practices of instruction. Specifically, it attends to three groups of brain networks, which are highly relevant to learning: the recognition networks (related to resourcefulness and knowledge), the affective networks (related to purpose and motivation), and the strategic networks (related to strategy and goal orientation; Meyer, Rose, & Gordon, 2014). The concept of “flexibility,” built into the definition, refers to the degree to which students are enabled to learn material in multiple or preferential ways according to their needs (Rose & Meyer, 2000). In UDL, this flexibility is provided via multiple means of engagement (affective), multiple means of representation (recognition), and multiple means of action/expression (strategic; Meyer et al., 2014).

In recognition of the variability of the brain and the flexibility that is needed to reach students, methods such as VM may be *generally* effective and still may not be the most effective means of teaching chain tasks for students whose variability causes them to struggle with the attention processes and cognitive (mnemonic) aspects of the motor reproduction process. As a range of attention and cognitive ability may be part of a predictable variability among individuals with ASD,

providing alternative options (e.g., both picture prompts *and* VM on demand) to meet the needs of these diverse students would be considered a best practice according to UDL (Rose & Gravel, 2010). The practice of augmented reality is better reflective of UDL theory and practice, as it provides multiple means of engagement, representation, and action/expression.

Augmented reality provides an engaging multimedia approach that is always available in real-world contexts. The use of picture prompts with the options for VM and/or audio or textual instructions can be adapted to the needs of specific students. By using multiple means of representation, AR puts the individual with ASD in charge of his or her own support and encourages self-regulation. Additionally, the provision of options for physical action when using augmented reality is a component in providing multiple means of action and expression (Meyer et al., 2014). The physical motor act of having to point a mobile device at a visual trigger may increase the degree to which individuals with ASD must initiate and maintain attention (Afshari, 2012). Additionally, this physical act may make it easier to listen and maintain visual focus. For example, the audio and video are displayed only when the mobile device is positioned toward the trigger. However, if the device is not positioned toward the trigger, the audio and video will immediately cease, thus alerting the student that they need to return to a state of attention; no such provision is inherent to other forms of VM.

The purpose of this study was to examine whether augmented reality is an effective way to teach elementary students with ASD a chain task. Specifically, was using augmented reality effective as a means to teach elementary students with ASD how to brush their teeth? Also, what were the long-term effects of using augmented reality on the maintenance of teeth brushing? Finally, what was the social validity of using augmented reality to teach a new skill?

Method

Participants

Three male elementary students with ASD (Allen, Bart, and Chris) participated in this study. All students were eligible for special education services under the autism category. Also, all students' cognitive and adaptive functioning fell within the moderate intellectual disability range. Participants were selected based on the following criteria: (a) diagnosis of autism or an intellectual disability, (b) Individual Education Plan (IEP) goal to improve adaptive behavior related to personal care, (c) no physical disability which impeded the performance of the skill, and (d) agreeing to participate in the study. In addition, all students were unable to brush their teeth independently. Table 1 lists characteristics for each participant.

The first participant, Allen, was 6 years old and in the first grade. Allen had complex communication needs and used the Picture Exchange Communication System to communicate. The second participant, Bart, was also 6 years old and in the first grade. Although he had some verbal communication skills,

Table 1. Students' Characteristics.

Students	CTONI-2	VABS-II	GARS-II			
			Stereotype Behaviors (SS/%)	Communication (SS/%)	Social Interaction (SS/%)	Autism Index (SS/%)
Allen	55	46	8/25	15/95	14/91	115/84
Bart	48	65	7/16	13/84	13/84	106/65
Chris	54	50	13/84	8/25	6/9	94/35

Note. CTONI-2 = Comprehensive Test of Nonverbal Intelligence—Second Edition; VABS-II = Vineland Adaptive Behavior Scales-II, Second Edition; GARS-II = Gilliam Autism Rating Scale-II; SS = standard scores; % = percentile.

Bart primarily used a Pragmatic Organization Dynamic Display (PODD) book in order to communicate. Chris, the third participant, was 7 years old and in the second grade. Similar to Bart, Chris had complex communication needs and used a PODD book in order to communicate.

Setting

All students attended a special education classroom for part of their school day to address functional or life skill activities. Three other students with multiple disabilities also were present in the classroom. Pretraining instruction using an iPod touch device occurred in the participants' special education classroom. Baseline, augmented reality, and maintenance phases occurred in the special education classroom's bathroom as the skill of teeth brushing naturally occurred in that location. Within the bathroom, a five-step pictorial task analysis was displayed that the teacher used as a visual support.

Materials

This study incorporated the use of an iPod touch fourth generation, Aurasma (2014) augmented reality application, 62-s video clip, five-step static picture task analysis, individual student toothbrushes, toothpaste, and paper cups. The Aurasma augmented reality application was downloaded onto the iPod. Aurasma is a free app that allows users to create an augmented reality experience by matching a user-created visual marker to trigger user-created digital content that can include pictures, video, and/or audio. The Aurasma app uses the device's camera view to identify the marker to trigger the video.

The marker in this study was the five-step static pictorial task analysis that was already displayed in the bathroom, as illustrated in Figure 1. The video support was a 62-s VM clip of a 7-year-old female child without a disability brushing her teeth. The five-step static pictures were Boardmaker[®] images that were displayed on an 8 in. by 10-in. paper, which was printed in color, laminated and displayed horizontally next to the classroom sink. The video was filmed primarily from the child's point of view, edited using Windows Moviemaker[®], showed all steps continuously, and was narrated using the brushing teeth task analysis (see Table 2). The researchers linked the brushing teeth picture and the video clip via Aurasma. Therefore, when the picture was scanned using the iPod camera view, the video was initiated automatically and played

Table 2. Brushing Teeth Task Analysis.

1. Pick up and hold toothbrush
2. Turn on water
3. Wet the toothbrush
4. Remove cap from toothpaste
5. Apply the toothpaste
6. Put cap on toothpaste
7. Brush top teeth
8. Brush bottom teeth
9. Brush tongue
10. Put down toothbrush
11. Fill cup with water
12. Rinse and spit into sink
13. Wipe mouth with towel
14. Discard towel
15. Rinse the toothbrush
16. Put toothbrush away

the 16-step VM clip. The video was positioned below the picture prompt to create the augmented reality experience. When the student viewed the five-step picture task analysis through the iPod camera lens, the picture and the entire 62-s VM clip appeared. Augmented reality is innovative in its ability to provide supplemental visual and auditory information to any object, picture, or image. In this study, we added a 62-s video clip that readily displayed all 16 task analyzed steps.

Variables and Data Collection

The independent variable in this study was the use of augmented reality. An augmented reality video overlay was created and corresponded to the static-picture prompt of brushing teeth. The dependent variable was the number of task-analyzed steps completed independently for brushing teeth. Table 2 lists the 16 task-analyzed steps for brushing teeth. Data were collected through the use of a data sheet designed to record the task-analyzed chain. Event recording procedures were used to record each step as independently performed or incorrectly performed. An independent response was defined as initiating the first step in the task analysis within 5 s and completing each step within 10 s without teacher assistance, except for steps 7, 8, and 9, in which the students brushed their top and bottom teeth and tongue. Students were provided a maximum of 2 min to complete all three steps. The number of independent steps completed was divided by the total number of steps of the task

analysis (i.e., 16) and multiplied by 100 to calculate the percentage of steps completed independently, which was graphed for visual analysis.

Research Design

This study incorporated a multiple probe design across participants (Hammond & Gast, 2010) to demonstrate the relation between augmented reality and brushing teeth independently. All students started the baseline phase at the same time. However, augmented reality was introduced to Allen first. After Allen reached acquisition criteria (i.e., 100% independence for three consecutive sessions), augmented reality was introduced to Bart. When Bart achieved acquisition criteria, augmented reality was then introduced to Chris. By systematically introducing the augmented reality intervention at three different points in time, functional relationships could be demonstrated.

Procedures

Baseline. Each session during baseline, as well as the succeeding phases, consisted of one opportunity for completion of all the steps in the brushing teeth task. During baseline, the students were presented with all of the materials required for brushing their teeth. Then, the teacher reviewed the five-step picture task analysis for brushing their teeth and pointed to each picture. Lastly, students were given a single verbal cue for task performance (i.e., “time to brush your teeth”). The baseline phase continued for a minimum of five sessions or until stability was achieved. The 80–20% stability envelope criteria (Gast, 2010), which states that the data are considered stable if 80% of the data points fall on or within 20% of the mean of baseline, were used to determine stability.

Pretraining. Prior to introducing the augmented reality brushing teeth intervention, students participated in a pretraining phase. For the first phase of pretraining, students were instructed how to operate the iPod. They were instructed to physically turn on the device and to “scan the picture” using the device’s camera view to trigger a corresponding video clip. In the second pretraining phase, students were required to turn the device on, scan a picture of a hat that triggered a brief video of a student picking up a hat and putting it on his head, and to follow the video instruction. That is, the students were expected to pick up a hat and put it on their head. Each student was required to reach a criterion of 100% accuracy for two consecutive sessions prior to initiating the intervention phase.

Augmented reality. During the augmented reality intervention phase, students were presented with all of the materials required for brushing their teeth. Students were given a verbal cue for task performance. The teacher said, “[student name] scan the picture and brush your teeth” while pointing to the static picture of brushing teeth. Except for Steps 7, 8, and 9, in which the students brushed their top and bottom teeth and tongue, if a student did not independently initiate the first step

of the task analysis within 5 s or complete a specific step within 10 s, then teacher assistance was provided using the system of least prompts. The least-to-most prompt hierarchy consisted of the following levels that included 5 s wait time for the student to respond before progressing to a more intrusive level of assistance: (a) verbal prompt, (b) gesture, (c) gesture plus verbal explanation, (d) modeling plus verbal explanation, and (e) physical assistance plus verbal explanation. If the student correctly completed the step using a verbal prompt, then it was recorded as assisted. Criterion for completion of this phase was 100% independent performance of all steps for three consecutive sessions.

Maintenance

Follow-up probes were conducted 9 weeks after the student met acquisition criterion. During maintenance phase, procedures similar to baseline were implemented. The teacher instructed the students with “[student name] brush your teeth.” Follow-up probes were collected to determine whether the initial instruction maintained the students’ performance over time.

Social Validity

Following the conclusion of the study, the classroom teacher and teacher assistant completed a social validity questionnaire regarding the social acceptability of using augmented reality to teach a chain task. The questionnaire consisted of a 5-item Likert-type scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Items included (a) the materials were difficult to create, (b) students benefited from using the augmented reality experience, (c) students benefited from using the augmented reality experiences more than the static-picture prompts, (d) I would recommend augmented reality to other teachers, and (e) I would use augmented reality again to teach other skills. The possible scores ranged from 5 to 25 with higher scores indicating greater social acceptance. Following the 5 items, an open-ended question asked, “What else do you think?” We also asked each participating student: (a) did you like the video, (b) do you think the video help you learn to brush your teeth, and (c) would you like more pictures to become videos? All questions were read aloud and students responded verbally and/or by pointing to a smiley face with the word “yes” printed underneath or a frowning face with the word “no” printed underneath.

Interobserver Agreement (IOA) and Procedural Integrity

The classroom teacher and a member of the research team collected IOA data and procedural reliability data simultaneously. Interobserver and procedural reliability data were collected during 20% of baseline and each subsequent phase. Observers independently and simultaneously recorded the number of steps each student performed independently or the required prompt and response time. IOA was calculated by dividing the number of agreements of student responses by the

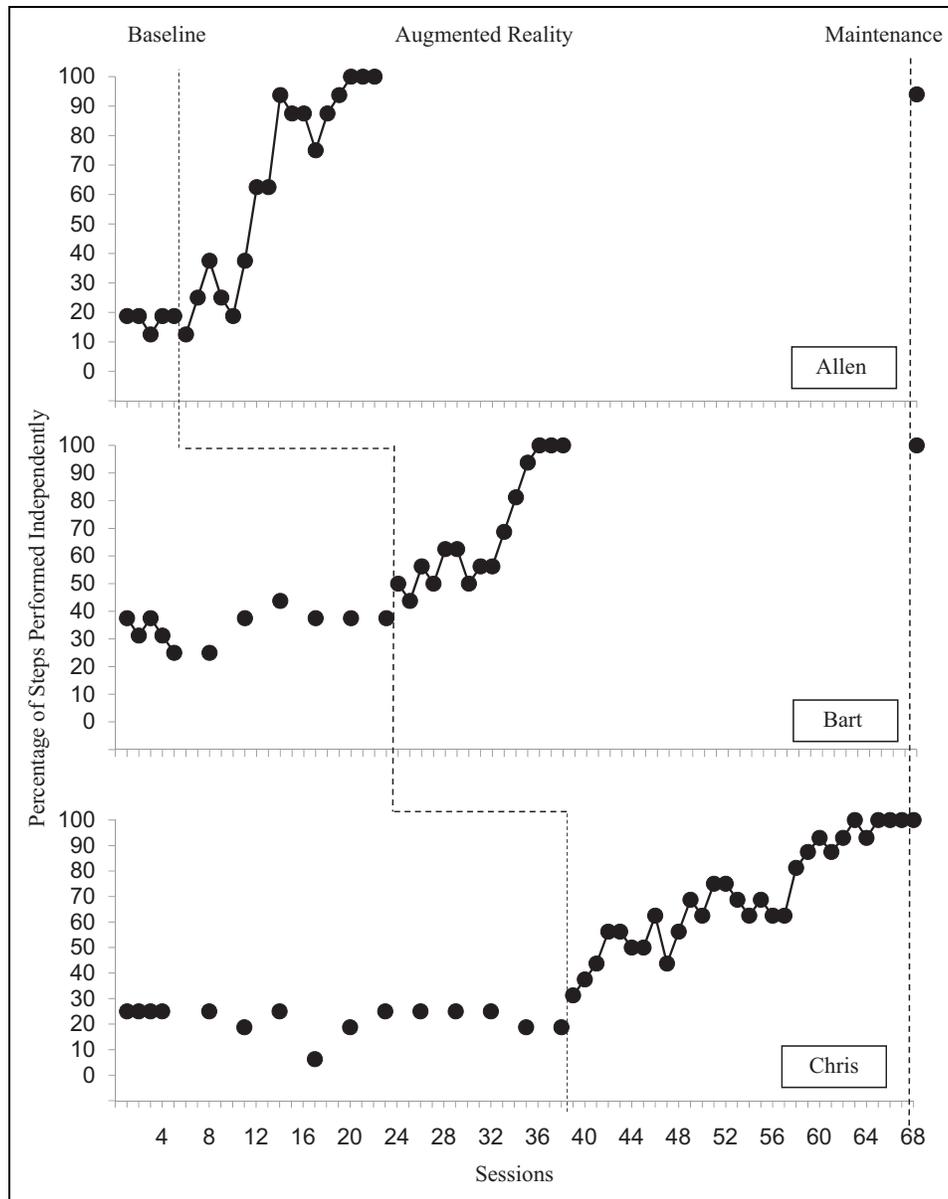


Figure 2. Acquisition and maintenance of brushing teeth across students using augmented reality.

number of agreements plus disagreements and multiplying by 100. The mean IOA for each student was Allen, 100%; Bart, 97.6% (range 95–100%); and Chris, 100%.

Procedural integrity measures were employed to determine the classroom teacher's performance according to the prescribed procedures. The classroom teacher behaviors included having all materials available and using the correct prompting hierarchy and response time. The classroom teacher was trained using an itemized checklist that listed the 16 task-analyzed steps of the task and the level of prompt. The teacher was considered successfully trained after completing 100% of the checklist for three consecutive trials. Scores for the procedural agreement levels were calculated by dividing the number of observed teacher behaviors by the number of planned teacher behaviors and multiplying by 100 (Billingsley, White,

& Munson, 1980). The mean procedural reliability agreement for each student was Allen, 95.8% (range = 89–100%); Bart, 97.1% (range = 92–100%); and Chris, 94.7% (range = 87–100%). Most procedural errors were the result of not providing the appropriate amount of response time between levels of least prompt procedures.

Results

The percentage of steps performed independently for each student is presented in Figure 2. Overall, students' independent performance immediately increased when augmented reality was introduced with 98% nonoverlapping data. During baseline, Allen completed a mean of 17.5% of steps for brushing his teeth independently. During intervention, his performance

immediately improved with 94% nonoverlapping data. Additionally, Allen completed all task-analyzed steps independently for three consecutive sessions in 17 sessions. He typically also required verbal and gestural prompts. Allen maintained 94% of the steps 9 weeks later. Bart's mean percentage of steps performed independently during baseline was 34.7%. Following intervention, his mean performance immediately ascended with 100% nonoverlapping data. Bart required 15 sessions to reach acquisition criteria. During intervention, Bart also required verbal, gestural, and one partial physical prompt. As he progressed in intervention, he only required a verbal prompt until he demonstrated independence. Nine weeks later, Bart maintained 100% performance. Chris's mean percentage of steps performed independently during baseline was 22.1%. Following intervention, his mean performance immediately increased with 100% nonoverlapping data and he required 29 sessions to reach acquisition criteria. Like Bart, he also required verbal, gestural, and partial physical prompts during intervention. Chris continued to demonstrate 100% independence 9 weeks later.

Social validity data indicated the classroom teacher, teacher assistant, and students perceived the augmented reality intervention as an acceptable way to learn new skills. The students liked how the picture turned into a video and wanted more pictures to turn into videos. The teacher and teacher assistant indicated that the materials were relatively easy to develop, they would continue to use augmented reality to complement other static visual strategies, and they would recommend the intervention to other teachers.

Discussion

The purpose of this study was to examine the effects of augmented reality on the acquisition of a chain task for elementary-age students with ASD. Following the introduction of the intervention, all students acquired and maintained the chain task of brushing their teeth independently and a functional relationship was established. The percentage of nonoverlapping data ranged from 94% (Allen) to 100% (Bart and Chris), which indicates that the augmented reality intervention was highly effective (Scruggs & Mastropieri, 2001).

These findings add to the current literature regarding a promising strategy to teach chain tasks to students with ASD. It is well established that students with ASD tend to learn better through visual means (e.g., Ayres & Langone, 2005; Bryan & Gast, 2000; Hine & Wolery, 2006; Rayner et al., 2009). This generalization is supported by practical approaches in the literature such as the use of picture prompting and VM (Ayres & Langone, 2005; Bryan & Gast, 2000; Cihak et al., 2004; Delano, 2007; Hine & Wolery, 2006; Mechling et al., 2013; Rayner et al., 2009).

Mechling (2008) noted that the evolution in technology for teaching self-care skills is promising and advancing. The current study extends the research of visual supports by examining the effects of augmented reality to teach students with ASD to brush their teeth. Few studies exist regarding the effectiveness

of augmented reality as a learning tool for students with ASD and/or intellectual disabilities (Richard, Billaudeau, Richard & Gaudin 2007; McMahon et al., 2015, 2016), and the researchers found no previously published study that explores how augmented reality may be used to effectively teach chain tasks to students with ASD. This study offers evidence to support the hypothesis that augmented reality may be an effective tool for teaching chain tasks to students with ASD.

This study also extends the literature by demonstrating how augmented reality may be supported by SLT and UDL. In terms of SLT, augmented reality requires a physical demonstration of attention from students in that they must open the augmented reality application on their mobile device, and then intentionally focus the device at a marker, which instigates the augmented reality video. The physical movements encouraged participants to focus on the task at hand (brushing their teeth), and thus—in accordance with SLT—this attention may well have been a key component in the participant's success.

The use of augmented reality for chain task performance utilizes some of the principles outlined in the UDL guidelines (Meyer et al., 2014). Specifically, this method is designed to help facilitate multiple means of engagement (minimizing distractions by focusing the child's attention, facilitating personal skills and strategies with a tool that can be used for many applications), multiple means of representation (skills taught through an on-demand dynamic visual component and audio/verbal component of which the child may choose to attend to both or either), and multiple means of action and expression (expression of a kinesthetic attention whereby the student engages physically and directionally toward the relevant object/marker, then watches and/or listens and responds). In this sense, augmented reality provides more options for students to approach the learning process than picture or video prompting. Whereas picture prompting provides options for *static* text and image and VM provides options for *dynamic* text and images as well as an option for an audio/verbal aspect, augmented reality includes all the options of VM but adds a kinesthetic aspect which may be key for some students with ASD.

In addition, the use of augmented reality for chain task performance incorporates some principles of Applied Behavior Analysis. For some individuals with ASD, even simple tasks can present complex challenges. Analyzing tasks into a sequence of smaller steps or actions has been identified as an evidence-based practice for teaching new skills to students with severe developmental disabilities (Spooner, Knight, Browder, & Smith, 2012). Having an understanding of all the steps involved for a particular task can assist in identifying any steps that may need extra instruction and will help teach the task in a logical progression (Cooper, Heron, & Heward, 2007). After a task analysis was developed, chaining procedures were used to teach the task. A task can be presented using forward, backward, or total task chaining procedures. This study incorporated the total task chaining strategy. Using this strategy, the entire skill was taught and prompts were provided for steps that were not performed independently. An advantage of total task

training is that the individual is able to learn the entire routine without interruption, and they are able to complete any steps that have been mastered (Cooper et al., 2007).

Teacher Implications

The use of augmented reality technology is a promising option for teaching chain tasks to students with ASD, and thus teachers may consider it a tenable intervention to try. However, no method or approach to teaching is universally a good fit. The strengths of using augmented reality to teach chain tasks will be best utilized for students who have difficulty attending or maintaining attention with VM, but need more support and/or more means of representation than that which is offered by picture prompting. Augmented reality does require access to a smart device (e.g., tablet or smartphone) and also requires some physical dexterity to navigate to the augmented reality app and aim the device at the marker, either of which may be prohibitive in some cases.

Limitation and Future Research

As with all research, these results must be interpreted in the context of this study. We did not control for students brushing their teeth outside of school or at home. Mostly likely, students did brush their teeth at home daily, which might have contributed to the results of the augmented reality experience. Also, the system of least prompts was used as an error correction procedure during the augmented reality intervention; it was not parceled out during the intervention phase. Therefore, the use of least prompt procedures might have contributed to students' outcomes. Also, only one maintenance probe was collected. Additional maintenance data would have provided a stronger conclusion regarding the skill maintaining over time. Lastly, only three students participated in this study, which limits external validity.

The relative newness of augmented reality technology and its usage as an instructional tool for special education leaves many avenues yet in need of research. Some potential next steps include studies that examine efficacy of augmented reality among persons with ASD from different age groups and/or persons with intellectual disability, studies that examine the use of augmented reality to teach skills and tasks other than independent living (e.g., academic, vocational, and social-communicative skills), and studies that explicitly juxtapose augmented reality and other forms of evidence-based practices (such as VM and picture prompting) in group designs.

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