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Comparison of Imitation From Screens Between Typically Developing Preschoolers and Preschoolers With Autism Spectrum Disorder

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Typically developing (TD) children exhibit a transfer deficit imitating significantly less from screen demonstrations compared to a live demonstrations. Although many interventions for children with autism spectrum disorder (ASD) include video materials, little research exists comparing the effectiveness of video demonstration over live instruction. The current study compared imitation learning from live and screen-based demonstrations of how to make a puzzle by 3- to 4.5-year-old TD children (n = 68) and children with ASD (n = 17). Children were tested on either on a three-dimensional (3D) magnet board (MB) with magnetic puzzle pieces or a 2D touch screen (TS) with virtual puzzle pieces. Neither TD nor ASD children exhibited a transfer deficit suggesting that for this task, the transfer deficit ends around 3 years of age. Children with ASD were less efficient overall than TD children on the task and performed worse than their TD counterparts when they were tested with the 3D MB puzzle. These findings suggest that children with ASD have greater difficulty acting on 3D objects than 2D TSs. Future studies should investigate if TSs can be used to teach children with ASD other tasks (184 words).

Keywords: autism spectrum disorder; imitation; transfer deficit; learning; preschoolers

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Imitation, which is the replication of the means and the goal of a specific action (Vivanti & Hamilton, 2014), is thought to have evolved for rapid transmission of information and is highly developed in humans (Csibra & Gergley, 2006, 2009; Hipp et al., 2017). Imitation involves a complex set of cognitive and social processes which depend on subtle and dynamic changes in eye contact, body movements, vocal changes, and responses to contingent interactions (e.g., Huang & Charman, 2005; Nielsen & Blank, 2011; Over & Carpenter, 2011, 2013). Children imitate for social and cognitive purposes (Ingersoll, 2008; Uzgiris, 1981). Typically developing (TD) infants and toddlers readily imitate an adult model (Hayne, Barr, & Herbert, 2003; Heimann & Meltzoff, 1996; Heimann, Nordqvist, Rudner, Johansson, & Lindgren, 2013; Johnson, Younger, & Furrer, 2005; Jones & Herbert, 2006; Jones & Herbert, 2008; Learmonth, Lamberth, & Rovee-Collier, 2004; Meltzoff & Moore, 1977; Meltzoff & Williamson, 2010). There is evidence that TD children imitate even when the actions are not clearly relevant to the goal state (e.g., Jones, 2007; Meltzoff, 1995). Over and Carpenter (2013) postulate that children often imitate unnecessary and irrelevant actions, or overimitate, because they want to form a social connection with the person they are imitating. That is, imitation not only has a cognitive function that makes imitation a major source of early learning but also has a strong social function (Uzgiris, 1981).

Research shows that children with autism spectrum disorder (ASD) have a deficit in imitation in comparison to TD children (for a review, see Edwards, 2014) which distinguishes autism from other developmental disorders (Stone, Lemanek, Fishel, Fernandez, & Altemeier, 1990; Stone, Ousley, & Littleford, 1997). Charman et al. (1997) used four imitation tasks, in which an instructor faced a child and interacted with objects in specific ways, finally prompting the child by asking “what can you do with this?” Infants with ASD produced significantly fewer imitative behaviors than both TD children and children with other developmental delays. Ingersoll (2008) took this a step further and examined imitation in either a structured, experimental condition or a more spontaneous naturalistic condition. Results showed children with ASD exhibited an imitation deficit relative to their TD peers overall and the effects were particularly large in the naturalistic-spontaneous setting.

One explanation for this imitation deficit could be problems with information-processing and perceptual organization, as demonstrated by the cognitive inflexibility and difficulty with attention, memory, coding, and motor skills often seen in children with autism (Smith & Bryson, 1994). These difficulties may manifest themselves in an imitation deficit through difficulty relating visual “other” to motor “self” information (Rogers & Pennington, 1991) or understanding intention behind action (for review see Vanvuchelen, Schuerbeeck, Roeyers, & De Weerdt, 2013; Vivanti & Hamilton, 2014). Others have suggested that the mirror neuron system is impaired in children with ASD (Dickerson, Gerhardstein, & Moser, 2017; Fabbri-Destro, Cattaneo, Boria, & Rizzolatti, 2009); this is also a possible explanation of the imitation deficit in children with ASD.

Alternatively, deficits in social communication and an apparent lack of desire to participate in social acts could explain these findings (Edwards, 2014; Van Etten & Carver, 2015). Chevallier, Kohls, Troiani, Brodkin, and Schultz (2012) describe social orienting, social reward, and social maintenance as components of social motivation, all of which are diminished in ASD. Additionally, adolescents with ASD demonstrated a degree of social anhedonia on a self-report survey about social situations and are less concerned with impression management (Chevallier et al., 2012). Vivanti, Nadig, Ozonoff, and Rogers (2008) demonstrated an overall diminished focus on social information and social stimuli in children with ASD. While children with ASD and TD children spend equal time looking at the region where action is occurring during an imitation task, children with ASD spend significantly less time looking at the face of the model doing the task (Vivanti et al., 2008). Similarly, when observing a naturalistic visual model of social and object stimuli, eye tracking measures show that children with ASD spend significantly less time than TD children looking at the social stimuli and more time looking at the objects (Chevallier et al., 2015). Hobson and Lee (1999) found that children with ASD could imitate goal-oriented actions to complete the final goal, but failed to imitate the gestures or style of the action to attain the goal.

The relationship between imitation deficits and other deficits common of ASD was demonstrated by Stone et al. (1997), who found a strong association between body movement imitation and expressive language and a strong association between action imitation and play skills. Ingersoll and Schreibman (2006) found, using naturalistic techniques to teach imitation, that including contingent imitation improved not only spontaneous imitation, but also joint attention, language, and pretend play, as well as social communication as rated by blind observers. Nadel et al. (2000) used a still face paradigm, in which young children with ASD played in a room with a stranger who first presented a still face, next imitated the child, and lastly, presented with another still face phase. Nadel and colleagues found that the children ignored the stranger in the first phase, but all attempted to interact with the stranger in the third phase. These findings suggest that the mirroring of the child's own behavior might be an effective way to increase social interaction. Heimann, Laberg, and Nordoen (2006) confirmed this conclusion. They adapted this paradigm to demonstrate that increased social interaction after an experimenter's imitation in the still face experiment generalized to an increase in child imitation scores from a pre- to post-imitation test. These results were only found in the group exposed to the still face/child imitation/still face paradigm and not found for the group exposed to a still face/contingent play/still face paradigm.

Because improving imitation may be a key to improving many other social and communicative deficits characteristic of ASD, it is important to determine an effective way of increasing imitation performance in children with ASD. One possible intervention technique that has been the focus of recent research is video modeling. There are several reasons why videos may be an effective way to teach children with ASD. Children with ASD have demonstrated hyper-systemizing behavior and prefer predictable outcomes (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003). Videos may appeal to this affinity for systemization and increase a child's attention, as videos tend to be more predictable and fixed, and do not change across repeated presentations (Kylliäinen, Jones, Gomot, Warreyn, & Falck-Ytter, 2014).

Although TD children are prolific imitators, there is a *transfer deficit* in learning from television and tablets. It is easier for young children to learn from real-life interactions with people and objects, compared with information delivered via a screen (Barr, 2013). A puzzle imitation task (Barr et al., 2016; Dickerson, Gerhardstein, Zack, & Barr, 2013; Moser, Olsen, Rusnak, Barr, & Gerhardstein, 2019; Moser et al., 2015; Zimmermann et al., 2015; Zimmermann, Moser, Lee, Gerhardstein, & Barr, 2017; for review see Hipp et al., 2017) was developed to examine factors affecting transfer of learning from screen media. The task involved construction of a three-piece magnetic or virtual puzzle that formed either a "fish" or a "boat." The study design allowed manipulations involving transfer between two-dimensional (2D) and 3D contexts, as well as alterations of perceptual, contextual, and social cues. Children exhibit a transfer deficit. That is, they imitate fewer actions in transfer conditions (e.g., demonstration on a touch screen [TS] and test on the magnetic board [MB]) than in no transfer conditions (e.g., both demonstration and test on the TS). Across a series of studies, this puzzle task has been used to test transfer in 2- to 3-year-olds via video, on a TS, and live using a 3D MB. The findings from this set of studies demonstrate that for TD children the transfer deficit persists at least through 3.5 years of age (Dickerson et al., 2013), and that the transfer deficit decreases with enhanced social scaffolding and increases when social scaffolding is minimized (Zimmermann et al., 2017). Other tasks have demonstrated that the extent of the transfer deficit, however, depends upon task complexity. For example, Reiß, Krüger, and Krist (2019) showed that 4- to 5-year-olds exhibit the transfer deficit on a theory of mind task, but children of the same age show no transfer deficit on the Tower of Hanoi task (Tarasuik, Demaria, & Kaufman, 2017).

Explanations for this transfer deficit have focused on immature memory flexibility in young children (i.e., the inability to retrieve information after a change in cues; Barr, 2013; Moser et al., 2015; Zack, Barr, Gerhardstein, Dickerson, & Meltzoff, 2009), poor symbolic understanding of the connection between 2D and 3D sources (Troseth, 2010), the difference between 2D and 3D presentations (Callaghan, 1999; Callaghan, & Rankin, 2002; Claxton, 2011; Johnson, Younger, & Cuellar, 2005; Leighty, Menzel, & Fragaszy, 2008; for a different perspective see Tarasuik et al., 2017) and a lack of social contingency in 2D sources (eye contact, contingent behavior: Ganea, Ma, & DeLoache, 2011; Hopper, 2010; Troseth, Saylor, & Archer, 2006). These explanations are unlikely to be mutually exclusive and include a combination of both cognitive information processing factors and social factors where children are sensitive to social communication rules that are violated by screens. For children with ASD who may have some cognitive processing difficulties, media may increase cognitive load. On the other hand, the violation of social conventions and increase in predictability of videos may reduce processing load for children with ASD.

There is some evidence suggesting that children with ASD will not show a video deficit at all. Golan et al. (2009) used videos to teach children with ASD to identify emotions. Over the course of many sessions of this video intervention, children with ASD improved significantly in their emotional vocabulary and ability to match appropriate emotional expressions to situations. At the end of the intervention, emotion identification by the ASD intervention group was not significantly different from the TD group. In a similar study conducted by Moore and Calvert (2000), a computer program was used to enhance the vocabulary acquisition of young children with ASD. Children in the computer intervention group were more attentive, remembered more nouns, and were more interested in continuing the intervention after completion than children in the teacher presentation intervention group (Moore & Calvert, 2000).

Video modeling has also been used to enhance a wide array of important social behaviors in young children with ASD, such as social initiation skills (Nikopoulos & Keenan, 2003), use of social communication skills (Wilson, 2013), and compliment-giving behaviors (Apple, Billingsley, & Schwartz, 2005). A small case study design by Charlop-Christy, Le, and Freeman (2000) demonstrated that video modeling may actually be more effective than live modeling. Five children with ASD were presented with two important tasks such as expressive labeling of emotions, spontaneous greetings, cooperative play, one in a video model, and one in a live model that performed the given task. After the demonstrations, the children were tested for speed of acquisition and generalization across settings, people, and given stimuli, all of which improved more in the video condition than the live condition (Charlop-Christy et al., 2000). One explanation for enhanced learning from videos is that videos take away most of the social stimuli that children with ASD have difficulty processing. A second possible explanation is that children with ASD, who are characteristically preoccupied with movie lines, display better attention to a video. Perhaps because it is more difficult to process, Cardon and Azuma (2012) found that both TD children and children with ASD attend longer to stimuli presented via video when compared with a live demonstration. Despite this finding, research shows that while attending to videos is important for learning through video modeling, it is not enough (MacDonald, Dickson, Martineau, & Ahearn, 2015).

The promise of these video interventions is clear; they appear motivating and attractive to the children as well as easy to use for a caregiver. However, the evidence that the video is as effective as, or possibly more effective than, instruction provided by a person, is incomplete. Intervention studies include multiple elements and video modeling is only one component. McDowell, Gutierrez, and Bennett (2015) directly compared video to live demonstration techniques and found an advantage of video modeling, but the findings must be treated with caution as there were only four participants.

TSs have become universally available (Rideout, 2017). TSs enhance learning in preschoolers (Wood et al., 1981) and in children with intellectual and physical disabilities (Howe, 1984). Learning from TSs has been exhibited by 11-month-olds (Ayoun, 1998), 15-month-olds (Zack et al., 2009) infants. Touchs creens have been used to investigate visual search in 1- to 3-year-olds (Gerhardstein & Rovee-Collier, 2002), spatial search in 2- to 4-year-olds (Sutton, 2006), and imitation in rhesus monkeys (Subiaul, Cantlon, Holloway, & Terrace, 2004) and imitation in preschool (Moser et al., 2015; Subiaul et al., 2004) and children with ASD (Subiaul, Lurie, Klein, Holmes, & Terrace, 2007). The experimenter demonstrated how to touch a series of pictures in the correct order. The child then had the opportunity to imitate the sequence. Completing the sequence in the correct order results in a 5-second rewarding video. There was no difference between TD and ASD children on the ability to imitate the sequences. All children learned the sequences significantly faster via imitation than by trial and error (Subiaul et al., 2007). These findings suggest that TSs may be another useful way to enhance imitation learning by children with ASD. The wide applicability of this technology (infants to adults, clinical and nonclinical, human and animal populations) gives the approach broad interest and appeal. For children with ASD in particular, TSs represent a middle ground in which objects move more predictably and there are more constraints than with real objects. Furthermore, interactions can be completed via TS-initiated behavior, potentially reducing motor demands.

THE PRESENT STUDY

The innovation of the present study is that it provides a direct comparison of imitation from video and live demonstrations and tests on real objects and TSs. Many opportunities for learning are lost for children with ASD because they do not imitate readily and thus must rely on training techniques that involve considerably more time and effort. A clearer picture of how children with ASD imitate may lead to impactful and cost-effective intervention approaches as well as the development of more reliable assessment measures. Assessment measures of social learning can be challenging to administer, potentially leading to underestimation of skills. Prior research has a number of limitations, including lack of direct comparisons between live and video conditions and small sample sizes that make interpretation regarding the effectiveness of video models difficult.

The current study is also an examination of a possible explanation for imitation deficits in ASD. The idea that TD children and children with ASD approach imitation differently is not new, but the novelty lies in looking at the specific strengths and weakness of the two populations together which could allow an explanation that accounts for both populations. If imitation from video is easier for children with ASD, numerous possible interventions could be developed to use video to encourage these children to imitate some of the same skills that their TD peers learn more easily. It is also possible that a close look at how children imitate will show differences in how children with ASD approach an imitation task. We had two primary research questions:

First, do TD and ASD children show differential learning from video as compared to live demonstrations? And second: Is there a difference in performance as a function of device used by the TD and ASD groups? We hypothesized that children with ASD would imitate less overall, but video demonstration will enhance learning. We also hypothesized that imitation performance would be inversely correlated with severity of ASD.

METHOD

Participants

A total of 68 TD participants (36 boys) between 33 and 54 months (*M* = 43 months, 9 days, standard deviation [*SD*] = 3 months 25 days) were recruited from two sites. Children were recruited and tested in local preschools (*n* = 42), a university laboratory (*n* = 1), or in the home (*n* = 25); these latter children were drawn from data from prior studies (Dickerson et al., 2013; Moser et al., 2019). An additional 12 participants were excluded from the sample due to experimenter error (*n* = 5) and refusal to complete the task (*n* = 5) or parental interference (*n* = 2). Participants were predominantly from highly educated, middle to high income households and the sample was nationally representative for race and ethnicity with ~70% White and the remaining identified as other.

A total of 24 children with ASD between 37 and 54 months (*M* = 44 months, 8 days, *SD* = 6 months 8 days) were recruited; 7 of whom were excluded from the sample (1 for not diagnosed with ASD and 6 for refusal to play), yielding a sample of 17 (12 boys). To confirm autism diagnosis, an Autism Diagnostic Observation Schedule (ADOS) exam was clinically administered. See ”Stimuli” section for description and interpretation of this clinical tool (for a breakdown of ADOS scores, see Table 1).

Apparatus

The puzzle apparatus was a black plastic case (35 cm tall x 42 cm wide x 23 cm deep) with a removable yellow magnetic metal board (Figure 1) that could be slid in and out of the case. Behind the metal board was a TS monitor (Figure 1) with a resolution of 1024 x 768 (17” diagonal extent; Keytec Inc.), such that the apparatus could display a video or the TS puzzle. The

TABLE 1. Breakdown of ADOS Scores and Number of Months of Intervention for ASD Participants

Symptom Level	*N*	Mean ADOS Comparison Score	Mean Mos. Early Intervention
Low	4	3.3	7.75
Moderate	8	5.9	11.3 (*n* = 6)
High	5	9.4	15.75

Note. ADOS = Autism Diagnostic Observation Schedule; ASD = autism spectrum disorder.

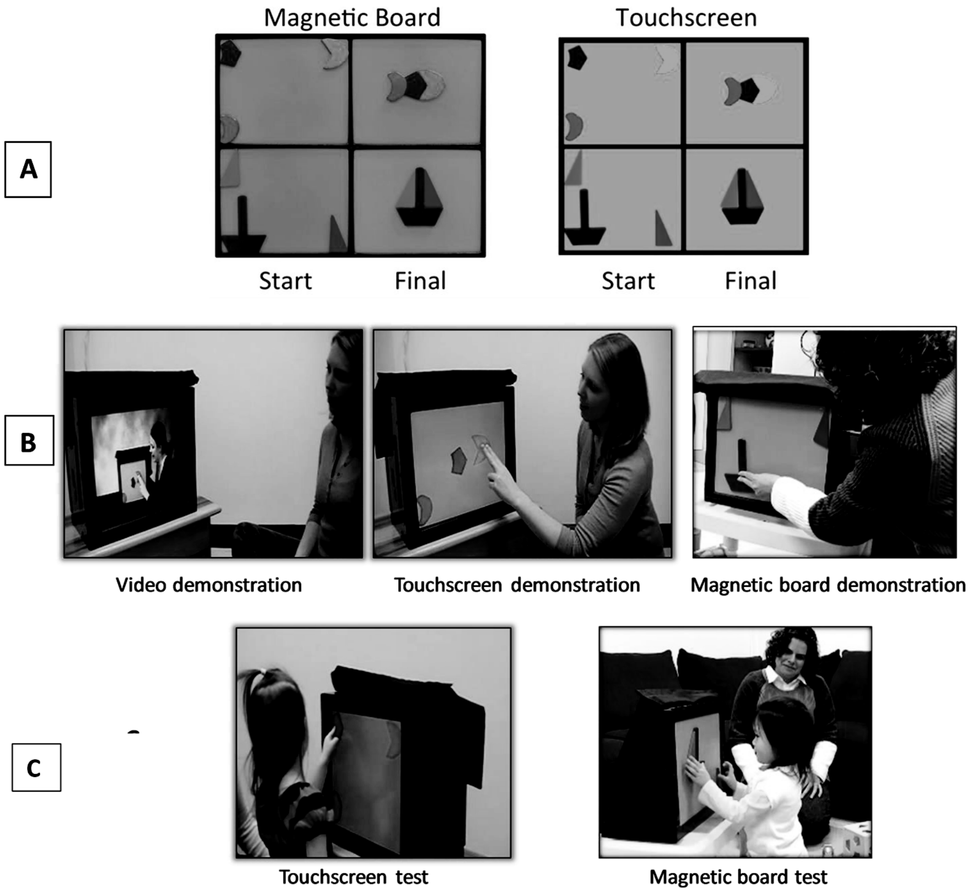

FIGURE 1. (A) Stimuli. Left: Magnetic board (MB) puzzle (three dimension [3D]) start and end configurations for boat and fish. Right: Touch screen (TS) puzzle (2D) start and end configurations for boat and fish. (B) Demonstration conditions. Left: Target actions demonstrated in a video (V). Middle: Experimenter demonstrates target actions on a TS. Right: Experimenter demonstrates target actions on a MB. (C) Test conditions: Left: TS test; Right: MB test. Parts of figure reprinted with permission Springer.

enclosure resembled a standard television set from the front (see Figure 1). There was a slit in the top of the apparatus where the metal MB (painted orange) could be inserted or removed. The touch-sensitive display was used to play the demonstration video clip in the video (V) groups, demonstrate the actions on the TS and test on the TS. The MB was used to demonstrate the actions on and to test in the 3D conditions.

Stimuli

3D. Both a “fish” and a “boat” puzzles were used; each was composed of three plastic magnet pieces (0.5 cm thick). The pieces were held to the board magnetically, but could be easily slid across the board. The pieces were arranged at three of the four corners before the start of the task and assembled together in the middle of the board at the end of the task (Figure 1). The child can pick up and move these 3D objects.

2D. The "fish" and "boat" puzzles appeared on a 2D screen as high-resolution photos of the original magnetic puzzle pieces. Starting and ending positions were the same as those used in the 3D task (Figure 1). On the TS the child can only move the 2D objects within the screen.

Autism Diagnostic Observation Schedule. ADOS scores were collected for the 17 participants with ASD (see Table 1). ADOS primarily assesses communication, social interaction, and repetitive behaviors. There were four different modules and the correct module for scoring was chosen based on age and language level. All children were scored using either Module 1, which is directed at individuals who do not regularly exhibit spontaneous 3+ word combinations (phrase speech), or Module 2, directed at individuals who do exhibit phrase speech but are not entirely verbally fluent, which is defined as the language development of a typical 4-year-old. Both modules are intended for young children. Modules 3 and 4 are designed for older age groups and were therefore not included. Children were given both an ADOS-2 score, which is typically used in reference to cutoff scores to identify whether or not a child has ASD, and an ADOS-2 Comparison Score, which measures severity of ASD-related symptoms (Lord et al., 2012). From this information, it was found that four ASD participants had a low symptom level, eight participants had a moderate symptom level, and five had a high symptom level (Table 1).

Procedure

All participants were tested during individual sessions. Children were seated on a small child's stool, facing the apparatus (see Figure 1). The researcher knelt on the ground next to the apparatus so that they were between the child and the apparatus. This seating arrangement allowed for the researcher to perform the demonstration tasks for the participants. The parents were present in the room during the trials, as was the consulting clinician (for children with ASD) and research assistants. All children were presented with one condition of the puzzle task. The demonstration and the test phases were conducted. Then, children with ASD completed the ADOS with a consulting clinician. TD children completed a distractor task that consisted of a matching game, which was selected to be effortful, and an object search task. Following the ADOS or the distractor task, a small subset of children (n = 26) completed a second imitation trial with a different puzzle task and in a different condition. Due to the small subset, it was not possible to statistically analyze this data and the second trial will not be considered again. Children were randomly assigned to a Video or live (MB or TS) demonstration and TS or MB test (see Table 2).

Imitation Trials. There were two phases to each imitation trial, the demonstration phase and the test phase.

Demonstration Phase. The experimenter sat next to the apparatus, facing the child, and lifted the black curtain to reveal the display (3D MB puzzle, 2D TS puzzle, or video). In all conditions, the experimenter slid the puzzle pieces one by one using the middle and index fingers (correct

TABLE 2. Participants per Testing Condition

	TS-TS	Video	MB-MB
TD	5	33	30
ASD	6	7	4

Note. ASD = autism spectrum disorder; MB = magnet board; TD = typically developing; TS = touch screen.

slides) to create a fish or a boat by connecting the pieces in the center of the board (correct connections). Correct slides were accompanied by nonspecific comments ("Look at this!," "What was that?," or "Isn't that fun?") to maintain the child's attention. After the completion of the puzzle, the experimenter covered the display with the black curtain and moved the pieces back to their starting positions. This sequence was repeated three times over the course of approximately 60 seconds (M = 58.7 seconds, SD = 12.4 seconds). In the video demo condition, the experimenter pressed play on the TS and the same demo sequence was displayed in a prerecorded 60-second video of a different experimenter. After the video was finished, the experimenter inserted the MB into the plastic case, placed the black cloth to cover the board, and attached the pieces to the board in their start configuration if the child was tested with the MB. For the TS test the experimenter placed the black cloth over the screen and activated the TS.

*Test Phase.*Children participated in either a 3D or 2D test, but the protocol remained the same: The experimenter lifted the black cloth away from the front of the board and told the child, "Now it's your turn!" The test began the first time the child touched one of the puzzle pieces and lasted for 60 seconds thereafter. If the child did not approach the apparatus to interact with the pieces, he/she was encouraged by the experimenter ("It's your turn to play").

ADOS Administration. A consulting clinician conducted the ADOS assessment for the children with ASD. The ADOS assessment, as well as the experiment, was conducted in a location that was determined to be most convenient for the participants and their families. The child with ASD completed the first task of the assessment. Then the ADOS assessment was completed. The consulting clinician was present during the study to provide a familiar face for each child with ASD and to redirect the child's attention to the task if the experimenter needed help in doing so. Upon completion of the study, the researcher consulted with the parents. The researcher answered the parent's questions and provided them with necessary information. In addition, when an ADOS was completed, the researcher explained the process to the parents and informed them of written report expectations and timelines.

RESULTS

Scoring

Coding guidelines were adapted from Moser et al. (2015). Each session was video-recorded for later coding in Datavyu (Datavyu Team, 2014), a software program designed for flexible behavioral coding. All behaviors were time-stamped and coded for gestures and goals.

On-Task Behaviors

Each contact with a puzzle piece (beginning when a piece was touched and ending when the touch ended) was coded along two dimensions: gesture and goal. The combined behavior was considered an on-task behavior. On-task behaviors excluded exploratory play (interactions where the piece was removed from the board for more than 3 seconds) and micro-gestures (interactions where a piece was "nudged," meaning that it was moved less than one-sixth of the board) not resulting in any connection.

Gesture Coding

Coded actions included *correct slide*, *incorrect slide*, *strategy switch*, *pick up and move* (3D only), and *swiping* (2D only; Table 3). All gestures were scored based on the movement of the puzzle

TABLE 3. Definitions for Coding Goals During Test Session on the Touch Screen and Magnet Board

Gesture Code	Definition
Correct slide	Child maintained contact with the face of the puzzle piece using at least one finger for the duration of the slide and an orientation similar to that at the start of the action (a maximum rotation of 45° was allowed)
Incorrect slide	Child made contact with the sides of the piece using any of the fingers or rotated the piece more than 45° (3D pieces were often grasped and slid). The touch screen equivalent would be dragging or pushing the piece
Pick up and move (3D only)	Child lifted a piece off the board for 3 second or less and moved it to a new location more than one sixth of the board away from the onset location
Swipe (2D only)	Child began gesture either before the onset of the piece and swiped across the face of the piece and/or action was evident in the offset by the finger rapidly swinging up and beyond the piece
Strategy switch	Child began correctly sliding the piece and then switched to an incorrect slide or the reverse
Gesture imitation	Number of correct slides / three (maximum possible correct slides)
Action fidelity	Number of correct slides / number of on-task behaviors

Note. 2D = two-dimensional.

pieces and the relation to the point of finger/hand contact. Importantly, children could use any variation of hand shapes when interacting. Despite the differences in the physical properties between 3D and 2D pieces, definitions of nondemonstrated actions were equated across dimension types.

Goal Coding

Coded actions that connected puzzle pieces included the following categories of goals: *correct connection*, *target error connection*, and *connect other* (Table 4).

Reliability

Based on 27.3% of all test sessions that were rescored by a second coder, inter-rater reliability was above the acceptable level of .70 (kappas on each of the subscales: $k_{gesture}$ = .737,

TABLE 4. Definitions for Coding Goals During Test Session on the Touch Screen and Magnet Board

Goal Code	Definition
Correct connection	Puzzle piece is connected to the central piece in the correct location and orientation within approximately 2 mm of touching
Target error connection	Pieces (a) connected in the correct location, but incorrect orientation (e.g., one piece turned sideways), (b) connected not within the 2 mm threshold, or (c) disconnected before the end of the behavior
Connect other	Connections made to nontarget pieces (e.g., connecting the two sails together in the boat puzzle)
No connection	An on-task behavior that did not result in any type of connection
Goal imitation	Number of correct connections / two(maximum possible correct connections)
Goal efficiency	Number of correct connections / number of on-task behaviors

$k_{goal} = .811$) and a third coder was also reliable (kappas on each of the subscales: $k_{gesture} = .714$, $k_{goal} = .814$).

Goal Imitation Score

Following Dickerson et al. (2013), children received one point for each correct connection (max = two correct connections). The goal imitation score was then converted to a proportion (out of two). The goal imitation score is distinct from the gesture imitation score in that if a child used an incorrect gesture to correctly connect two puzzle pieces, the child still received one point for the goal.

Goal Efficiency Score

This measure expresses correct connections as a proportion of all on-task behaviors prior to first puzzle completion. This classifies participants on a continuum, with higher proportions indicating highly efficient puzzle reproduction and lower proportions indicating failure to reproduce the puzzle at all. For example, for the boat puzzle, a child might simply move the two sails to most efficiently complete the puzzle, another child might imitate by first moving the mast and then the sails, and still another child might produce 20 on-task behaviors in the course of making the puzzle, a highly inefficient approach.

Gesture Imitation Score

Following Dickerson et al. (2013), children received credit for each target puzzle piece that they correctly slid, up to a maximum of three, during the 60-second test period. The resulting gesture imitation score was then converted to a proportion to allow for cross-measure comparison. No additional points were given for multiple correct slides with the same puzzle piece.

Data Analysis Plan

We compared performance of all TD and ASD children who completed one puzzle and conducted a between subjects design (n = 85, TD = 68, ASD = 17). We had two primary research questions. Due to power limitations, we analyzed each question in separate analyses. We examined whether there was a transfer deficit comparing performance when learning involved transfer for a video presentation to either a 2D or 3D test situation. We also examined whether the device influenced task performance comparing performance when children were tested on a TS or the real magnet puzzle pieces. With these constraints in mind, we conducted a series of 2 (demonstration, video vs. live experimenter) × 2 (condition, TD vs. ASD) analysis of variance (ANOVA) tests on our imitation measures and 2 (test device; TS, vs. puzzle) × 2 (condition; TD vs. ASD). Because we were interested in whether the transfer deficit was present or not in children with TD and ASD, we tested both traditional models as well as doing follow-up Bayesian statistics when group differences were not observed. Baseline estimates for this task are uniformly low (near zero; see Dickerson et al., 2013; Moser et al., 2015).

Preliminary Data Analysis

There was, not surprisingly, an overrepresentation of males in the ASD group (71% male) and a more balanced sample in the TD group (53% male). In preliminary models we entered gender; while there were no main effects of gender, cell sizes were too small and unequal to be able to interpret any interactions. Preliminary models also tested for age-related differences in imitation scores. We will only consider age-related effects where significant.

Research Question 1. Do TD and ASD children show differential learning from video as compared to live demonstrations?

Goal Scores

As shown in Figure 2, a 2 [demonstration; video (transfer), live experimenter (no transfer)] × 2 (condition: TD, ASD) ANOVA on goal scores yielded no significant differences (F (1,81) < 1 for all main and interaction effects).

Goal Efficiency Scores

As shown in Figure 2, a 2 [demonstration; video (transfer), live experimenter (no transfer)] × 2 (condition: TD, ASD) ANOVA on goal efficiency yielded a main effect of condition, $F(1,81) = 5.47$, $p = .02$, $\eta_p^2 = 0.06$, no main effect of demonstration $F(1,81) < 1$, $p = .37$, $\eta_p^2 = 0.01$, and no interaction effect, $F(1,81) < 1$, $p = .40$, $\eta_p^2 = 0.01$.

Gesture Scores

As shown in Figure 2, a 2 [demonstration; video (transfer), live experimenter (no transfer)] × 2 (condition: TD, ASD) ANOVA on gesture scores yielded no significant differences. There was no main effect of demonstration $F(1,81) < 1$, $p = .83$, $\eta_p^2 = 0.01$, no main effect of condition, $F(1,81) = 2.33$, $p = .13$, $\eta_p^2 = 0.028$ and no interaction effect, $F(1,81) < 1$, $p = .73$, $\eta_p^2 = 0.01$.

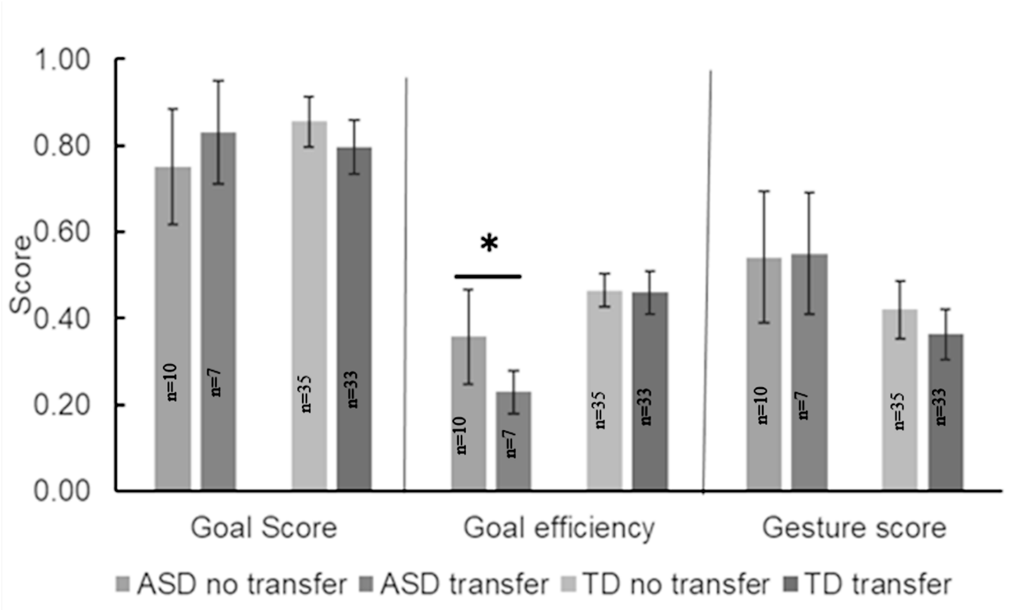

FIGURE 2. Goal, goal efficiency, and gesture score by typically developing (TD) and autism spectrum disorder (ASD) groups as a function of demonstration condition.
*$p < .05$.

Follow-Up Bayesian Analyses

Next, we conducted confirmatory analyses to examine whether or not there were differences between the live and video groups and TD children and children with ASD. A Bayes factor less than 1 is consistent with a significant *p* value <.05 but the larger the Bayes factor, the more consistent it is with the probability that a null finding is correct (Jarosz, & Wiley, 2014). Bayesian statistics provide a meaningful assessment of the probability of a null effect. Using the Rouder method, a follow-up Bayesian *t* test on goal scores comparing live versus video demonstration showed positive evidence for the null hypothesis, $t(83) < 1$, $p = .71$, Bayes factor = 5.63. Comparing ASD and TD groups there was also positive evidence for the null, $t(83) < 1$, $p = .76$, Bayes factor = 4.72. We interpret these findings to indicate that there is no difference between TD and ASD groups on the ability to complete the puzzle either after a video or a live demonstration. Furthermore, these findings provide no evidence of a transfer deficit. A follow-up Bayesian *t* test comparing TD versus ASD on goal efficiency showed positive evidence for the alternate hypothesis, $t(83) = -2.41$, $p = .02$, Bayes factor = .39. We interpret these findings to indicate that although both groups can imitate the puzzle task, children with ASD are less efficient at reaching the goal than TD children. A follow-up Bayesian *t* test comparing TD versus ASD showed weak evidence for the null hypothesis on gesture score, $t(83) =1.63$, $p = .12$, Bayes factor = 1.58, and positive evidence for the null when comparing gesture performance from video or live demonstrations, $t(83) < 1$, $p = .60$, Bayes Factor = 5.27. We interpret these findings to indicate that children with ASD were imitating gestures slightly more faithfully than TD children, but that there was no transfer deficit on gesture score.

Research Question 2. Is there a difference in performance as a function of device used by TD and ASD groups?

Goal Scores

As shown in Figure 3, we conducted a 2 (test: TS or MB) × 2 (condition: TD, ASD) ANOVA on goal scores. There were no main effect of test device $F(1,81) < 1$, $p = .34$, $\eta_p^2 = 0.01$, no main effect of condition, $F(1,81) < 1$, $p = .76$, $\eta_p^2 = 0.001$ and no interaction effect, $F(1,81) = 2.07$, $p = .15$, $\eta_p^2 = 0.025$. The trend for an interaction provides weak evidence to suggest that children with ASD are doing better on a 2D screen test than 3D objects, while TD children show no difference.

Goal Efficiency Scores

As shown in Figure 3, a 2 (test: TS or MB) × 2 (condition: TD, ASD) ANOVA on goal efficiency there were no main effects on condition, $F(1,81) = 2.40$, $p = .13$, $\eta_p^2 = 0.03$, no main effect of device $F(1,81) < 1$, $p = .55$, $\eta_p^2 = 0.004$, and no interaction effect, $F(1,81) = 1.41$, $p = .24$, $\eta_p^2 = 0.02$.

Gesture Scores

As shown in Figure 3, a 2 (test: TS or MB) × 2 (condition: TD, ASD) ANOVA on gesture scores was conducted. There was a main effect of device, $F(1,81) = 16.41$, $p < .001$, $\eta_p^2 = 0.17$, no main effect of condition, $F(1,81) < 1$, $p = .81$, $\eta_p^2 = 0.001$, and no interaction effect, $F(1,81) < 1$, $p = .80$, $\eta_p^2 = 0.01$. Overall, children performed the gestures better on the TS than on the MB puzzle. It is possible that the reduction of affordances on the TS may have supported learning by children.

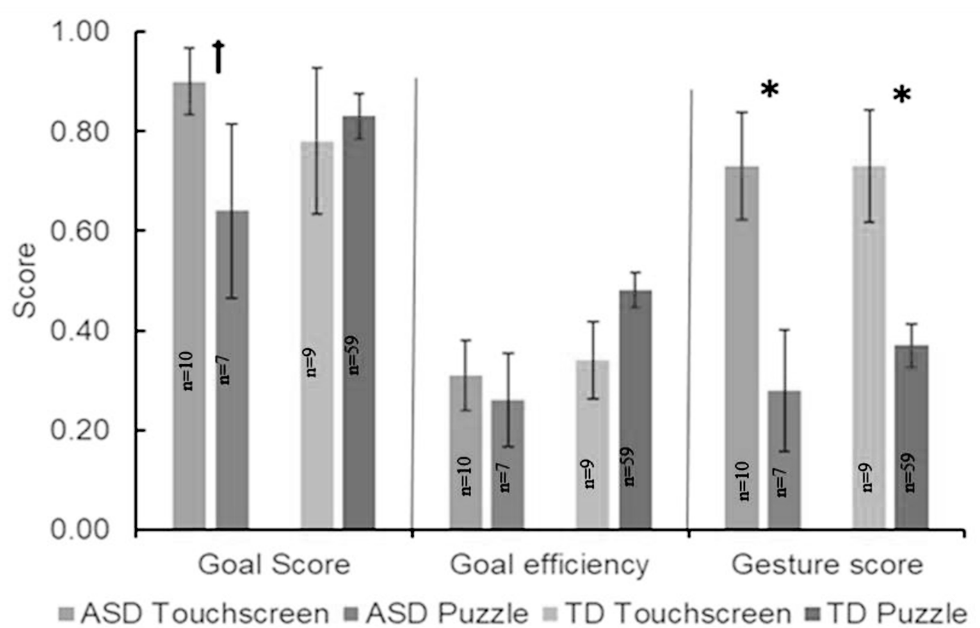

FIGURE 3. Goal, goal efficiency, and gesture score by typically developing (TD) and autism spectrum disorder (ASD) groups as a function of device (touch screen or puzzle).
*$p < .05$. *$p < .10$.

Follow-Up Bayesian Analyses

A follow-up Bayesian t test on goal scores comparing the TS and the MB puzzle showed positive evidence for the null hypothesis, $t(83) < 1$, $p = .73$, Bayes factor = 4.84. We interpret these findings to indicate that there is no difference between reaching the puzzle goal on either the T Sor the MB puzzle. However, the way in which the actions were performed and the efficiency with which the goal was reached did differ as a function of device. A follow-up Bayesian t test comparing the TS to the MB puzzle on goal efficiency showed weak evidence for the alternate hypothesis, $t(83) = 1.94$, $p = .056$, Bayes factor = .95. We interpret these findings to indicate although both groups can imitate the puzzle task, they are less efficient on the MB puzzle. A follow-up Bayesian t test comparing TS versus MB puzzle showed positive evidence for the alternate hypothesis on gesture score, $t(83) = 4.50$, $p < .001$, Bayes factor = .001. We interpret these findings to indicate that all children imitated the gestures better on the TS than the MB puzzle.

Correlation Analysis

To assess whether there were any relationships between the imitation scores, we ran a first order Pearson product moment correlations between goal score, goal efficiency, and gesture score separately for TD children and children with ASD (Tables 5 and 6). For the children with ASD, we also correlated measures with ADOS scaled scores ($M = 6.29$, $SD = 2.47$).

There was no relationship between the ADOS and imitation performance (Table 6). The lack of correlation between the ADOS severity and imitation scores cannot be attributed to a lack of range in ADOS scores. These findings suggest that performance on this task represents a strength for many children in the ASD group. For the ASD group, there is a correlation between gesture score and goal score and between goal score and goal efficiency. In contrast, the goal score and gesture score are not correlated in TD children (Table 5), whose results look more like a

TABLE 5. Correlations Between Goal, Goal Efficiency, and Gesture Scores in the TD Group ($n = 68$)

	Gesture Score	Goal Score
Goal score	.06	_
Goal efficiency	−.18	.78**

Note. TD = typically developing.
*$p \le .05$. **$p \le .01$.

TABLE 6. Correlations Between Goal, Goal Efficiency, and Gesture Scores and ADOS in the ASD Group ($n = 17$)

	Gesture Score	Goal Score	Goal Efficiency
Goal score	.61**	_	_
Goal efficiency	.38	.63**	_
ADOS score	−.09	.07	−.09

Note. ADOS = Autism Diagnostic Observation Schedule; ASD = autism spectrum disorder.
*$p \le .05$. **$p \le .01$.

pattern of emulation (Hopper, 2010; Subiaul, Vonk, & Rutherford, 2011). The higher correlation between gesture score and goal score for the children with ASD suggests that they are imitating more faithfully than the TD children.

DISCUSSION

The present study demonstrated there was no transfer deficit on the three-step puzzle imitation task and that this did not differ by group status. Both TD and ASD groups imitated the goal successfully, constructing the boat and fish puzzles. Children with ASD, however, were less efficient at reaching the goal. The lack of a transfer deficit and the lack of an imitation deficit in children with ASD are both striking findings. On a task where performance can be equated, there were no group differences. These findings cannot, however, be explained by a general ceiling effect. The children with ASD performed marginally better on the TS, indicating that the use of TS stimuli support imitation in children with ASD. All children were better able to copy gestures when completing the puzzle on the TS than when completing the MB puzzle. Our findings were not in line with our hypotheses. A video model did not enhance learning; further, TD and ASD groups did not differ on overall performance. Potential explanations for the findings, future directions, and implications for educational practice are discussed below.

Previous research clearly indicated that children with ASD usually do not imitate as robustly as TD children (Charman et al., 1997; Ingersoll, 2008; Stone et al., 1990; Stone et al., 1997; for a review, see Edwards, 2014, but see also Subiaul et al., 2007). The children with ASD in the current study were less efficient, but they were successful in imitating the goal to the same level as the TD children. Note that the task, putting together a puzzle, was selected to appeal to the children with ASD and may have done so more successfully than anticipated. By this explanation children with ASD in this study were more successful than they would have been on another task. Another task-related issue could be that the task was simple and the simplicity of the task allowed children who have difficulty imitating to succeed. The finding that the children with ASD completed the task less efficiently speaks to this possibility. That lower level of efficiency could result in failure to imitate in a more complex task. However, it is also possible that children with ASD were imitating more faithfully/directly. Imitation occurs when an observer learns and reproduces the methods or steps used by a demonstrator to complete a sequence of actions and produce a certain result (Tomasello, Kruger, & Ratner, 1993). Emulation occurs when an observer learns and reproduces the result or goal of the demonstrator's actions, rather than the specific sequence of actions the model performed to produce the result (Tomasello et al., 1993). While imitation emphasizes the means as well as the end, emulation emphasizes the end, but allows for flexibility in the means used to achieve the final goal, allowing for greater efficiency. McGuigan, Whiten, Flynn, and Horner (2007) tested children between ages 3 and 5 using a live or video demonstration. They found that in the live demonstration, children continued to overimitate, copying irrelevant tasks to reach a goal, despite having adequate causal knowledge of a more efficient means, regardless of age. Interestingly, when children received a video demonstration, 5-year-olds overimitated, a less efficient approach, but 3-year-olds were more likely to adopt an emulative approach. McGuigan et al. (2007) suggest that younger children may have had more difficulty inferring the intentionality of the demonstrator in the video, and thus focused more on the task outcome as opposed to the specific actions of the experimenter. In the present study, it appears there is a tradeoff between imitation fidelity and goal efficiency, which differed between TD and ASD children. It is possible that prior mixed findings of imitation deficits in children with ASD may be due to the specific aspects of imitation measured. The difference between children with ASD and TD in the deployment of approaches to goal-directed learning on tasks acrossing tasks of varying complexity requires further empirical attention.

During this task, the experimenter and child did not face each other, rather they faced the board or TS. This reduced the need for direct eye contact in the context of a social demonstration. This arrangement is typical in computer, tablet, and video technology set-ups and may provide a more supportive context for learning for children with ASD. The possibility that screen media provides a more supportive context for children with ASD requires empirical attention. If learning is enhanced, educators and practitioners would need to also consider other opportunities for face-to-face engagement to ensure that technology does not replace face-to-face interaction. This is not to say that a nonsocial situation would be expected to produce better outcomes in ASD children. The point is that a reduction in the complexity of the social situation (removing face-to-face interactions) may result in a benefit to the ASD child learner, reducing the need for divided attention as well as the potential stress of a typical social interaction and reducing sensory-integration demands.

The findings of imitation on TSs are also significant. Subiaul et al. (2007) showed impressive rates of imitation on a three-item sequence that was demonstrated on a TS. Similarly, performance by children who saw the puzzle demonstrated on the TS and were then tested on the TS performed almost at ceiling on reaching the goal. Goal performance was higher than with younger children who had previously been tested on this task (Moser et al., 2015). The lack of transfer deficit and reduced motoric demands, hint that the TS may support successful imitation for all the children even though our findings only indicate that advantage for the children with ASD. There are a number of additional reasons why TS may have supported the complex task of learning a puzzle via imitation. The TS reduces not only motor demands, but also affordances. The virtual puzzle piece moves predictably and does not slip or rotate, meaning that children do not have to make as many online adjustments or changes. This may reduce memory flexibility and planning demands that may also be impaired in children with ASD. Finally, once the child adjusts to the surface of the tablet, sensory-integration demands are also reduced. Answering these empirical questions will have important educational implications for children with ASD as well as TD children.

TS tablets are widely available (Rideout, 2017) and app developers have the opportunity to develop educational enriching apps for children with ASD. Hirsh-Pasek et al. (2016) summarized decades of work from the Science of Learning using four guidelines describing how children learn best, which they called "The Four Pillars of Learning." These four pillars can be used by parents, teachers, and other adults to help identify high quality children's media. They can be easily remembered by the acronym "E-AIMS": Engaging, Actively Involved, Meaningful, and Social. Specifically, the approach is supported by earlier research with an interactive multimedia platform designed to increase language and literacy in children with intellectual disability and ASD (Tjus, Heimann, & Nelson, 2004). The program was most effective when it was delivered in a social context by teachers who engaged the students around the platform (Tjus, Heimann, & Nelson, 2001). Language improved, and in the children with ASD, willingness to seek help and engagement increased as well. Future research should focus on features of the design and interaction that will support learning and transfer of skills like imitation as well as more specific skills. Researchers should examine whether tablets are effective for children with higher sensory integration difficulty or those with poorer cognitive flexibility or executive functioning performance. Then it may be possible for practitioners to develop more tailored transfer tasks to extend learning beyond the app, depending on individual constraints on learning. This finding supports the use of TSs as a tool for teaching skills to all children. Further research into this in both populations would help clarify the pattern seen in these data.

The hypothesis that the patterns would be different stemmed from the research indicating the value of TSs and other technologies for children with ASD (Charlop-Christy et al., 2000; Golan et al., 2009). Although we did not find an advantage for the children with ASD in the video conditions, we did not find a disadvantage either. The lack of a transfer deficit suggests a notable development achievement in preschoolers with ASD. Additional research is needed to examine differences in how TD and ASD children are solving the video transfer problem. Well-designed cognitive neuroscientific experiments could evaluate whether TD and ASD children's brains process media content differently from one another and determine the neural resources needed to transfer learning in both groups.

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