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Virtual reality's effect on children's inhibitory control, social compliance, and sharing

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ABSTRACT

We compared the effects of different immersive technologies on four- to six-year-olds' inhibitory control skills, social compliance (i.e., walking upon request), and sharing (i.e., physical stickers) with a children's media character (Grover from Sesame Street©). Children ($N = 52$) completed an inhibitory control task, *Simon Says*, with Grover either via TV or VR. Children using VR were less likely to suppress a dominant motoric response during *Simon Says* (i.e., not imitating Grover's actions at the appropriate time) compared to children using TV. More children in the VR condition approached Grover, and they shared a greater number of stickers with Grover compared to the TV condition (among those that shared). There were no differences between conditions for emotional or physical distress or children's enjoyment of the experience. These preliminary findings suggest that VR may elicit differential cognitive and social responses compared to less immersive technology.

Introduction

While two-dimensional (2D) screens (i.e., television) have been the predominant platform for young children's media consumption (Rideout, 2017), children are increasingly getting access to virtual reality (VR) technology (Aubrey, Robb, Bailey, & Bailenson, 2018; Somaiya, 2015). VR can create perceptually rich and socially real media simulations with virtual characters that could influence young children's reactions to content differently than other mediums (i.e., television). A virtual reality headset can block out the audio and visual sensory information of the physical world, drawing attention to the virtual environment. In addition, VR can create realistic simulations by allowing users to interact with the virtual environment using naturalistic movement, similar to how they would navigate the physical world (i.e., controlling their point of view by turning their head as opposed to pushing a button). Research with adults and children has shown that the brain can respond to VR stimuli as if it were real (see Bohil, Alicea, & Biocca, 2011; Hoffman et al., 2006 for review and discussion); for example VR has been shown to reduce the experience of pain among children as young as four-years of age (Aminabadi, Erfanparast, Sohrabi, Oskouei, & Naghili, 2012). Understanding the effect of VR (compared to other mediums) can provide insight on how technological immersion could influence children's experience of content, and how children might apply that information. The aim of the current study was to examine VR's effect on young children's cognitive and social responses compared to a less immersive medium (i.e., 2D screen).

VR has the potential to transform how children learn from media. For instance, there continues to be VR developments in education and clinical settings. Through the technology, children can experience instruction personalized to their needs (Passig & Eden, 2010) or visit new environments not possible in their physical world, such as interacting with gorillas inside a zoo habitat (Allison, Wills, Bowman, Wineman, & Hodges, 1997). Researchers and medical providers have used VR to reduce children's emotional and physical pain during medical procedures (Bohil et al., 2011) and as an assessment tool for diagnosing ADHD (Pollak et al., 2009). There are many potential opportunities to use VR to enhance the lives of children. However, most of the literature has focused on the effect of VR with adult populations. More research is needed to better understand how young children process content in VR.

The effects of VR on young children's inhibitory control

The developmental changes that occur during the preschool years

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(i.e., 3-to 5-years of age) could make young children sensitive to the perceptual and social realism of VR technology. The preschool years are associated with rapid maturation of higher order cognitive abilities such as executive functioning skills (Carlson, 2005). Inhibitory control (IC) is an executive function skill associated with emotion and behavior regulation. IC relates to a person's ability to resist distractions or temptations, and the ability to suppress impulsive thoughts or responses (Obradović, Portilla, & Boyce, 2012). Impulsive responses can be verbal (e.g., blurting out a secret), motor (e.g., reaching for a desired object), or oculomotor (e.g., looking at distracting stimuli). IC has been associated with children's school readiness and adaptive classroom behaviors (Allan, Hume, Allan, Farrington, & Lonigan, 2014).

Increasing the salience of objects in media could influence children's ability to suppress a dominant response (e.g., resist temptations). For instance, a study with 3- and 4-year-old children found that when the features of a desired object (i.e., candy) were made more salient, the more challenging it was for children to use their IC skills to resist pointing at the object (Carlson, Davis, & Leach, 2005). By creating sensory rich content, VR could increase the realism of objects and their salience. This increase in realism and salience could influence how children utilize their developing cognitive skills like IC to suppress a dominant action (e.g., not moving their bodies). An important aspect of learning involves the ability to direct and suppress actions, like visual attention and body movement at appropriate times. Understanding how children utilize their IC skills while using different technologies will provide insights on when and how to present educational media content to young children. For example, increasing the realism or salience of objects could draw children's attention to important information for learning or training, but it could also make it harder for children to use their IC skills to suppress other impulses. Determining how children use their cognitive skills in VR is an important initial step in (a) developing immersive technologies and content suited for young children, and (b) identifying potential strengths and challenges of these technologies.

The effects of VR on young children's social behavior

While in VR, children can interact with virtual characters controlled by computer algorithms called embodied agents (Blascovich et al., 2002). The first-person view in VR creates the illusion of being surrounded by the virtual environment and sharing the same physical space with the embodied agent. Embodied agents that behave socially contingent through verbal (e.g., asking questions) and non-verbal responses (e.g., directed eye contact, proximity) could influence children's social behaviors in and out of virtual environments.

Blascovich et al.' (2002) model of social influence in immersive virtual environments posits that when an embodied agent acts socially real and users believe that it is a real person, users are more likely to be influenced by that embodied agent (Blascovich et al., 2002). For example, in a study by Claxton and Ponto (2013), 5-, 7-, and 9-year-olds completed a decision making task in which they received information from a live person and an embodied agent on a 2D TV screen (Claxton & Ponto, 2013). Seven- and 9-year-olds were much more likely to use the information given to them by the live person over the embodied agent, whereas 5-year-olds used information from the live person and the embodied agent equally. Furthermore, 5-year-olds were much more likely to say that they felt that the embodied agent could see them.

By occluding the stimuli of the physical world from children's senses (i.e., seeing, hearing), VR could potentially enhance the social realism of interactions with an embodied agent and the social influence of that embodied agent. How children respond to socially contingent characters in VR could provide insight into the ways children apply information from social characters to their everyday lives. For example, children might be more likely to follow the instructions of a character in VR compared to a less immersive medium like 2D TV.

In addition, many young children develop one-way emotionally-tinged relationships, called parasocial relationships, with their favorite media characters. Parasocial relationships with familiar media figures can promote learning from media content, such as improving young children's math skills (Calvert, Richards, & Kent, 2014; Gola, Richards, Lauricella, & Calvert, 2013). Overall, children's feelings of attachment, friendship, and social realism towards media characters emerge as stable dimensions that define these relationships (Aguiar, Richards, Bond, Brunick, & Calvert, 2019; Richards & Calvert, 2016). For instance, preschoolers are likely to experience their favorite media characters as real (Aguiar et al., 2019; Richards & Calvert, 2016) and engage in positive social behaviors towards them, such as nurturing stuffed animal replicas of the character (Calvert et al., 2014).

Characters in immersive mediums like VR could appear as more real than less immersive mediums, possibly increasing opportunities for children to develop parasocial relationships. By creating socially real interactions with familiar characters, VR could increase the likelihood that children view familiar characters as socially real friendship partners that they treat as real friends. By developing attachments to media characters, VR could facilitate different learning opportunities than less immersive mediums. Children can share the same learning environment with a trusted character, and interact in the same virtual space to practice prosocial behaviors.

Study overview and hypotheses

Content presented in VR could influence children's cognitive and social responses differently than less immersive mediums (i.e., 2D TV screens). The current study examined the effects of technological immersion (i.e., VR versus TV) on young children's inhibitory control skills, social compliance, and sharing. Children interacted with a blue fuzzy character, Grover, from the children's show Sesame Street©, either via VR or TV (Fig. 1).

The unique affordances of VR could make content appear more realistic and thus be more salient compared to content presented using less immersive mediums like traditional TV. VR technology that incorporates multiple levels of tracking (i.e., systems that dynamically respond to a person's body movements), wide views of the content, stereoscopic vision, and spatialized sound, have been associated with users experiencing the content as more “real” (Cummings & Bailenson, 2016; Kobayashi, Ueno, & Ise, 2015). For example, a virtual reality headset with stereoscopic vision renders a slightly different image to each eye, which can enhance the perception of three-dimensional (3D) virtual objects. Although TV has visual cues that can create the illusion of depth (e.g., via the use of shape and position), VR may provide additional depth cues that increases the realism of the experience. While TV typically has greater resolution that can enhance photorealism, increased resolution has not been shown to have as large of an effect on experiencing the content as real compared to the aforementioned features (Cummings & Bailenson, 2016).

Hypothesis 1. (H_1). By creating realistic and salient content, VR could make it challenging for children to use their IC skills, such as suppressing a dominant motoric response (i.e., not imitating a virtual character's actions). We hypothesized that children using VR would perform worse on an inhibitory control task with a virtual character (i.e., Grover) compared to children completing the same task via TV.

By blocking out the stimuli of the physical world, VR can create the illusion of sharing the same space with a virtual character. A VR headset (i.e., head-mounted display; HMD) can provide children with a greater field of regard of the content (i.e., a greater amount of possible views of the virtual scene) than TV, creating the feeling of being inside the content. For example, even though an HMD restricts children's overall peripheral vision, when they turn their heads 90-degrees in VR (because of head tracking), children would see more of the virtual scene, while children using a TV would see less.

Hypothesis 2. (H_2). By creating the feeling that the virtual character is

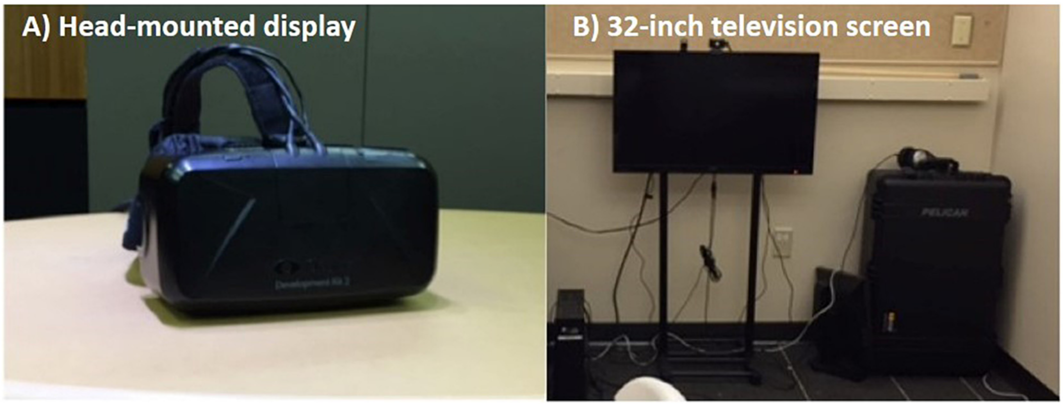

Fig. 1. Experimental equipment.
Children interacted and played *Simon Says* with a virtual character either via (A) a HMD (VR condition) or (B) a 2D television screen (TV condition). Children in both conditions started 51-in. away from the television screen.

physically present, VR could increase the character's social realism and thus its social influence, such as complying with a request given by that character. Research with adults has shown that the more socially real a virtual character feels to a person, the more likely they will be influenced by that character (Blascovich et al., 2002). We hypothesized that a greater percentage of children in the VR condition would socially comply with a request given by Grover compared to the percentage of children in the TV condition.

Social realism has been shown to be an important factor for young children developing parasocial relationships with familiar media figures (Richards & Calvert, 2016). Furthermore, children show prosocial behaviors towards the characters with whom they develop positive social attachments (Calvert et al., 2014). By enhancing the realism of a socially contingent and familiar character like Grover, VR could make a character seem more similar to a real-world friend compared with seeing that character on TV. This could potentially influence children's positive social behaviors towards a character they interact with in VR, such as sharing. Sharing behaviors (both "altruistic" and "selfish" sharing) have been shown to occur in children as young as 15-months of age (Schmidt & Sommerville, 2011), and preschoolers are more likely to share a desired object (e.g., stickers) with a friend and family member than a non-friend peer (Garon, Johnson, & Steeves, 2011; Moore, 2009).

Hypothesis 3. (H_3). VR could increase the social realism of a familiar character, potentially increasing children's social affiliation with the character. We hypothesized that children in the VR condition would share more of a desired object with Grover compared to children in the TV condition.

During the experiment, we also assessed children's self-reported emotional distress (i.e., fear, sadness, and worry) and physical distress (i.e., simulator sickness) pre- and post-treatment as well as their overall enjoyment of the virtual experience. Because VR can create the illusion of sharing the same space as a physical person, a familiar children's entertainment figure (i.e., Grover) was used to reduce the risk of children responding adversely to an unfamiliar embodied agent (e.g., fear). In addition, studies with child populations have shown that with short exposure, there are no major differences in negative physical symptoms between VR and TV (Kozulin, Ames, & McBrien, 2009; Neveu, Blackmon, & Stark, 1998).

Hypothesis 4. (H_4). We expected no differences between conditions in emotional distress and physical distress.

Hypothesis 5. (H_5). We expected no differences between conditions on children's enjoyment of the virtual treatment.

Potential covariates. Finally, dimensions of children's temperament (i.e., inhibitory control, shyness, and attentional focus) and recognition of Grover were measured to ensure randomization to condition. These measures were examined as potential differences between conditions that could affect the outcome of the results, and were considered as possible covariates if differences arose between the two conditions. Temperament dimensions of inhibitory control and attentional focus could influence children's ability to understand and follow instructions of the IC task, and shyness could influence children's social compliance to a request made by Grover (i.e., "Come over here."). Additionally, children's familiarity with Grover could influence their social compliance and sharing behavior.

Method

Participants

Four- to six-year-old children from the San Francisco Bay area were recruited to participate in the study ($N = 55$). Data were collected in a university lab setting (44% of the sample) and at a local museum (56% of the sample). Children were excluded if they had a seizure disorder, epilepsy, or any condition that would make them susceptible to dizziness, disorientation, or nausea (no parents reported any of these issues). Three children were automatically removed from the sample due to either technical failure, wanting to stop the experiment, or for failing to understand the inhibitory control task's instructions (i.e., demonstrated more than five errors in each practice round without showing any signs of improvement).

The final sample consisted of 52 children ($M = 67.83$ months, $SD = 10.61$ months; 25 girls and 27 boys). There were 26 children in each condition, with 12 female and 14 male children in the VR condition ($M = 67.58$ months, $SD = 10.83$ months), and 13 female and 13 male children in the TV condition ($M = 68.08$ months, $SD = 10.59$ months). Parents reported their child's race: 31% Caucasian, 25% Asian/Asian-American, 17% race/ethnicity not reported, 8% Asian Indian, 8% Asian/Asian- American and Caucasian, 6% Latinx/Hispanic and Caucasian, 4% other race not indicated, and 2% Latinx/Hispanic (see Table 1 for breakdown by condition). Participants provided informed consent and assent, and received $15 for their participation. The Institutional Review Board approved all aspects of the study.

Procedure

Children were randomly assigned to complete the virtual treatment either via TV or VR. Parents silently completed a questionnaire

Table 1
Demographic information of sample by condition.

	Condition	
Race/Ethnicity	TV(n = 26)	VR (n = 26)
Caucasian	13%	17%
Asian/Asian American	13%	12%
Race/ethnicity not reported	6%	12%
Asian Indian	6%	2%
Asian/Asian-American and Caucasian	4%	4%
Latinx/Hispanic and Caucasian	4%	2%
Other race	2%	2%
Latinx/Hispanic	2%	0%
Child's Sex		
Female	25%	23%
Male	25%	27%
Age in months		
M (SD)	68.08 (10.59)	67.58 (10.83)

assessing their child's temperament and demographic information in the same room during the experiment. Children were verbally administered a pre-test questionnaire measuring their emotional and physical distress levels. After the questionnaire, the researcher assessed children's recognition of the Sesame Street character Grover. Immediately after assessing children's recognition of Grover, the researcher told each child that they would be playing a game with Grover.

Next, children were introduced to the inhibitory control task, *Simon Says*. They were instructed to only imitate the actions of the leader when they heard the phrase "Simons says" first (e.g., "Simon says touch your head"), and to resist doing the action (i.e., to suppress a dominant motoric response) when "Simon says" was not spoken first. All children completed at least two practice rounds of *Simon Says* in the physical world before the virtual treatment. The first practice round children were told "Simon says touch your head," and during the second practice round children were told "Touch your shoulders." Children received verbal feedback from the researcher on their performance during each round and were given the same instructed action when they made a mistake. The researcher automatically moved to the next round when children either corrected their mistake or were unable to do the correct action after three or more attempts. A third practice round (i.e., "Touch your ear") was only completed for children that made more than two mistakes in each of the previous rounds.

After the practice session of *Simon Says*, children completed an orientation phase of the virtual environment using the technology they were assigned (either TV or HMD). During this phase, children saw the virtual room with a blue ball on the floor directly in front of them. The researcher asked if the children could see a blue ball, and made any adjustments to the equipment if they could not see it. Once children confirmed that they could clearly see the ball, the researcher started the virtual treatment with a computer key press.

The virtual treatment started with Grover growing from the ground in the same place as the blue ball, which faded out as he appeared. After growing, Grover automatically greeted children by waving and saying, "Hello! It is me, your loveable friend Grover." With a key press by the researcher, Grover said, "Come over here towards me, come closer." After a pre-programed 3-s delay, Grover said, "Now we are going to play *Simon Says*." An automated version of *Simon Says* began, and lasted 2.5-min (Fig. 2). During the task, audio files of the researcher's voice read all the commands as Grover completed the actions. Children did not receive feedback on their performance.

After the virtual treatment was completed, children were verbally administered a post-test questionnaire assessing their emotional distress, physical distress, and enjoyment of the virtual experience. Once the questionnaire was completed, the researcher assessed children's sharing behaviors (i.e., sharing physical stickers) with Grover. Parents and children were then debriefed about the experiment. Sessions were video recorded for coding purposes.

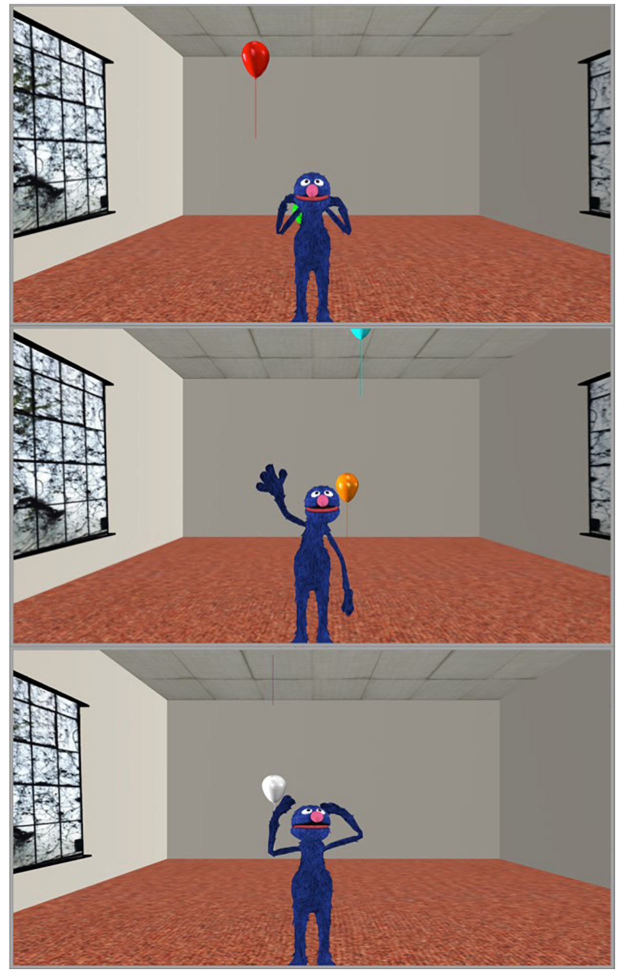

Fig. 2. Experimental treatment.
The figure shows the virtual environment and three of the 40 trials of the *Simon Says* game that all children played. They were told to imitate the actions of the character when they heard "Simon says" spoken and to resist imitating the action when they did not.

Measures

Child temperament (pre-virtual treatment). Three subscales from the Children's Behavior Questionnaire Short Form (CBQ) were completed by parents to assess children's temperament (Putnam & Rothbart, 2006): Inhibitory Control (Cronbach's alpha = 0.63), Attentional Focus (Cronbach's alpha = 0.77), and Shyness (Cronbach's alpha = 0.83). Subscales response options range from 1 (extremely untrue of my child) to 7 (extremely true of my child), and included "not applicable" as an additional option. The Inhibitory Control subscale (M = 5.02, SD = 0.91) measures children's ability to suppress an inappropriate response under instruction, or in uncertain or novel circumstances. The Attentional Focus subscale (M = 5.22, SD = 1.12) measures children's tendency to maintain attention and focus during tasks. The Shyness subscale (M = 3.49, SD = 1.26) measures children's tendency to be inhibited or slow during novel or uncertain situations. Higher scores indicate greater tendency for that temperament dimension.

Child pre- post-test questionnaire. A questionnaire assessed children's self-reported emotional distress, physical distress, and enjoyment of the virtual experience. The researcher read aloud each question and all response options. Children selected one of three possible response options: *not at all*, *some*, or *a lot*. The response options were scored as "0" (*not at all*), "2" (*some*), and "4" (*a lot*). A picture of three glasses of water, small (empty), medium (one-third full), and large (two-thirds full), was used to represent the response options *not at all*, *some*, and *a lot*. Children could answer verbally as well as point at the corresponding glass. To start, children responded to one practice question to ensure that they understood the scale (i.e., "How much do you like ice cream?"). The response options and their scoring were adapted from measures designed to assess young children's subjective self-report (Calvert, Strong, Jacobs, & Conger, 2007; Hoeft, Vogel, & Bowers, 2003; Varni, Seid, & Kurtin, 2001).

Emotional distress (pre- and post-test). Three questions were adapted from the PED-QL 4.0 Emotional Functioning subscale self-report questions for 5- to 7-year-old children (Varni et al., 2001). Children were asked how afraid, sad, and worried they felt at that moment. An emotional distress score was calculated as the mean of children's responses to the three emotional distress questions. A mean score was created separately for pre- and post-treatment responses. The overall mean of the emotional distress scores was 0.59 with a standard deviation of 0.69, and the range of those mean scores were from 0.00 to 4.00.

Physical distress (pre- and post-test). Physical distress was measured using four questions that assessed for simulator sickness. Children were asked how much their head, stomach, and eyes hurt, as well as how dizzy they felt at that moment. The questions were adapted from measures used to assess simulator sickness in children (Hoeft et al., 2003) and adults (Kennedy, Lane, Berbaum, & Lilienthal, 1993). A physical distress score was calculated as the mean of children's responses to the four questions. A score was calculated separately for pre- and post-treatment responses. Across all scores there was a mean of 0.29 with a standard deviation of 0.51, and the range of the mean physical distress scores were from 0.00 to 3.00.

Enjoyment (post-test only). Children's enjoyment of the virtual experience was assessed with two questions: (1) "How much fun was it to play with Grover?' and (2) "How much would you want to play more games with Grover?"

Recognition of the character (before virtual treatment). Before experiencing the virtual treatment, children were shown a computer image of Grover on a tablet and asked if they recognized him and knew his name. Children's responses were coded as either: (a) failed to recognize Grover, (b) recognized Grover and provided the correct name, (c) recognized Grover but used the incorrect name, or (d) recognized Grover but did not provide any name. For children that either (a) did not recognize Grover, (b) gave the wrong name, or (c) gave no name, the researcher told them Grover's name.

The recognition measure was collapsed into two levels; either children recognized Grover or did not recognize him. Children that indicated that they recognized Grover, either providing the correct name, using the incorrect name, or not providing a name, were classified as having recognized Grover. All other children were categorized as not having recognized Grover.

Inhibitory control task (during virtual treatment). Inhibitory control was indexed by children's performance in a virtual game of *Simon Says* with Grover (Carlson, 2005; Carlson & Wang, 2007; Jones, Rothbart, & Posner, 2003; Strommen, 1973). In *Simon Says*, the game leader completes an action and gives the child instructions to complete the action (Carlson, 2005; Jones et al., 2003; Strommen, 1973). Studies have shown that children are capable of playing *Simon Says* using a virtual environment (Schwebel, Li, McClure, & Severson, 2016; Zannatha et al., 2013). Behind Grover, virtual balloons floated up out of the ground (Fig. 2). Initial pilot testing of the virtual *Simon Says* task revealed a ceiling effect on performance for all children. The balloons were added in the background to make the game more challenging (adding minor visual distractions), thus potentially increasing the variability in children's performance.

The game comprised of 24 activation trials (i.e., imitating the character's movement when "Simon says" is spoken first) and 16 inhibition trials (i.e., suppressing imitation when "Simon says" is not spoken first). Children's performance on each trial was rated as *no movement*, *partial movement*, *wrong movement,* or *full movement*, and scoring was adapted from methods developed by Carlson and Wang (2007). Scores for each trial ranged from 0 to 3 by trial type (see Carlson & Wang, 2007). The final score for both types of trials was the proportion of points scored out of the total possible points (72 activation points, 48 inhibition points).

Children's performance on the activation trials was used to assess their comprehension of the task (i.e., appropriately imitating Grover's movements when "Simon says" is spoken). Based on previously established research, a minimum score of 0.90 or above accuracy on the activation trials was considered meeting the passing criteria, and understanding the task (Carlson, 2005; Jones et al., 2003). Performance on inhibition trials measured children's inhibitory control skills (i.e., correctly suppressing movement when "Simon says" is not spoken). Higher scores in both trial types indicated better performance.

Children that fell below the required 0.90 minimum activation score were removed from the inhibitory control analyses. A total of 7 children did not meet this minimum and were excluded from the IC analyses: five children were from the VR condition and two children were from the TV condition. The overall results of the inhibitory control analyses remained the same when these children were included in the data. This exclusion criterion was used only to remove children from the analysis of the inhibitory control variables and not from any other analyses. For the entire sample, activation scores ranged from 0.18 to 1.00 ($M = 0.93$, $SD = 0.15$) and inhibition scores ranged from 0.21 to 1.00 ($M = 0.75$, $SD = 0.20$). For children that met the passing criteria of 0.90 ($n = 45$), activation scores ranged from 0.92 to 1.00 ($M = 0.98$, $SD = 0.03$), and inhibition trial scores ranged from 0.21 to 1.00 ($M = 0.76$, $SD = 0.20$).

Two coders rated each of the individual trials in the *Simon Says* game. The first coder made ratings in real time during the experiment ($n = 52$) and a second coder, a trained research aide not associated with the experiment, made ratings using the available video recordings ($n = 37$). There was substantial inter-rater reliability (Landis & Koch, 1977) between the live and video ratings for all the *Simon Says* trials (Cohen's *kappa* = 0.76). The live coding data for all trials in the *Simon Says* game were used for data analysis to ensure that children without video recorded sessions were not excluded from the study.

Social compliance (during virtual treatment). The social compliance measure was based on research examining preschoolers interactions with socially acting TV characters (Anderson et al., 2000), and the use of interpersonal distance as a measure of embodied agents' social influence (e.g., Bailenson, Blascovich, Beall, & Loomis, 2003). During the virtual treatment before the *Simon Says* game, children were rated as being socially compliant if they walked towards Grover after he instructed them to, "Come over here towards me. Come closer." Two coders rated whether or not children walked towards Grover. The first coder made ratings in real time during the experiment ($n = 52$) and a second coder, a trained research aide not associated with the experiment, made ratings using the available video recordings ($n = 37$). There was substantial inter-rater reliability (Landis & Koch, 1977) between the live coding and video coding raters for the approach ratings (Cohen's *kappa* = 0.79). The live coding data for all children's approach behavior was used to ensure that children without video recordings were not excluded from the study.

Sharing behavior (after virtual treatment). To assess sharing post-treatment, the researcher placed 10 stickers on a table in front of each child, and said "These stickers are for you." The researcher then placed a small bowl next to the stickers and said, "Grover is also collecting stickers. You can give him as many or as few as you want." Children were instructed to place the stickers that they wanted to give Grover in the bowl and to tell the researcher when they were finished. Children were not given any additional information on how or when Grover would receive the stickers. All children received the same 10 stickers (images of 10 different animals). The more stickers that children gave Grover represented greater sharing behaviors. The number of stickers that children gave Grover, ranged from 0.00 to 10 ($M = 3.51$, $SD = 3.28$). Five children in the VR condition and two in the TV condition did not give Grover any stickers ($n = 45$). Equitable sharing continues to develop during early childhood (Fehr, Bernhard, & Rockenbach, 2008), suggesting that sharing behaviors as a measure of social affiliation with an embodied agent would have sufficient variance among young children. At the end of the experiment, the researcher gave children stickers equal to the number that they had given away, resulting in all children receiving the same number of stickers at the end. The researcher told children that they received these additional stickers because they shared with Grover.

Virtual environment and equipment

Worldviz's Vizard VR toolkit was used to program and render the virtual experience. A desktop computer rendered the scene, and the simulation was either displayed on an HMD (VR condition) or 2D TV screen (TV condition). Children in the VR condition wore the Oculus Rift Developers Kit 2 (DK2), an HMD with stereoscopic views and a 100-degree horizontal field of view. The Oculus Rift DK2 screens had a resolution of 960 × 1080 per eye and a refresh rate of 75-frames per second. An infrared LED light camera (Oculus Camera) was used to detect LED light sensors on the HMD to track the translation (along x-, y-, z-axis) of the child's gross head movements. An orientation sensor integrated within the HMD (Oculus VR™ Sensor, update rate of 1000hz with a 30-millisecond latency rate) tracked children's physical head translation (x-, y-, z-axis) and orientation (pitch, roll, yaw) via a gyroscope, accelerometer, and magnetometer. The virtual environment updated based on the child's head movements.

The TV condition used a 32-in. Seiki SE32HY10 TV screen that had a resolution of 1366 × 768 with a refresh rate of 60 Hz. The TV was a LED high definition 2D screen with approximately a 30-degree horizontal field of view (calculated by the visual angle of the screen based on children's starting position). There was no body tracking in the TV condition, and the viewpoint of the virtual environment stayed locked in one position. We selected to use a standard consumer-grade TV to compare to VR because it is the type of screen technology that young children use most often (Rideout, 2017). The digital content was the same between both conditions.

In both conditions, children's viewpoint was placed directly in front of Grover, who was located in the middle of the virtual room. In the VR condition, positional head tracking was used to scale Grover to be the same size as the child, and the experience contained spatialized sound. The sound files for Grover's voice and the *Simon Says* instructions were attached to the 3D model of Grover. In addition, the physics engine was turned off on the 3D model of Grover, and children had the capability of walking through him if they chose to do so. However, no children in the study passed through any part of Grover's body.

The experiment room was the same set up for all children, and the TV remained off when not in use (Fig. 1). During both conditions, the TV screen displayed the virtual environment. The view of children in the VR condition was displayed on the TV to: (a) make parents more comfortable by enabling them to see the content, (b) to allow the researcher to monitor the child's physical safety while observing the child's view of the virtual environment, and (c) to create similarity between the conditions' physical environment. All children started 51-in. from the TV screen, wore the same noise-cancelling headphones, and heard the same audio files. We wanted all children to walk the same length of distance in the physical world to reach Grover. However, by keeping the physical distance the same between conditions, the viewing angle of Grover was larger in the VR condition than in the TV condition. A research assistant kept all wires and equipment in the physical world out of children's way. Adjustments were made before the treatment to ensure children's comfort and the ability to see the virtual scene clearly.

Results

Data analyses examined the effect of technological immersion (VR versus TV) on children's inhibitory control skills, social compliance, and sharing with an embodied agent, Grover, as well as their emotional distress, physical distress, and enjoyment of the experience. All data analysis was completed in *R* (R Core Team, 2015). Randomization worked according to children's temperament scores (i.e., Inhibitory Control, Attentional Focus, and Shyness subscales), age (in months), gender (i.e., girl, boy), and children's recognition of Grover. Children's temperament scores did not differ between the VR and the TV conditions: Inhibitory Control subscale, $t\ (49) = 0.64$, $p = .53$, Cohen's $d = 0.18$; Attentional Focus subscale $t\ (50) = -0.78$, $p = .44$, Cohen's $d = 0.22$; and Shyness subscale, $t\ (47) = 0.72$, $p = .48$, Cohen's $d = 0.20$. There was no significant difference in the mean age between the VR and TV conditions, $t\ (50) = 0.17$, $p = .87$, Cohen's $d = 0.05$, and the number of girls and boys was equivalent between conditions, χ^2 (1, $N = 52) = 0.00$, $p = 1.00$, Cramer's $V = 0.00$. Finally, there was no significant difference between the VR condition ($n = 23$; 56.52%) and the TV condition ($n = 25$; 56.00%) on whether or not children recognized Grover, χ^2 (1, $N = 48) = 0.00$, $p = 1.00$, Cramer's $V = 0.00$. Because there were no differences between conditions in temperament, gender, or recognition of Grover, these measures were not used as covariates in the rest of the analyses.

Inhibitory control

Performance on activation trials represented children's understanding of the task, and inhibition trials measured children's IC skills. Higher scores represent increased performance. Children's age in months was examined as a covariate, as research has shown that the use of IC during *Simon Says* improves with an increase in age (Carlson, 2005).

Linear multiple regression models were used to analyze the effect of condition (VR versus TV) on children's performance on the inhibition trials and activation trials. Age (in months) was associated with better performance on the inhibition trials, $r\ (n = 43) = 0.37$, $p = .01$, and thus, it was included in the model as a covariate. There was a significant main effect of condition on inhibition trial scores, $b = 0.15$, $t\ (42) = 2.99$, $p < .01$, $R^2 = 0.26$, and a significant effect of age, $b = 0.01$, $t\ (42) = 2.64$, $p = .01$, $R^2 = 0.26$. Children in the TV condition ($n = 24$; $M = 0.83$, $SD = 0.15$) demonstrated better inhibitory control compared to the VR condition ($n = 21$; $M = 0.67$, $SD = 0.21$) during the task (Fig. 3).

As expected, age was not associated with performance on the activation trials, $r\ (n = 43) = 0.22$, $p = .14$, and was not included in the model. A separate linear regression model analyzed the effect of condition on children's performance on the activation trials. There was no significant effect of condition on children's performance on the activation trials, $b = 0.01$, $t\ (43) = 1.01$, $p = .32$, $R^2 = 0.00$ (Fig. 3), demonstrating no differences by condition on children's understanding of the task.

Social compliance

A chi-square test was used to analyze the effect of condition (VR versus TV) on children's social compliance (indexed by a binary variable of whether or not children walked forward), when Grover requested that they come closer. A greater percentage of children in the VR condition ($n = 15$; 57.69%) compared to children in the TV condition ($n = 5$; 19.23%), approached Grover when he requested that they come closer, χ^2 (1, $N = 52) = 6.58$, $p = .01$, Cramer's $V = 0.36$. In addition, the results of a binomial logistic regression showed that age (in months) did not predict whether children walked towards the

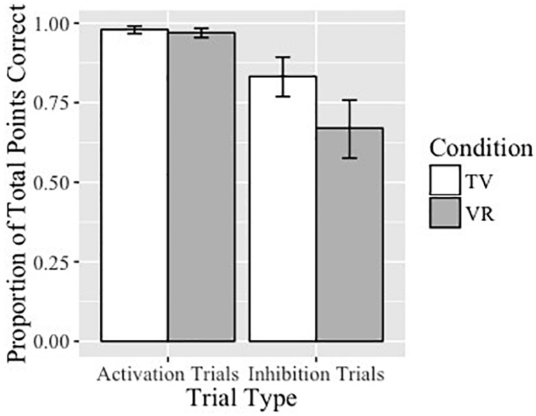

Fig. 3. Performance on *Simon Says* by condition.
The mean scores and 95% confidence intervals of the proportion of total possible points children scored during the *Simon Says* game for activation and inhibition trials ($n = 45$). Higher levels indicate better performance. Activation scores represent understanding the task, and inhibition trials represent inhibitory control.

character, $z = 1.04$, $p = .30$, odds ratio = 1.03.

Sharing behavior

A Fisher's exact test was used to examine differences between conditions (VR versus TV) in children giving Grover at least one sticker compared to no stickers. Within each condition, 71.42% of children in the VR condition and 85.50% of children in the TV condition shared at least one sticker with Grover. However, there was no significant difference between conditions in the number of children that gave Grover at least one sticker compared to children that gave him none, $p = .27$, odds ratio = 0.37.

A *t*-test was used to examine the effect of condition on sharing behaviors of all children, including those that gave none. There was no significant difference between the number of stickers that children in the VR condition gave to Grover ($n = 21$; $M = 4.19$, $SD = 3.94$), compared to the number of stickers that children in the TV gave him ($n = 24$; $M = 2.92$, $SD = 2.50$), $t\ (33) = 1.28$, $p = .21$, Cohen's $d = 0.39$.

Finally, because the tendency for equitable sharing matures during early childhood (Fehr et al., 2008), we examined only the children that shared at least one sticker with Grover. A t-test was used to determine the effect of condition on their sharing behavior. Of the children that shared at least one sticker with Grover, children in the VR condition gave significantly more stickers to Grover ($n = 15$; $M = 5.87$, $SD = 3.42$) than children in the TV condition ($n = 21$; $M = 3.33$, $SD = 2.39$), $t\,(24) = 2.47$, $p = .02$, Cohen's $d = 0.89$. In addition, there was no significant correlation between age and the number of stickers children gave to the Grover, $r\ (n = 34) = -0.02$, $p = .89$.

Emotional and physical distress

Mixed-effects models (see Table 2) were used to determine the effect of condition (VR versus TV) on emotional distress (Model 1) and physical distress (Model 2) pre- and post-treatment. Emotional distress measured the degree of children's fear, sadness, and worry, and physical distress measured the degree of children's head, eyes, and stomach pain, and dizziness. Condition (VR and TV) and time of measurement (pre- and post-treatment) were treated as fixed factors in the models. Participant was treated as a random factor.

There was a main effect of time on emotional distress, $b = -0.38$, $t = -2.24$, $p = .03$; overall, children felt less emotional distress post-treatment ($M = 0.41$, $SD = 0.42$) compared to pre-treatment ($M = 0.77$, $SD = 0.85$). There was no main effect of condition, $b = -0.15$, $t = -0.82$, $p = .41$, and the interaction effect of condition and time was not significant, $b = 0.03$, $t = 0.12$, $p = .90$. For physical distress, there were no main effects of condition, $b = 0.06$, $t = 0.41$, $p = .69$, or time, $b = 0.19$, $t = 1.63$, $p = .11$. The interaction effect of condition and time was not significant, $b = -0.26$, $t = -1.64$, $p = .11$.

Table 2
Linear mixed-effects models for emotional and physical distress by condition and time (pre- and post-test).

			s^2	*b*	*SE*	*t*	*p*
Emotional distress							
Model 1: Condition*Time (pre & post)							
Random	Participant	Intercept	0.10				
Fixed	*Condition* (TV)			−0.15	0.19	−0.82	0.41
	Time (post-test)			−0.38	0.17	−2.24	0.03
	Condition (TV) **Time* (post-test)			0.03	0.24	0.12	0.90
Physical distress							
Model 2: Condition*Time (pre & post)							
Random	Participant	Intercept	0.10				
Fixed	*Condition* (TV)			0.06	0.14	0.41	0.69
	Time (post-test)			0.19	0.11	1.63	0.11
	Condition (TV) **Time* (post-test)			−0.26	0.16	−1.64	0.11

Enjoyment

Overall, the vast majority of children in both the VR and TV condition enjoyed the experience: 92.00% of children in the VR condition and 88.46% of children in the TV condition reported that the game was *some* or *a lot* fun to play with Grover. In addition, 92.00% of children in the VR condition and 88.46% of children in the TV condition indicated wanting to play *some* or *a lot* more games with Grover. Because the percentages were similarly high in both conditions, only descriptive statistics were conducted.

Discussion

The purpose of our study was to investigate how immersive technologies like VR could influence children's interactions with content and familiar characters compared to less immersive mediums like a 2D TV screen. Overall, results showed that children had different cognitive and social responses to content based on the type of technology that they used, providing evidence to support that content presented via different mediums can influence young children's psychological responses. The majority of our hypotheses were supported. Confirming our predictions, children in the VR condition performed worse on an inhibitory control task compared to children in the TV condition (H_1), and a greater percentage of children in the VR condition demonstrated social compliance towards Grover (i.e., approached him upon his request) compared to the percentage of children in the TV condition (H_2). Hypothesis 3 was partially supported: among those that shared with Grover, children in the VR condition shared more stickers with him compared to children in the TV condition. To elicit stronger social affiliation behaviors, the interaction with Grover may have needed to be longer, particularly for this population who are still developing the tendency for equitable sharing. Finally, similar to previous studies (e.g., Kozulin et al., 2009), children in our study enjoyed a short VR exposure with minimal physical and emotional distress (H_4, H_5 were supported). The insights gained from this study have implications for educational and clinical settings, and others factors to consider for future research and media design.

VR and inhibitory control

Our study provides an additional step towards determining whether technologies with different immersive features can influence young children's cognitive responses. The technological features unique to VR could influence how children use certain executive function skills like inhibitory control. In our study, children in the VR condition were less likely to suppress a dominant response (i.e., resisting imitating Grover's actions) at the appropriate time compared to children using TV.

Simon Says has been shown to be a particularly challenging IC task for preschoolers and early elementary school-aged children (Carlson, 2005; Marshall & Drew, 2014; Strommen, 1973), and playing *Simon Says* in VR could have been similar to playing with someone in person. The VR condition's ability to block out the physical world, provide additional depth cues, and generate a large visual angle of Grover could have made the content realistic and more salient. Children in the TV condition were able to see the experimental room, potentially pulling their attention away from Grover's body movements, possibly making it easier for them to suppress motor action during the *Simon Says* inhibition trials. While TV is not devoid of depth cues (e.g., TV's use of relative size, shape, and position of objects), the stereoscopic vision, greater field of regard, and multiple levels of tracking in the VR condition may have made Grover seem more like a real-world person than when he was on TV. This may have also been coupled with the fact that the visual angle of Grover was wider in VR than on the TV screen, making him appear much larger and physically closer, similar to a live person. In addition, the balloons in the scene could have appeared more salient in VR than on TV, and thus more likely to elicit an orienting response from children, making it harder to suppress movement during the inhibition trials. Future work could compare children playing *Simon Says* in VR with a non-mediated version as well as playing with different levels of distraction.

Young children's lower scoring on IC tasks in VR could provide an opportunity to use immersive technologies to assess certain EF skills like IC. One overall challenge for assessing EF is using the same task for children across various ages and abilities. If completing certain EF tasks such as *Simon Says* is more challenging in VR, it has the potential to allow older children to complete the same task as their younger counterparts using a controlled automated measurement tool. Furthermore, by increasing the challenge of an EF task, VR could also be used as part of a cognitive intervention for children. Studies have shown that interventions using EF games that increase the challenge over time can improve certain EF skills (Diamond, 2013). Future research could examine how experiences in immersive technologies like VR relate to other dimensions of EF such as working memory, cognitive flexibility, and other IC skills. Investigating other skills related to EF could provide additional insight on how children's developing cognitive skills influence their interactions and experiences of immersive media.

In addition, through the affordances of VR, educators and clinicians can increase or decrease the amount of sensory information presented to children as well as change the type of learning environment and the media figures within it. By doing so, VR could be well suited to help children focus on relevant information by adjusting the salience of the content. For example, spatialized sound could be added or removed. The number of objects or the type of objects in the learning environment could be manipulated. More research will be needed to determine how different aspects of the technology influence young children's interpretation of information in VR. It may be that older children with more developed IC skills may reap greater benefits from using VR for advanced instruction than younger children. However, in some instances, an important part of learning is imitating the behaviors of others. Our results suggest that VR may provide a unique opportunity for young children to learn through imitating embodied agents.

VR and social behavior

Often young children's learning takes place within social contexts, through interactions with trusted adults and peers (Rogoff, 1990). Our results suggest that using VR with young children may be well suited for experiences that leverage social contexts and actors. Children in the VR condition were more likely to approach Grover, and demonstrated some differences in sharing behavior compared to the TV condition. These differences in social behavior suggest that affinity towards Grover was strengthened and sustained via the more immersive technology.

Enhancing the salience of Grover and the context may have increased his social influence more so than the less immersive medium. For instance, seeing the physical world in the TV condition could have made the distinction between a simulated reality (i.e., virtual environment) and physical reality (i.e., physical world) more pronounced. Children could see the researcher not responding to Grover's actions or his requests. With this distinction, people in the physical world could have been more socially influential to children in the TV condition compared to children using VR.

The additional depth cues afforded by VR coupled with head tracking, may have signaled to children that the virtual environment was a physical 3D space to be navigated, similar to how they interact in the physical world. This could also relate to some of the differences between conditions in sharing behaviors. For example, after the treatment children were given stickers to share with Grover. Children in the VR condition could have thought the environment was a physical space where Grover could receive stickers, potentially making them more inclined to share their stickers with him. By creating realistic social environments and drawing children's attention to the characters, VR has the potential to provide effective social simulations. For instance, VR simulations could act as an avenue for children to practice prosocial behaviors through empathy training.

Woolley and Ghossainy (2013) have argued that the media context can influence whether young children view media characters as real and credible sources of information. When media figures are identified as trusted knowledgeable sources of information, young children are more likely to transfer that information to another context (Schlesinger, Flynn, & Richert, 2016). For example, the immersive features of VR could have created a realistic sensory context that made Grover seem more realistic and therefore a more credible source of information. Thus, VR may be useful for certain educational simulations, as it may make virtual characters seem like legitimate sources of knowledge. By placing a greater emphasis on building social relationships and less on traditional classroom academic learning, VR could be used to promote positive social outcomes and enhanced emotional growth for young children, such as training social skills for children diagnosed with ASD or cognitive-behavior therapy. Educational immersive content for younger children will need to be carefully designed to best meet their skills and abilities to direct attention and behaviors to the important information.

VR and information processing

The literature shows that VR has the potential to facilitate certain actions and responses but to also hinder or mitigate others. Our results suggest that experiences in VR have the potential to affect both children's in-the-moment processing as well as transferring media information to the physical world. The children in our study had automatic responses in VR differently than those that experienced the same content via TV; more children walked towards Grover when he requested they come closer and they performed with lower accuracy during *Simon Says*. Experiencing perceptually real and salient content in VR could affect young children's automatic responses, as they are still developing the skills to regulate their behaviors and emotions. Understanding these automatic and unconscious responses to media will need to be taken into consideration when designing technology content that will keep children safe and to allow them to practice positive behaviors.

While research with adults has shown users transferring experiences from VR to the physical world, such as with prosocial behaviors (Rosenberg, Baughman, & Bailenson, 2013), less is known about how children experience and transfer VR content. It may be the case that VR is uniquely positioned to transfer social and emotional experiences to the physical world. Our results suggest that in certain circumstances, children may transfer their social experience in VR to the physical world. For instance, if children felt a greater level of social realism of Grover via a parasocial interaction in VR than in TV, it may explain why some children shared more stickers in the physical world. The perceptually and socially rich media experiences that VR can facilitate, may influence children's responses in different ways, and will be important to consider when designing interventions, educational content, and entertainment experiences for children. Future work will need to tease out how technological immersion affects more automatic and in-the-moment processing as well as how it may affect children transferring content to the physical world.

Additional factors to consider

Other factors working in tandem with the technological features of VR could also contribute to how children respond to media content (compared to less immersive mediums). For instance, children's previous experience with 2D screen media and other abilities that rapidly mature during the preschool years could influence outcomes. We discuss these two areas as potential factors contributing to our results as well as points to consider for understanding the impact of VR on children's lives and their responses.

Experience with media. Children's previous experience with 2D screens may contribute to differences in reactions to VR and TV. Children as young as 19-months of age demonstrate that they understand that objects on a TV screen cannot be physically grasped or touched (Pierroutsakos & Troseth, 2003). Humans' early ability to determine the behavioral affordances of TV screens may occur via the dorsal perceptual visual pathway in the brain, which is associated with processing visual depth perception cues, and transforming visual information to motor action on 3D objects (Freud, Plaut, & Behrmann, 2016). In our study, children's knowledge that objects on the TV were not physically present and how they processed the visual content on the 2D screen could explain why a smaller percentage of children in the TV condition approached Grover compared to the VR condition. It could be possible that children's developing brains process VR content differently than a less immersive platform.

In addition, children with little to no experience with technologies like VR could be affected by the visual novelty of content presented in an immersive virtual environment. Brain imaging research has shown that the brain processes novel stimuli differently than more familiar stimuli, and that novel events draw more attention (Corbetta & Shulman, 2002; Lange, Seer, Finke, Dengler, & Kopp, 2015). The novelty of the VR experience in our study may have captured children's attention in a way that negatively impacted their performance on the IC task. Children's repeated use of VR may provide additional insights as to when and how immersive technologies influence responses to educational and therapeutic content. To maximize educational benefits, VR experiences for young children may need to start off slow and simple and then increase in complexity after repeated exposure.

Many children's TV shows are created with media characters that act in socially contingent ways, and preschoolers that are familiar with this type of content respond to and interact with these characters more often than children with less experience (Crawley et al., 2002). As illustrated in our study results, even some children in the TV condition approached Grover upon his request. Even though the virtual experience with Grover was a brief and simplified social interaction, children in VR demonstrated some differences in sharing compared to the TV condition. Additional experience with characters in VR may further facilitate positive social behaviors as children practice them with socially responsive embodied agents.

Individual differences in developmental abilities. Other psychological abilities that rapidly develop during early childhood could also contribute to children's responses to media characters in VR. For instance, Theory of Mind (ToM), the ability to assess and infer the mental states of others, is associated with improved performance on inhibitory control tasks (Carlson, Claxton, & Moses, 2015; Sabbagh, Xu, Carlson, Moses, & Lee, 2006). However, research on parasocial relationships with media characters indicates that children as young as 3-years-old tend to perceive beloved and familiar media characters (such a Grover from Sesame Street) as humanlike, having feelings, wants, and needs (Richards & Calvert, 2016). This suggests that very young children can perceive media characters as social beings. Future research could examine the extent ToM is associated with children's responses to content and the development of parasocial relationships with embodied agents in VR.

Finally, young children are still developing an understanding of the boundaries that distinguish fantastical experiences from real ones. Given the immersive features of VR, children may likely experience media characters as “real.” For example, a study with Segovia and Bailenson (2009) showed preschoolers and early elementary school aged-children confusing personalized content of an impossible event shown in VR (i.e., swimming underwater with whales) as having happened in their lives (Segovia & Bailenson, 2009). The combination of sensory rich stimuli and children's developing sense of the fantasy-reality distinction could have made it easier for children to view Grover, a familiar character, as “real.” This view could have made children more inclined to imitate his actions, and to show Grover positive social responses (i.e., approach behaviors, sharing). Furthermore, children that view media content as real are more likely to transfer that information to other contexts (Bonus & Mares, 2015). Additional studies could examine how children's understanding of fantasy and reality intersects with the level of immersion, context, and types of characters within virtual environments. If VR seems more real to children than other mediums, there are educational opportunities for children to apply what they have learned in media to other areas in their lives.

Limitations and future directions

This preliminary study demonstrates how VR can influence young children's IC skills and social behaviors. The interpretation of these results needs to be considered in the light of the study's limitations, which can be areas for improvement in future work. First, the study did not include baseline measures of ToM, tendency for social compliance, and prosocial sharing. In addition, the study did not ask parents about previous experience with VR versus TV (at the time of the study, fully immersive VR was not widely available on the consumer market). Even though children were randomly assigned to conditions, it is always possible that the two groups were not equivalent in these domains.

Second, although we collected data on temperament dimensions related to attentional focus, inhibitory control, and shyness (via Children's Behavioral Questionnaire), future research will need to collect additional validated and sensitive measures of EF. Parent report is a valid measure of EF (Carlson & Moses, 2001) albeit different than other EF measurements.

Third, we did not use tracking sensors to measure children's behaviors. VR has the capability to collect thousands of data points measuring users' head movements. Unobtrusive technology (e.g., eye tracking devices, infrared cameras tracking body heat) could be used to measure children's attention and approach behaviors to provide a more nuanced comparison between VR and TV.

Fourth, while the study showed some differences between our specific TV and VR devices, it is unclear how the specific combination of immersive features (e.g., field of view, tracking capabilities) affected children's cognitive and social responses to the content. It could be possible that the VR hardware itself (i.e., HMD, cables) could have influenced the results of our study. However, it is unlikely that the VR equipment restrained children from moving their bodies, as there were no differences between conditions on movement during the activation trials of *Simon Says* and a greater percentage of children in the VR condition walked towards Grover. Although unlikely, there is a possibility that the proprioceptive feedback that children felt from wearing the HMD could have distracted them from suppressing motor action at the appropriate time. Future studies could examine how specific technological features affect various social behaviors (e.g., approaching versus talking to characters) and performance on different types IC tasks (e.g., "hot" versus "cold" or conflict versus delay of gratification tasks).

Fifth, sharing and approach behaviors are two of many social behaviors that could have been measured, and it is unclear what these behaviors specifically demonstrated; social presence and parasocial relationships are two possible concepts. Other prosocial behaviors could be tested. For example, research with adults has demonstrated that even after short exposures, VR experiences can facilitate altruistic behavior (Rosenberg et al., 2013). Future research could examine the effect of immersion on children's prosocial behaviors, and how these social behaviors correspond with other measures of children's social presence and parasocial relationships.

A sixth limitation of the study is that we used self-report to assess emotional and physical distress pre- and post-treatment. Future research could employ various assessments of physiological emotional responses during the virtual experience. And finally, children experienced only one exposure to a brief treatment, and it is unclear what the long-term effects of VR experiences have on children's emotions, attitudes, and behaviors.

Conclusion

By examining the effect of technological immersion on children's behaviors, the results of this study provide insights and potential opportunities for the future use of digital devices for children. Educational technologies have increasingly become a stable feature in children's learning environments, and VR is likely to be harnessed by educational companies to promote children's early social and academic learning. As technology evolves, understanding how to navigate content in immersive mediums may be an important future skill for children. Understanding the effects of VR on development will provide insights on which virtual experiences and immersive features are appropriate for children and at what ages. This information can then be utilized to develop age-appropriate VR content that can best facilitate interventions for both academic and social learning.

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