"Awesomely freaky!" The impact of type on children's social-emotional perceptions of virtual reality characters

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ABSTRACT

While VR, through decades of research, has shown to successfully improve young children's lives, more research needs to examine the appropriateness of VR for children, including its design. The type of character in combination with the perceptual realism of virtual reality (VR) may influence children's perceptions of VR experiences. A within-participant experiment examined 5- to 9-year-old children's ($N = 25$) perceptions of three different character types in VR (i.e., human, animal, and anthropomorphized creature) based on their level of social realism. Results showed that character type impacted children's (a) social-emotional descriptions of the VR experience, (b) if VR's realism was an asset or a hindrance, and (c) primed thoughts about fantasy versus reality. However, children experienced the embodiment and personification of the characters similarly across all character types. Finally, children recalled the salient aspects of the characters they remembered and identified elements to improve the VR characters' design.

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); • **Social and professional topics** → User characteristics; Age; Children.

KEYWORDS

virtual reality, child development, parasocial relationships, uncanny valley, social-emotional

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1 INTRODUCTION

Research shows that VR alleviates pain and anxiety during medical procedures for children as young as four-years of age [2], improves mental health [21], transforms educational lessons [4], and provides social skills training [33]. VR blocks out the surrounding world and inundates children with perceptually real stimuli creating vivid media interactions [8, 17]. Furthermore, young children continue to gain greater access to VR technology: In 2016, the Mattel View Master designed a small handheld VR headset for children 7-years and older [22], and in 2015, McDonalds in Sweden sold VR headsets made out of happy meal boxes, a menu item geared towards children, and included access to the company's commercially developed content [36]. Within these VR experiences, children can interact with embodied agents that look and behave as if they are actual social actors. However, there is evidence that children feel stronger emotional effects of VR content compared to adults [14, 15], and further exploration of VR as an appropriate tool for youth is warranted. For instance, Cadet, Reynud, and Shainay [15] discovered that unlike adults, children 10- to 14-years of age felt strong emotional responses to negative VR stimuli regardless of the image quality. This study suggests that the mere experience of VR can impact children's emotions regardless of its visual quality. However, it is unclear how specific design aspects of VR impact children's emotions and perceptions of the experience. If immersive and perceptually rich technologies like VR continue to be leveraged to improve the lives of children, they must be developed to mitigate any social-emotional and physical harm while maximizing any benefits for children.

While VR, through decades of research, has shown to successfully improve young children's lives, more research needs to examine the appropriateness of VR for young children. There are ethical concerns on the emotional and physical safety of children using VR. Children in early to middle childhood (i.e., 5- to 12-years-old) may be emotionally vulnerable to the perceptual realism of VR, particularly in reaction to certain design elements of embodied agents. VR technology can make the characters often found in children's media (i.e., children, animals, puppets) feel real and salient. As a result, characters that represent fantastical artificial entities (e.g., Muppet) that appear highly realistic (i.e., embodied living creatures) may negatively impact children's social-emotional perceptions compared to other character types. Concern also exists about the negative impact of VR usage on children's physical health, such as experiencing eye strain or nausea. To better understand how to design positive VR experiences for children, the following study explored 5- to 9-year-old children's perceptions of embodied agents in VR that represent characters commonly used in 2D screen formats that represent various levels of plausibility of occurring in their daily lives (e.g., levels of social realism). This study contributes to the HCI discussion on children, technology, and perceptions by (a) reporting on the social-emotional language that children use when describing their subjective perceptions of various types embodied agents in VR, (b) how the type of embodied agent impacts children's subjective perceptions of the VR experience, and (c) insights on the design of VR characters and the appropriate use of VR for children.

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2 BACKGROUND

Children in early to middle childhood often develop meaningful social-emotional connections with media figures (i.e., parasocial relationships), that provide social companionship [45], help facilitate academic learning [16, 38], and improve social skills [42]. In addition, research shows that children in early to middle childhood prefer television shows that contain other children, animals, puppets, and animated characters [1, 3, 24]. The level of social realism is one of the key features that influences whether children develop emotional attachments, like parasocial relationships, with media figures [7, 12, 20]. According to Rosaen and Dibble [37], "Social realism refers to how likely a show's characters and events are to occur in the real world. A character is considered to be socially real if it can be imagined without resorting to fantastical thinking [. . .] On the other hand, if a character could only exist if certain physical principles were violated, that character would be considered to be low in social realism" (p. 147-148). The authors found that with 5- to 12-year-olds, the more a child's favorite character behaved and appeared real, the stronger their emotional attachment to that character [37]. However, VR's perceptual realism can make socially acting characters appear to be physically embodied and realistic, and could potentially impact how children view various characters.

In addition to social realism, children develop positive emotional attachments to characters that utilize perpetual cues that invoke feelings of safety and comfort [12], and the specific type of perceptual cues can impact the type of emotion children feel [12, 41, 50]. For example, a meta-analysis revealed that positive social-emotional connections with media figures was significantly associated with the physical and social attractiveness of the media figure [45]. VR can generate high levels of perceptual realism through its technological features of (a) tracking children's movements so that they can use their bodies to interact with the virtual environment and (b) providing stereoscopic vision and a wide first-person field of view of the content that allows children to see the virtual world similarly to how they visually view the physical world (e.g., depth cues, peripheral vision). By replacing the physical world's sensory information with artificial stimuli, VR can make fantastical characters appear embodied similar to sharing space with another person. VR's ability to create realistic characters may be particularly salient for children in early to middle childhood who are still developing a more mature understanding of the distinction between fantasy and reality as well as estimating the plausibility of events occurring [11, 48]. For example, children in early to middle childhood have confused VR experiences where they saw themselves from the third person as real [40], and the probability of events in VR occurring in their lives [39]. Furthermore, evidence supports that young children show more social behaviors towards characters in VR compared to characters on 2D TV [5].

However, the perceptual cues created by VR could provoke emotional discomfort towards embodied agents representing different levels of social realism. Often referred to as experiencing the uncanny valley, the theory posits that as the appearance of an entity becomes more humanlike, the greater a person's affinity towards it grows [25, 31]. However, this linear increase occurs until it hits a tipping point of human-likeness that causes the entity to be "uncanny," and creates a backlash of negative feelings [31]. Once the entity moves past that negative tipping point of human-likeness, the upward trajectory of affinity restarts. According to the perceptual mismatch hypothesis [25], the uncanny valley creates feelings of discomfort because of "an inconsistency between the human-likeness levels of specific sensory cues" (p. 7). More specifically, the perceptual mismatch occurs with an inconsistency between artificiality and realism. For example, the uncanny valley can occur when an embodied agent has an artificial, unrealistic or cartoonish face with very human-like or realistic eyes [30] or impossible facial features on realistic faces [30, 43]. Often associated with the colloquial term "creepy," the uncanny valley begins during childhood [10] and can be applied to children's perception of a variety of technologies. For instance, Yip et al. [50] found that 7- to 11-year-old children used physical appearance and predictability as factors that define technologies as "creepy." As computing systems like VR improve and technology advances, children will more likely interact with highly realistic artificial entities (i.e., embodied agents), and it will be important to understand the salient factors that impact their experience of these tools.

3 METHOD AND MATERIALS

3.1 Study Overview

A mixed-methods study explored children's perceptions of three different character types of VR embodied agents (Figure 1): (a) a human (i.e., child; high social realism), (b) an animal (i.e., giraffe; moderate social realism), and (c) a puppet, an anthropomorphized character from a children's television show (i.e., Muppet; low social realism). A child, animal, and anthropomorphized puppet character were selected as they represented character types typical of children's 2D screen media experiences [3], and also represented various levels of social realism. Characters high in social realism reflect a high plausibility of an experience occurring in children's daily lives [37]. A child character has the highest level of social realism as children typically interact with other children. A wild animal like a giraffe has a moderate level; while the animal exists in the "real world," it is unlikely that children would share up close indoor space with the animal without using fantastical thinking. Finally, a Muppet has the lowest level of social realism (i.e., a fantastical creature that only exists as a living being in a television show). A giraffe was selected to be familiar but somewhat novel, similar to the novelty of the Muppet character and the child character (i.e., a human that did not represent a specific TV character). Three research questions drove the current study: (1) What are children's perceptions of different types of embodied agents in VR?, (2) What features are important and salient for the design of different types of embodied agents in VR for children?, and (3) How do children's interactions with embodied agents in VR impact their emotional and physical well-being?

The study focused on the unique capability of VR that allows children to approach and stand next to embodied agents similarly to how they would with a live physically present person. Using the VR headset, children saw all three characters in a simple virtual room, then selected and approached a character. When they stood in front of the selected VR character, they reported their initial subjective perceptions of that character. Children then repeated this with the other two characters. After the VR experience, children reported

the salient features that they remembered and provided any suggestions for improving the characters' design. All characters were programmed with idling movements and to turn and look at the children. We kept the interactivity of the characters to a minimum to gain insights on the impact of character type on children's initial impression of approaching an embodied agent without conflating it with extensive body movements. The uncanny valley theory states that movement can intensify the negative response to artificial entities [31], and we were interested in the effect of the overall social realism of the character, not necessarily the impact of their social actions.

Hypothesis 1 (H1): It was hypothesized that the child embodied agent would have a significantly greater number of positive descriptions compared to the giraffe and the Muppet agents, with the giraffe having a significantly greater number compared to the Muppet.

Hypothesis 2 (H2): It was hypothesized that the Muppet agent would have a significantly greater number of negative descriptions compared to the giraffe and the child agents, with the giraffe having a greater number compared to the child.

Hypothesis 3 (H3): It was hypothesized that children would use a significantly greater number of realism descriptors for the child agent compared to the giraffe and Muppet agents, with the giraffe having a significantly greater number of realism descriptors compared to the Muppet.

The study was designed not to negatively impact children's emotional and physical well-being, and evidence supports that VR in certain cases can reduce young children's perceived emotional and physical distress [19]. The selected characters were similar to those found in children's popular media [3], and children's recognition of the characters was measured beforehand to confirm familiarity of these types of characters (i.e., confirming recognition above a 50% threshold). Moderately familiar characters were used to avoid the effect of the embodied agents eliciting negative feelings associated with meeting a stranger. The child character's appearance was similar to characters often found in children's television shows or films, the giraffe represented a non-threatening wild animal, and the Muppet was Grover™ from Sesame Workshop™. Children's emotional distress levels were measured before and after the VR experience to examine the impact of VR on children's emotional well-being. In addition, simulator sickness or cybersickness [18, 29] and physical strain are potential negative side effects of VR. However, short term VR use (i.e., less than 30-minutes) has been shown not have significant and lasting negative effects on children [27, 32, 49]. For example, a study by Yamada-Rice et al. [49] showed that there were no significant negative effects of short VR use (i.e., 20-minutes) on children's binocular vision and balance. In addition, some research suggests that viewing screen content using a properly set up virtual reality headset may be more ergonomic [13] than looking at small handheld screens such as with mobile phones [44]. Children in our study used VR for less than 20-minutes (M = 12.11 minutes, SD = 3.32 minutes), and we measured their physical distress levels before and after the VR experience.

3.2 Participants

The study recruited 28 children, 5- to 9-years of age, from a mid-size city in the southern United States. The final sample consisted of 25 children, with one child excluded for removing the VR headset several times during the VR experience, and two children excluded for stopping the study early. In addition, children were excluded if they had epilepsy, a seizure disorder, or any condition that would make them susceptible to dizziness. No parents reported their children with any of these conditions. Parents and guardians identified their children's birthdate, gender identity (girl, boy, non-binary, a gender not listed), born sex (female, male), and race/ethnicity. No differences existed between how parents identified their children's gender identity and born sex. Parents reported their children's gender identity as 8 girls (32%) and 17 boys (68%), and their age was calculated using children's reported birthdate and the day they started the study (N = 25; M = 95.13 months, SD = 13.66 months, median age = 94.13 months).

Parents identified their children's race and ethnicity as 4% Asian (n = 1); 4% as Black, Latinx/Hispanic, and Native American/First Nation (n = 1); 4% Black and White (n = 1); 4% as East Asian and White (n =1); 4% as Latinx/Hispanic (n = 1); 12% identified as Latinx/Hispanic, Asian, and White (n = 3); and 68% identified as White (n = 17). In addition, parents reported their children's previous technology experience: 56% never used VR before (n = 14), 40% having used it less than once a month (n = 10), and 4% having used it several times a month (n = 1). The majority of children recognized all of the character types, with 76% recognizing the child character, 100% recognizing the giraffe, and 84% recognizing the Muppet.

3.3 Equipment and Virtual Environment

Children wore the Oculus Rift consumer-version (CV1) head-mounted display (HMD). The CV1 contained a gyroscope, an accelerometer and a magnetometer that tracked children's gross translational movements and orientation. The virtual environment was a replica of the physical lab space. The lab space was a large room with two desks and a large TV screen at the front, one desk at the back of the room, and couch off to the side. In the virtual lab, the characters (Figure 1) were randomly placed in one of three spots along a semi-circle, equal distances apart and away from children's starting position. Children viewed the content from a first-person point of view without a rendered virtual body. The positional tracking of the children's height (i.e., along the y-axis) was used to scale each virtual character to the same height as each child. During the experience, an external screen mirrored children's viewpoint for parents and guardians to see their child's experience.

3.4 Procedure

Children provided verbal assent, and their parents provided written consent for participation in the study. Parents and guardians completed an online demographic questionnaire while children completed a pre-test questionnaire (from a larger study), including their emotional and physical distress levels. After the completion of the pre-test questionnaire, the researcher showed children a printed picture of each of the characters and assessed children's recognition of the characters.

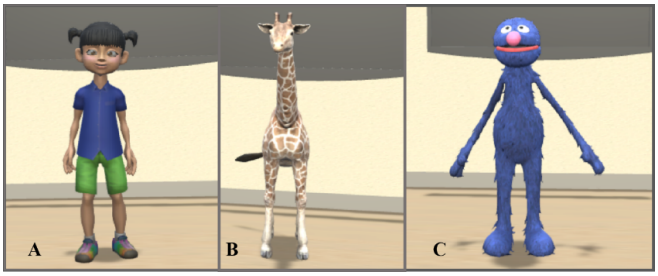

Figure 1: Children interacted in VR with three different character types: (A) human (i.e., child), (B) an animal (i.e., giraffe), and (C) an anthropomorphized creature (i.e., Muppet). The child character was selected, out of 13 options, that had the closest appearance to the child participant.

Next, the researcher placed children into VR. The virtual room contained three different colored spheres located in front of children's views. As part of an orientation phase, the researcher instructed each child to identify the colored spheres. The researcher would adjust the HMD if children were unable to see the spheres or if children's view, displayed on an external screen connected to a computer, showed children's view askew. Next, the researcher stated that the characters would come out to play and used a computer keypress for the characters to appear. Simultaneously, each character grew from one of the locations of the spheres (i.e., randomly assigned), all equidistance from each other and the child participant.

Once the characters stopped growing, the researcher instructed children to walk toward a character. When children walked up to and stopped in front of a character, facing forward, they were asked their initial subjective perception of the character. Once completed, the researcher guided children back to the starting position and the process repeated for the remaining two characters. Once children selected each character, the researcher removed them from the HMD and assessed (a) children's emotional and physical distress, (b) the salience of the characters, and (c) the desired design of the characters. Finally, participants were paid $20 and given a small prize (i.e., a sticker). All aspects of the study were approved by the Institutional Review Board.

3.5 Measures

3.5.1 Demographic Information (pre-test). Parents and guardians completed a questionnaire on their child's (a) race and ethnicity, (b) birthdate, (c) gender identity, (d) sex assigned at birth, and (e) previous VR experience. Next, to assess children's recognition of the characters, a researcher presented children with a printed picture of each of the different characters that they would see in VR (i.e., child, giraffe, and Muppet). A researcher asked children if they recognized what was in the picture, and children's response options were yes, no, or sort of. Children were rated as having recognized the character if they responded with "yes" or "sort of."

3.5.2 Physical Distress (pre- and post-test). Children answered four questions that assessed their physical discomfort before and after the VR experience. The questions were adapted from simulator sickness questionnaires [23, 26]. Children were asked how much their tummy, head, and eyes hurt as well as any experience of dizziness. First, the researcher used a branching method asking a yes or no (0) question and when applicable, responded with the follow-up response options a little bit (1), some (2), or a lot (3). The questions were read aloud to children, and children could answer verbally or select from a visual scale. The scale consisted of a picture of three glasses of water: (a) a small glass with approximately 1/6th full for a little bit, (b) a medium sized glass, approximately 1/3 full, for some, and (c) a large glass, approximately 2/3 full, for a lot. A mean score was calculated across the four questions, with a separate score calculated for before (time 1) and after the experience (time 2). Higher scores indicate greater physical distress. Scores from time 1 ranged from 0 to 1 with a mean score of 0.09 with a standard deviation of 0.23 ($N = 25$). Scores taken at time 2 ranged 0 to 1.25, with a mean score of 0.12, and a standard deviation of 0.28 ($N = 24$).

3.5.3 Emotional Distress (pre- and post-test). Children answered three questions to assess their emotional distress levels. Questions were adapted from the PEDs-QL 4.0 Emotional Functioning subscale questions for 5- to 7-year-old children [46]. Children were asked how afraid, sad, and worried they felt. First, the researcher used a branching method asking a yes or no question and then responded with the follow-up response options a little bit, some, or a lot. The same process and scoring as the physical distress measure were used (see above). A mean score was calculated across all three questions, with separate scores calculated for time 1 ($N = 25$; $M = 0.31$, $SD = 0.47$) and time 2 ($N = 25$, $M = 0.13$, $SD = 0.32$). The pre-test scores ranged from 0 to 1.67, and the post-test scores ranged from 0 to 1.33. Higher scores represent greater emotional distress.

3.5.4 Initial Subjective Perceptions of Characters (during experience). An open-ended question assessed children's subjective perceptions of each of the embodied agents. Children approached each character during the VR experience. Once children were in front of the character, the researcher asked, "What is it like to see this character?" A broad open-ended question was used to identify the categories and language that children used to describe their experience of VR embodied agents, without leading children to a specific answer.

3.5.5 Salience of Characters (post-test). As part of the post-questionnaire, children answered an open-ended question assessing the factors of the VR characters that were most salient. A researcher asked, "What do you remember about the characters?"

3.5.6 Desired Design of Characters (post-test). As part of the post-questionnaire, children answered an open-ended question to assess their desired design choices for the VR characters. A researcher asked, "Is there anything you wish was different about the characters?" and asked for reasoning when children responded with "yes."

4 RESULTS

4.1 Overall Data Analyses and Coding Techniques

Data analyses utilized a mixed-method approach and were completed using *R* [35]. Thematic analysis, following Braun and Clark's

6 phase process [9], identified and analyzed themes related to children's subjective perceptions of the VR characters. We used inductive coding to give initial codes to children's responses for each question. Within each question, similar codes were grouped together to generate themes and definitions of those themes. This process was repeated four times for the finalized themes and codebook. Children's responses to the initial subjective perception question was first given initial codes according to each character, and then themes were developed across all character codes. For the post-test questions (i.e., the salience and desired design of the characters), initial codes and themes were created for each individual question. For the quantitative data analyses, mixed-effects models utilized the lmerTest package to obtain p-values, and the child character acted as the base comparison character.

4.2 The Effect of Type on Children's Initial Subjective Perception of VR Characters

4.2.1 Children's Overall Perceptions of VR Characters as Social-Emotional Reactions and Views on Realism. Children's responses centered around (a) the overall social-emotional experience of the character (i.e., positive, negative, perplexing, neutral, and a combination of positive and negative) and (b) the characters' realism, centering around the characters' life-like realism, behavior, personhood, embodiment as well as tensions around fantasy-reality distinctions. Each child's responses were given one unique code per theme category (i.e., overall social-emotional impression, experience of realism). Children's responses about the character being life-like were coded when they stated that the character looked "real," similar to real life, or specifically stated that the character was akin to their physical world counterpart (e.g., like a giraffe or human). For the Muppet, if children referred to the character being in another media form, such as "like from TV," it was coded as a physical world counterpart. When children described how the character's body moved, including eye movement, it was coded as the character's behaviors. When children described the characters as having human internal abilities or social qualities, such as emotion, intelligence, or social categories (i.e., "It feels happy," friend), they were coded as personifying the character. The character embodiment code represented responses where children noted the character's virtual body, including (a) proximity of the characters, (b) the size or appearance of the characters' bodies, and (c) the desire to physically touch the characters or to go inside the characters' virtual bodies. Finally, children that commented on the characters as being fantastical or making comparisons between fantasy and reality were coded as discussing the fantasy-reality distinction.

Children reported a wide range of perceptions about the experience of seeing each of the characters. There were 58 unique reports on children's overall social-emotional impressions of the characters (Table 1) and 47 unique reports related to themes of realism (Table 2). Many children described their impressions of the giraffe positively while describing both the child character and the Muppet negatively (Table 1). However, the child character was the only type that covered the entire range of social-emotional descriptions, including a middle ground (i.e., neutral). Each character had at least one participant (among two different children) that used conflicting emotional language when describing the experience, specifically as weird and enjoyable: "Kinda normal except it's kinda cool and kinda weird. It's a cartoon." (referring to child character [P17]), "Kinda creepy. Weird, amazed, realistic" (referring to giraffe character [P8]), and "Awesomely freaky" (referring to Muppet character [P8]).

A mixed-effects binomial logistic regression model analyzed if there was a significant effect of type on whether children reported a positive impression of the embodied agent (Table 1). Character type acted as a fixed factor and participant as a random factor. Significantly fewer children described seeing the child agent ($n = 6$) using positive terms compared to the giraffe (n =12, $b = 3.23$, $z = 2.25$, $p = 0.02$). However, there was not a significant difference in the number of children that described the child agent positively compared to the Muppet agent ($b = 0.34$, $z = 0.34$, $p = 0.34$). Utilizing planned orthogonal contrasts, there were significantly a greater number of children that described the giraffe positively ($n = 12$) compared to the Muppet ($n = 6$; $b = 1.45$, $z = 2.19$, $p = 0.03$). However, there was no significant difference in the number of positive descriptions of the child character compared to the average of both the giraffe and Muppet ($b = 0.60$, $z = 1.71$, $p = 0.09$). Overall children experienced more positive social-emotional perceptions of the giraffe compared to the child and Muppet characters.

A mixed-effects binomial logistic regression model analyzed the effect of character type on children's negative descriptions, with character type as a fixed factor and participant as a random factor. Analysis showed that there was a significant effect of character type on the number of children that used negative terms. There were significantly more children that negatively described the child character (n =10) compared to the giraffe character ($n = 4$; $b = -2.24$, $z = -1.98$, $p < 0.05$). There was no difference in the number of participants describing the child character negatively compared to the number describing the Muppet negatively ($n = 10$; $b = -0.27$, $z = -0.31$, $p = 0.76$). Furthermore, planned orthogonal contrasts showed no significant difference in the number of children that described the Muppet in negative terms compared to the giraffe ($b = -0.98$, $z = -1.83$, $p = 0.07$), and no significant difference when comparing the number of children describing the child character negatively compared to the average of both the giraffe and Muppet ($b = -0.57$, $z = -0.89$, $p = 0.37$). Overall, more children had a negative social-emotional response to the child and Muppet characters.

Finally, a mixed-effects binomial logistic regression model tested for significant differences in the number of realism descriptions between the three types of characters (child, giraffe, Muppet). There was no significant difference in the number of realism descriptions between the child character (n =11) and the giraffe (n =17; $b = 0.49$, $z = 1.20$, $p = 0.23$). In addition, there were no differences between the child character (n =11) and the Muppet on the number of realism descriptions (n =19; $b = 0.62$, $z = 1.54$, $p = 0.12$). Planned orthogonal contrasts showed no significant difference between the giraffe and the Muppet in the number of realism descriptions ($b = -0.06$, $z = -0.36$, $p = 0.72$), nor a significant difference between the child character compared to the average of both the giraffe and Muppet characters ($b = 0.18$, $z = 1.52$, $p = 0.13$). Overall, there was no significant difference in children describing the realism of the three characters.

Table 1: Children's Social-Emotional Impressions of VR Characters by Type

Overall Social-Emotional Impressions[a]	Child (n = 20)	Giraffe (n = 18)	Muppet (n = 20)
Positive (i.e., fun, cool, exciting)	6	12	6
Negative (i.e., weird, creepy, scary, dumb)	10	4	10
Perplexing (i.e., unsure, hesitant)	1	1	3
Neutral (i.e., typical, normal)	2	0	0
Conflicting (i.e., enjoyable and strange)	1	1	1

[a] Total represents individual children that described social-emotional impressions. All children interacted with each character (N =25)

Table 2: Children's Realism Perceptions of VR Characters by Type

Descriptions of VR Characters' Realism[a]	Child (n = 11)	Giraffe (n = 17)	Muppet (n = 19)
Life-like or Familiar Counterpart	5	8	8
Character Behaviors	1	3	3
Fantasy-Reality Tension	2	0	3
Character Embodiment	2	5	3
Character Personification	1	1	2

[a] Total represents individual children that reported descriptions of realism. All children interacted with each character (N =25)

4.2.2 Effect of Character Type: When VR Realism of Embodied Agents is an Asset or a Hinderance. The life-like realism of the characters was the leading realism descriptor that children described when standing in front of the embodied agents during the VR experience, and it acted as the major contributor to children's description of the experience as positive. However, this was primarily driven by their perception of the giraffe character: "Feels like seeing a real animal. Nice" (P18), "Like to see your own pet" (P19), "Kind of cool because I have never met a giraffe in my life" (P17), and "I have never seen one so it's really cool" (P25). In contrast, the overall negative descriptions of the VR characters as "creepy" and "weird" focused on the characters' behavioral realism, most notably with eye contact (e.g., "Strange. Looks like he is staring at me," referring to child character, P2). This was particularly true for the Muppet character: "Odd. Because it's moving, but not seeing me" (P5) and "Creeped out—he's just staring" (P13). In a few cases, the life-like realism of the giraffe elicited concerns of being too life-like: "Kinda scared it's going to run me over" (referring to giraffe, P20). This also carried over to the Muppet character: "Kinda creepy now. . .feels like, not sure, I have to run away because it's a monster" (referring to Muppet, P14). Although many children described the experience of seeing the Muppet as "weird," "creepy," or "scary," children that described the character in positive terms (n = 4), typically referred to the character's real-life counterpart being on TV: "Kinda cool. He is in a TV show" (P1) and "It's cool to see because I watch Sesame Street a lot" (P25). However, there were two cases when recognizing the Muppet had the opposite effect: "Dumb. Only a character on Sesame Street and that's baby stuff" (P4), and "Weird, reminds me of the Mu[pp]ets" (P10). Interestingly, the child character was the only VR character that generated a neutral impression, and it was related to the character being life-like (e.g., "Normal, because it's a normal human" [P10], and "I see them every day" [P25]). Instead of being too realistic or focusing on its behaviors, participants described the negative attributes of the child character in relation to its appearance, deviating from expectations of a human-counterpart: "Kind of odd because he kind of looks like me except his hair is different" (P18).

In summary, children described the perceptual realism as a positive feature for the character with moderate social realism, the giraffe, and as a hinderance for the child, high in social realism, and the Muppet, low in social realism. In some cases, the perceptual realism of the child character didn't impact children's responses positively or negatively, but only that it was similar to their typical lives. Children also noted that the behavior of the character was a key factor in their negative view of the embodied agents, particularly for the child and Muppet.

4.2.3 VR Character Type Primes Tension between Fantasy and Reality. Children's responses also reflected a struggle between understanding that the media figures represent fictional characters and the realism of the VR experience. Upon meeting the child character, one participant stated, "Kinda weird. This is not real right now" (P9). For the Muppet, children noted the fantasy-reality distinction in both positive and negative terms: "Cool, since I never knew he is alive but he is not alive" (P20), "Weird because it's not a real thing" (P3), and "Kinda funny, would not normally be seeing him. He is in a place not in real life and he looks kinda funny" (P17). This tension may be a result of the perceptual realism of the characters, the illusion that they were physically present. Children specifically commented on (a) the characters' virtual bodies appearing physically present, (b) trying to touch the characters, (c) the proximity of the characters, and (d) the size of the characters' bodies. For instance, when noticing these embodied characters, children commented on (a) not being able to touch the virtual bodies and (b)

being able to pass through the virtual bodies: "Nothing, can't even feel him" (referring to child character [P23]); "Can't feel it! Kinda creepy. Weird, amazed, realistic. Wow!" (referring to giraffe [P8]); and "When I touch him I don't feel anything" (referring to Muppet [P9]). Furthermore, children commented that the characters where in close proximity to their own bodies: "Weird because it's right next to me" (referring to giraffe [P5]), and "[It's] closer than the real TV" (referring to Muppet [P3]). When commenting on the size and shape of the characters, children emphasized the heads or faces: "He is really big. A little crazy and he has a big head" (referring to child character [P14]); "Weird. Hair looks weird" (referring to child character [P3]), "His face is big" (referring to giraffe character [P21]) and "I am touching the character, I saw right into his nose" (referring to Muppet character [P23]). Finally, in connection with the fantastical appearing real, children applied qualities of personhood across all three characters, suggesting they view them as physical beings: (e.g., "Like to see a friend," referring to child character [P1]). Often, children used the appearance and action of the characters as indicators of personhood: "I feel that it's happy. It's wagging its tail" (referring to giraffe [P25]), and "Gloomy and sad because of [the] color of [the] fur, and he is quite sad. I think he changes color" (referring to Muppet character [P22]).

4.3 Movement Over Visual Appearance: What Children Remember About and Desire for VR Characters

After the VR experience, a researcher assessed the salient features of the characters by asking children what they remembered about them. When remembering the experience, children prioritized how the characters moved over how they visually appeared. More than half of the children remembered the characters' body movements (n = 14), commenting on the characters' heads movements (i.e., moving back and forth), eye contact (i.e., staring at them, not noticing them, turning towards them), facial movements (i.e., smiling, blinking), gross body movements (i.e., turning towards them, their movements repeating, all moving in different ways), and shrinking into the spheres. For example, one child noted the speed of blinking from the child character was the biggest factor contributing to its creepiness, and another child explained that the characters acted "dumb" because they "didn't seem [like] they moved anything" (P4). As the next most common remembered aspect, children commented on the characters' visual appearance (n = 7). Children's descriptions emphasized the colors that they saw (n = 7), describing almost exclusively (a) the color of the shirt, shoes, and hair of the child character, (b) the Muppet character as blue, and (c) the giraffe having brown spots. However, deviating from only describing color, one child commented on the Muppet's face having large eyes, a red nose, and looking like a puppet, and two other children observed that the characters were the same height as them.

After commenting on movement and appearance, the remaining children focused on the characters as representing distinct categories (n = 4; i.e., a child, giraffe, and Muppet or "the blue one" from Sesame Street). When recalling the characters as distinct categories some children noted that they related to fantasy and reality, describing the giraffe and the child character as "from real life" and the Muppet from a television show (one participant categorized the child character as a cartoon). One child stated that the giraffe character "surprisingly looked kind of real" and was the reason that the experience was "freaking weird" (P8). In other cases, children noted that the categories related to a social-emotional intensity; "One was a boy. One a giraffe. One was crazy, and that one was Grover" (P20); "They were all different and each made me feel a different way"(P13). Next, children commented on the physical technology itself or that the VR experience afforded them the ability to pass through the characters' virtual bodies. Two children commented on the technology itself as being salient to them: "They are all projections in VR" (P19) or "coming from that thing" (referring to HMD, P9). This also included children noticing that the VR experience allowed them to pass through the characters' virtual bodies (n = 3), and one child specifically recalled this ability as a positive aspect of the VR experience.

Finally, children reported on any design improvements they had for the VR characters. Demonstrating greater intelligence via body movements was the design improvement children suggested most often (n = 10). Specifically, children wanted the characters to talk, move their heads more, blink more, have more facial expressions, and "see" or "notice" them. One child expressed that it "would make me feel more good [sic, if] they could look at me and say, 'Hi"' (P22). In addition to specific social behavioral movements, two children specifically stated wanting to play games with the characters. Another child wished that they were able to physically feel the characters and everything in the virtual environment, while another child wished that the characters were less "creepy" and that the Muppet "was the creepiest" (P9). Finally, one child simply wanted more characters "because it's really cool and that giraffe didn't bite" (P13).

4.4 Physical Distress

A mixed-effects linear regression model compared children's physical distress score at time 1 (pre-treatment) and time 2 (post-treatment). The model included time as a fixed factor and participant as a random factor. Results showed no significant difference between children's physical distress level at time 1 (n = 25; M = 0.09, SD = 0.23) compared to after the VR experience at time 2 (n = 24; M = 0.12, SD = 0.28; b =0.05, t = 0. 79, p = 0.44).

4.5 Emotional Distress

Finally, a mixed-effects linear regression model compared children's emotional distress score at time 1 (pre-treatment) and time 2 (post-treatment). The model included time as a fixed factor and participant as a random factor. Children reported significantly less emotional distress after the VR experience at time 2 (n = 25; M = 0.13, SD = 0.47), compared to before the VR experience at time 1 (n = 25; M = 0.31, SD = 0.32), b = -0.17, t = -2.36, p = 0.03).

5 DISCUSSION

This study explored children's perceptions of different embodied agents in VR. Analysis revealed that children experienced different types of social-emotional and realism perceptions based on character type. More specifically, the results suggest that the familiarity and social realism of the characters interact with the perceptual realism created by VR technology to influence children's initial

social-emotional experience. Overall, the giraffe, the character with moderate social realism, elicited the most positive descriptions, with children stating that the experience was fun and exciting. Children indicated that the life-like realism of the giraffe was "cool" and provided them with a new opportunity (i.e., "I have never seen one so it's really cool"). In contrast, the realism of VR acted as a hinderance for the Muppet, an anthropomorphized creature that only exists in fantasy (i.e., low social realism): "Weird because it's not a real thing." However, when children noted recognizing the Muppet from other 2D media experiences, the realism of the Muppet acted as a benefit: "Kinda cool. He is in a TV show." Repeated positive interactions may be particularly important for children using VR that include anthropomorphized creatures, like a Muppet, low in social realism. Children often develop parasocial relationships, or one-way emotionally tinged relationships, with media characters that they have interacted with in multiple formats [7, 12]. Selecting characters children have interacted with several times in advance, or introducing the characters beforehand may mitigate feelings of strangeness towards characters in VR. Finally, the majority of children's responses were positive or negative, with very few children describing the experience as neutral or calming. Interestingly, there was no significant difference between characters in their overall number of realism descriptions. This suggests that although characters can have various levels of social realism, children notice VR's perceptually realism similarly across character types. For instance, children described the embodiment and the personification of the characters similarly across types, and treated the characters' virtual bodies as being physical bodies, even though they acknowledged they knew the characters were not "real."

In addition, our results suggest that to evoke positive-social emotional responses in VR, human or highly novel anthropomorphized embodied agents may need higher behavioral realism compared to animal characters that are farther away from human-likeness. Potentially reflecting the perceptual mismatch hypothesis of the uncanny valley theory [25, 30], children in our study may have expected highly realistic behaviors from the human and anthropomorphized characters that appeared to be "real" (The uncanny valley hypothesis states that movement can intensify the effect of discomfort [31]). For instance, children attributed the movement of the child and Muppet characters' eyes (i.e., rate of eye blinking) and facial features as making the characters strange. This aligns with previous research on interactive technologies, with 7- to 11-year-olds stating that a "smart" toy doll's eye blinking and movements were creepy because it implied that the doll had "ulterior motives" [50], and with 9- to 11-year-olds rating virtual characters that lacked facial expressions in the upper part of the face as stranger and less friendly than those with full facial expressions [43]. However, children in our study desired increased intelligence and interactivity as the biggest improvement for the characters (i.e., adding speech capabilities, direct interaction with characters). In addition, body movement was the most salient feature that children remembered about the VR characters after the experience. Research by Piwek et al. [34] suggests that increasing the movement quality of animated computer-generated characters increases users' acceptance of them.

Our results also imply that leveraging photorealism for characters with moderate realism (i.e., giraffe) is beneficial. For example, the majority of children spoke about the giraffe as having "a pet" or similar to "real life." The child character may have benefited from appearing more proportional and photorealistic like a child in the physical world. For instance, children commented on the shape and appearance of the child character as being off putting (i.e., large head, "weird hair"). A research study with adults showed that characters with 50% photorealism for the eyes and 75% photorealism of the skin were rated as the most assuring of human computer-generated faces [30]. Increased photorealism of the child characters' face and eyes in addition to increasing the child character's behavioral realism might have reduced the feeling of eeriness for the participants in our study. It may be the case that when designing VR experiences, utilizing animal characters are more likely to provide a close to universal positive reaction during an initial introduction compared to a human or an anthropomorphized creature.

Previous research utilizing VR with children in early to middle childhood has shown the overall positive use of VR, particularly in the medical field [19, 47]. However, VR continues to be a powerful technology that tricks the mind to believe artificial stimuli is real [6], and precautions must be taken to determine its suitability for young populations, including developing the appropriate designs. Our results illustrate that children in early to middle childhood have intense emotional responses, both positive and negative, to embodied agents in VR. For the larger community of HCI, researchers and designers will need to consider the type of emotion that they hope to evoke from users that interact with embodied agents. For example, research shows that experiencing intense negative emotion when watching content (i.e., on a television) can negatively impact the ability to remember the content [28], and reduces the likelihood of accepting factual information as plausible [48]. In addition, future research could examine the impact of the social realism of embodied agents on both adults and children. Importantly, our results show that although some children experienced negative emotion during the experience, there was no lasting emotional and physical distress with a 20-minute or less VR experience, which follows previous research [49]. If researchers and designers want to leverage the benefits of VR and avoid negative emotions such as creepiness or fear, design recommendations are to avoid introducing anthropomorphized embodied agents low in social realism that children have not experienced in previous interactions. Additionally, increasing the behavioral realism of embodied agents may override the potential discomfort that they feel from an unfamiliar situation, and is an important factor for children interacting with agents in VR. However, interventions could be developed for users to practice experiencing negative emotions and accepting others such as utilizing a character whose appearance differs from their own. Finally, if VR is to be ethically used with young populations, experiences need to be short and the content designed for specific ways that can benefit children's lives beyond what other mediums can provide.

5.1 Limitations and Future Directions

The results of this study demonstrate that the type of characters that children encounter in VR influences their social-emotional perceptions. The interpretation of the results needs to be considered

in regards to its limitations, which provide opportunities for future directions. First, there were only three models used in the project which varied on their exact level of photorealism. Future research could utilize stimulus sampling to examine the effect of the intersection of character type, photorealism, and behavioral realism. For example, children may have a negative response to a highly unusual animal character or a more positive response to a highly photorealistic child character. Second, children reported their emotional and physical distress before and after the experience. Measuring children's real-time physiological emotional response during the experience would provide a deeper understanding of children's automatic responses to VR characters. Third, the study utilized a 3D model of the physical room of the study, and additional research could identify if the type of environment may intensify or mitigate children's emotional responses and their attention. Next, children interacted with the characters during a first one-time session, and only within VR. While these results shed light on children's initial introduction of VR embodied agents, repeated exposure to the different types of characters could influence their views of the characters as positive, negative, or conflicting, and experiencing these characters within less immersive mediums could show different effects of character type on children's perceptions. Also, expanding on the characters' social interactions could provide insight on how the intersection between character type and behaviors impacts children's perceptions of VR. Finally, our sample consisted of children with no previous VR experience and those with some, including one child that used it once a month. Novelty could impact children's experience with VR, and future studies could examine how children's previous experience with VR as well as their recognition of the characters impacts their perceptions of VR embodied agents.

5.2 Conclusion

Virtual reality has the potential to positively transform children's educational, medical, and entertainment experiences by transporting them to other worlds that feel perceptually real. As such, character designs created for immersive technology like VR must be carefully crafted to provide its intended benefits. Researchers and designers must continue to closely evaluate the use of and design of VR for children to inform the public of its impact and age-appropriateness.

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