CHAPTER 9

Immersive Virtual Reality and the Developing Child

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Virtual reality (VR) allows users to fly across the skies, swim through the depths of the ocean, and become mythical creatures with magical powers. Immersive virtual reality (IVR) places users directly into virtual scenarios by blocking out the physical world, creating vivid and personal environments (Bailey et al., 2015; Bainbridge, 2007). Ivan Sutherland developed one of the earliest forms of IVR in the 1960s. Small displays connected to an apparatus hanging from the ceiling were placed over participants' eyes, creating one of the first times that people fully entered a virtual space. In the same decade, Morton Heilig pushed the limits of humans in virtual spaces by creating the Sensorama, a machine that created multisensory experiences with haptic, olfactory, and visual feedback (see Blascovich & Bailenson, 2011). For many decades, IVR technology was only available to research institutions, governments, and universities. It is now becoming more accessible and available to the public, as giant media corporations invest billions of dollars in IVR hardware and software (Lamkin, 2015; Solomon, 2014).

Decades of research have examined the uses and effects of VR with adult samples, demonstrating its power to alter attitudes (e.g., Peck, Seinfeld, Aglioti, & Slater, 2013), behaviors (e.g., Blascovich et al., 2002), and physiology (Salomon, Lim, Pfeiffer, Gassert, & Blanke, 2013). However, little is known about IVR and children despite their frequent media use and willingness to adopt new technologies (Lauricella, Cingel, Blackwell, Wartella, & Conway, 2014; Rideout, 2013). Given that IVR technology is gaining traction in the consumer market, it will be important to consider the developmental implications of its use.

This chapter will define IVR from both a technological standpoint (i.e., tracking, rendering, embodiment of senses) and a psychological standpoint (i.e., immersion vs. presence). We discuss some of the unique

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attributes of IVR, and how they relate to topics of cognitive development, as pertaining to the development of executive functioning (EF) in early childhood. We also discuss the trends in empirical studies regarding IVR use among child populations, and provide future research directions.

WHAT IS VIRTUAL REALITY (VR)?

In virtual environments, a person is represented by an avatar, a digital representation of that person that he or she controls in real-time. In general, an avatar refers to any entity, digital, or nondigital, that represents the user in real time. When embodying an avatar, a person can have a first-person view of the virtual environment ("through one's own eyes") or a third-person view (having an outside perspective as if looking at a third party). In contrast to an avatar, an embodied agent is a digital representation that is solely controlled by a computer algorithm. What controls the digital representation, a person or a computer, determines if the representation is an avatar or an embodied agent. For example, a digital representation that looks like someone's aunt and is controlled by a computer algorithm is an embodied agent. However, if that same aunt controls a digital representation that looks like a dinosaur, it would be considered her avatar.

In a technological sense, VR can be defined by the tracking and rendering of a computing system or technology (e.g., computer, phone, tablet). Tracking captures the movement of the user (pushing a button, movement of the wrist, or swiping of fingers on a screen) and renders or updates the virtual world based on that tracked movement (e.g., the jumping of a character). Actions are tracked and rendered using translations (movement along *x*-, *y*-, *z*-axis) and/or orientation (pitch, roll, and yaw). A tracking device such as a sensor or a joystick detects a user's physical movements or location, and then renders or updates the virtual environment accordingly. For example, in a video game the player pushes the joystick forward (tracking his or her motion), and the virtual character moves up on the screen. Tracking body movements can occur through physical devices worn or held by the user (e.g., joystick, game pad, LED light sensor) or without the user wearing a device (e.g., infrared cameras). Senses that can be rendered in virtual environments are sight, hearing, touch, smell, and taste. Sight is the most common sense rendered in VR, and has been shown to elicit powerful responses from users even when other senses (i.e., touch, smell) are absent (Blascovich & Bailenson, 2011).

From a psychological vantage point, VR can be defined as an environment (actual or simulated) in which the perceiver experiences it as real

(Blascovich & Bailenson, 2011; Steuer, 1992). Presence is one term that is used to describe VR's psychological effect. Presence refers to the sensation of being located in a media event (Bowman & McMahan, 2007; Lee, 2004; Steuer, 1992), and is often used as an indicator of how involved a person feels or acts in a given event (Lombard & Ditton, 1997). People respond to virtual stimuli as if it were real, in ways that are similar to everyday experiences (Slater & Wilbur, 1997). Thus, a person feeling high presence staring into the eyes of a lion on a virtual Savannah, for example, would feel an increase in heart rate and perspiration. The overall concept of presence contains specific subcategories such as self-presence, social presence, and spatial presence. Self-presence refers to the degree that users identify with their avatars (i.e., experienced them as their actual bodies). Social presence refers to how other virtual representations or characters that are present seem real to the user (e.g., having the amount of interpersonal distance toward a digital character similar to that of a real person). Spatial presence refers to the degree that the virtual environment feels real; this term is often used interchangeably with the general term presence.

IMMERSIVE TECHNOLOGY

Immersion refers to the extent that a computing system can create a surrounding environment that shuts out the physical world, utilizing sensory modalities to create a rich representational experience (Slater, 2009). Immersion is defined by the objective capabilities of the technology. Immersive features can include, but are not limited to, the field of view, body tracking, frame rate, sound quality, or realism (Bowman & McMahan, 2007; Cummings & Bailenson, 2016; Slater, 2009). Presence refers to a subjective psychological experience while immersion refers to objective capabilities of the technology. For example, a person may feel a greater presence reading a novel, a form of media that has low sensory fidelity as compared with a television screen that has greater visual sensory feedback.

IMMERSIVE VIRTUAL REALITY (IVR)

IVR can be defined as a technological system consisting of a computer and a display (i.e., computer screen, projection screen). IVR has a rich sensory fidelity and immersive features that block out the physical world, and enable users to feel psychologically located in the simulated environment by experiencing it as real. Two types of technology commonly used to create

IVR are Cave Automatic Virtual Environments (CAVEs) and head-mounted displays (HMDs). A CAVE is a specially designed room in which the walls, ceiling, and or floor are covered with a screen that projects virtual images (Cruz-Neira, Sandin, DeFanti, Kenyon, & Hart, 1992). Three-dimensional views are created by either donning special eyewear such as stereoscopic glasses or by using autostereoscopic screens. In highly immersive CAVEs, the user is surrounded by the virtual environment (via the walls, ceiling, and floor). An HMD is a VR headset that places small screens in front of the user's eyes that block out other visual stimuli. It utilizes stereoscopic or monoscopic views, offering varying degrees of the field of view.

The assumption of many scholars is that greater levels of technological immersion create greater levels of presence. In a meta-analysis by Cummings and Bailenson (2016), it was found that immersion had a moderate effect on presence. The immersive features most associated with increasing levels of presence were the levels of tracking, stereoscopic vision, and the field of view. Other features such as sound quality and resolution had less of an effect. IVR is one type of technological system that has features that can elicit high levels of presence: it has the capability of providing many levels of tracking (i.e., the number and type of degrees of freedom) and the ability to mimic the human visual system with stereoscopic vision and a wide field of view. By experiencing high levels of presence, users will treat experiences in IVR as real, potentially influencing their behaviors and psychology in the physical world (Blascovich et al., 2002; Slater et al., 2006).

WHAT MAKES IVR UNIQUE?

IVR can provide users with multisensory experiences that replicate the physical world or create scenarios that are impossible or dangerous in the physical world (Blascovich et al., 2002). In the following, we focus on the unique capabilities of an HMD, an IVR technology that completely blocks out the physical world, including the user's body. Although a CAVE has many immersive qualities, the user cannot change how his or her body is represented in the virtual space from a first-person perspective. In contrast, with an HMD, users can look down and see their digital representation as a different sex, ethnicity, or body size; they can even embody an animal or an imaginary creature.

Through the powerful affordances of IVR, people treat their virtual bodies (i.e., their avatars) as their own, influencing their attitudes, behaviors, and physiology. Research has demonstrated that people are able to map their body schema onto virtual representations (i.e., avatars), and treat those representations as if they were their physical bodies (Banakou, Groten, & Slater, 2013; Blanke, 2012; Petkova & Ehrsson, 2008; Slater, Spanlang, Sanchez-Vives, & Blanke, 2010). Virtual embodiment can influence the brain such as to reduce pain perception (Hoffman et al., 2008), facilitate retraining for stroke rehabilitation (You et al., 2005), and even reduce skin or body temperature (Salomon et al., 2013). Findings also show that people claim a sense of ownership and agency over virtual bodies that differ drastically from their physical bodies (e.g., with a functional tail; Steptoe, Steed, & Slater, 2013), and can influence perceptions and attitudes in the physical world. For example, adults tended to overestimate the sizes of objects when embodying an avatar resembling a 4-year-old child versus an adult scaled to the same height as the child (Banakou et al., 2013). Peck et al. (2013) found that controlling an avatar of a different race reduced implicit race bias.

IVR has also been shown to alter how people interact in a virtual environment, which can influence how they interact socially with others. These transformed social interactions (TSI) refer to behaviors in the physical world that are filtered through a computer algorithm that transform the social interactions users have in the virtual world. These transformed actions can (a) alter how an avatar or embodied agent is presented to others (e.g., match the height of another user), (b) enhance the user's sensory capabilities (e.g., having confused audience members appear larger to the speaker as a signal that further explanation is needed), and (c) modify the context of the virtual experience (learning about ancient Greece from the Parthenon; Bailenson et al., 2008; Bailenson, Beall, Loomis, Blascovich, & Turk, 2004).

In IVR, users can transform the appearance and behavior of avatars and embodied agents to fit specific contexts to influence others socially. For instance, a person can present different versions (i.e., different genders, race, age, and height) of their avatar to different people simultaneously (co-workers, friends, strangers) to appear more appealing to a wide audience. Or in a virtual classroom, students could see a teacher whose race, gender, or affective qualities best suited their comfort and learning needs. Algorithms that change the appearance and behavior of avatars or embodied agents can yield real-world effects. A study by Bailenson et al. (2008) found that participants viewed embodied agents that mimicked their head movements during a speech to be more persuasive than those that did not.

TSI can enhance users' sensory abilities such as augmenting their view within the virtual environment. If a teacher lecturing in front of a virtual classroom does not maintain enough eye contact with one student, IVR can make the appearance of that student visually fade until the teacher regains adequate eye contact with the student (Bailenson et al., 2008). By extending the abilities of teachers in virtual classrooms, TSI in IVR could help train teachers (or any speaker) to distribute attention more evenly among students to facilitate learning.

Finally, the context of a virtual environment can be altered spatially and/or temporally. Users can always feel that they are at the front of a room regardless of where they are actually located in the virtual space to better see the speaker or they could pause the lecturer to catch up on note taking. In addition, altering the context could help students learn by interacting directly with course materials. For example, students in a marine biology class could interact with underwater plants and sea creatures in a virtual ocean ecosystem to learn about individual species, without the risk or cost of an actual scuba-diving expedition.

CHILDREN EXPERIENCING IVR AS REAL

Media effects scholars have demonstrated that the body responds to digital media-technology (e.g., computers, televisions, IVR) as if it were real (Reeves, 1989; Reeves & Nass, 1996), and that the mind has not evolved to respond to it any differently from the physical world (Reeves, 1989). When using IVR as adults, we may know that we are safely located in a room wearing an HMD, yet when looking over the edge of a virtual precipice, our hearts race and our palms sweat (Blascovich & Bailenson, 2011). We comfort ourselves by remembering that we are in the room, by holding in our minds both the physical representation of the room that we can no longer see and the virtual environment with its salient sensory features. Young children, in contrast, may respond cognitively and behaviorally to sensory salient and immersive media like IVR in ways that differ from adults. IVR places users directly into the media content, potentially making the experience very vivid and real for children. For example, Sharar et al. (2007), using an HMD, found children of 6–18 years of age reported higher levels of presence and "realness" of a virtual environment compared with adults 19–65 years of age. If young children experience IVR as more real than adults, they may be more likely to be influenced by the content in both positive (e.g., prosocial education) and negative ways (e.g., increased materialism).

Research suggests young children struggle with the representational nature of certain media (i.e., television) because of the medium or technology itself (Troseth & DeLoache, 1998). This is an issue related to dual representation, the ability to understand the relationship between a symbol and its referent:

> *A symbolic artifact such as a picture or a model is both a concrete object and a representation of something other than itself. To use such objects effectively, one must achieve dual representation, that is, one must mentally represent the concrete object itself and its abstract relation to what it stands for.*
>
> ***(DeLoache, 2004, p. 69)***

Dual representation allows children to understand the symbolic nature of media, which can facilitate and influence learning. This ability develops around the age of 3 and begins to develop fully during a time when executive function significantly improves (Obradović, Portilla, & Boyce, 2012).

Even in less-immersive media like a two-dimensional (2D) television screen, young children experience the content as real to a greater extent than their older counterparts, and this can affect how they behave and what they learn (Richert, Robb, & Smith, 2011). For instance, television research has shown young children are more likely to view the content as real compared with older children (i.e., thinking that popcorn will fall out of a bowl, if the researcher tips over the television screen holding the image; Flavell, Flavell, Green, & Korfmacher, 1990). Furthermore, children will use the content and characters in television as sources of information for decision making, if they feel the content and characters are real (Claxton & Ponto, 2013). Although research with less-immersive technologies has shown how children cognitively and socially experience content, it is unclear how children respond to IVR compared to these less-immersive technologies. IVR can create realistic sensory-rich experiences that place children directly into the content, which could make it challenging for them to recognize that it is a representation. For example, a young child may think that an embodied agent is an actual person, not a digital representation; this could influence the type of decisions that they make or the intensity of emotions they feel. According to DeLoache (2000, 2004), the more salient or appealing the appearance of the symbol, the more difficult it is for children to achieve dual representation.

How children cognitively and socially experience IVR as real could be influenced by brain development. The mental capabilities and skills of children develop differently over time according to a hierarchy of neural circuits in the brain (Fox, Levitt, & Nelson, 2010). For instance, younger adolescents may be less sensitive to social cues such as exclusion than older adolescents because regions of the brain related to social cognition mature slowly

(Blakemore & Mills, 2014). With the different neural circuits developing at different stages, it would be expected that children of different ages would respond to the same virtual experience differently. Brain-imaging research by Baumgartner et al. (2008) and Baumgartner, Valko, Esslen, and Jäncke (2006) suggests that adolescent and adult brains process virtual environments differently from how younger children do. Specifically, both adolescent (13–17 years of age) and adult (21–43 years of age) brains recruited regions located in the prefrontal cortex, an area associated with higher-level brain functioning, while younger children (8–11 years old and 6–11 years old, respectively) showed less activation in this brain region. Overall, based on how higher-order cognitive skills develop, one's developmental level may influence how media are understood and interpreted, and immersion may be one component of media that could influence cognition and behavior.

The immersive affordances of IVR have the potential to challenge young children's automatic reactions, such as motor or attentional reactions, and cognitive abilities. IVR can stimulate cognitive immersion, a process in which the mind and body become integrated with a virtual experience, given the technological affordances of the system. Specifically, IVR connects human senses with the technology, creating the illusion of being embedded in the content. By mimicking realistic and compelling scenarios, IVR has the potential to contribute to how concepts are created. Even in nonimmersive environments such as television, young children will prioritize information from a virtual character that acts socially contingent; they treat the virtual character as a live person, and claim that the character can see them (Claxton & Ponto, 2013).

Previous research on brain development and presence suggests that the development of EF may explain why young children respond to IVR as if it were real more than older populations, and experience cognitive immersion. EF skills could be one area to consider when examining children's cognitive experience of IVR. The prefrontal cortex, which is associated with EF, begins to develop throughout the preschool years (from 3 to 5 years of age) (Garon, Bryson, & Smith, 2008; Obradović et al., 2012). EF refers to self-regulatory abilities, and is often characterized as comprising inhibitory control, working memory, and cognitive flexibility (Obradović et al., 2012). Inhibitory control refers to the ability to suppress impulsive thoughts or behaviors and to resist distractions and temptations. Working memory refers to the ability to hold and manipulate verbal or nonverbal information in the mind over a short period of time (Obradović et al., 2012). Cognitive flexibility refers to the ability to shift attention between different and often competing rules and stimuli appropriately. Because the cognitive abilities supporting EF develop during the preschool years, young children will likely behave differently in IVR from adults.

Experiencing IVR may further involve simultaneously holding the idea of the physical world in mind while experiencing the virtual world. Immersive technology that has very salient sensory features may compromise children's ability to maintain the rules of the physical world, particularly when wearing a VR headset like an HMD that blocks out the location of objects in the physical world. Thus, it may be challenging for children to realize that they may walk into a wall while cognitively immersed in a virtual world. More research is needed to understand better how IVR may affect children's EF skills.

CHILDREN'S DISCOVERY OF THE SELF IN IVR

Children find themselves represented in digital form more often than previous generations: with a click of a mobile phone, a digital camera, or a handheld game, children's images can be placed within a virtual environment. Are younger children able to make that leap to understand the self-represented in IVR or the various forms that an avatar can take (i.e., first-person vs. third-person view of the self)? Experiencing immersive media such as IVR places users directly into the content, pushing the boundaries of self-representation, and the meaning of an avatar and an embodied agent.

Over time, children develop a sense that the self that exists in the present is the same as the self in the past, and that it will be the same person in the future (Fivush, 2011; Nelson & Fivush, 2004). Infants and toddlers can identify themselves in a mirror, demonstrating self-recognition (Courage & Howe, 2002; Nielsen, Suddendorf, & Slaughter, 2006). An extension of the mirror self-recognition task uses a video or photograph to measure the infant's more complex sense of self. In these tasks, children look at a delayed video recording or a series of photographs in which they see a mark being placed somewhere on them. Children who attempt to remove the mark after looking at these images pass the self-recognition test. Many studies show that by 3–4 years of age children successfully complete these tasks (Skouteris & Robson, 2006; Suddendorf & Butler, 2013; Suddendorf, Simcock, & Nielsen, 2007). Some scholars argue that the mirror recognition test measures a sense of a present self, whereas the delayed video or photograph tests represent an understanding of an extended temporal self (Suddendorf & Butler, 2013). These differences in performance based on the medium may be related to brain development. Results from neural imaging studies indicate that the neural mechanisms used to recognize the self in photographs are different from those used to recognize the self in a mirror (Suddendorf & Butler, 2013). Even with a live video stream, young children can struggle to pass the self-recognition test suggesting that the medium may influence self-recognition, and it is not solely an issue of delayed versus live feedback. With extensive practice over time, children under the age of 3 are able to counteract the "video deficit" (Troseth, 2003).

One dimension of presence in IVR is children being psychologically transported to the virtual environment (Lombard & Ditton, 1997). The ability to be psychologically transported to a virtual environment could be related to children developing a sense of self and understanding dual representation, that the self can exist in different forms, at different time points, and in different locations. Research from autobiographical memory provides some evidence as to why a sense of self is important for feeling psychologically transported. Autobiographical memory is a form of memory that reflects personal emotions, goals, and meaning (other forms of memory can be related to facts, skills, or lists), and "involves a sense of self experiencing the event at a specific point in time and space" (p. 488; Nelson & Fivush, 2004). Autobiographical memory develops during the preschool years (Nelson & Fivush, 2004). To remember the past, children are psychologically transported to that time in their mind to relive what happened to themselves (Fivush, 2011). Before the age of 3, children have not fully developed a sense of self in time and space (Skouteris & Robson, 2006; Suddendorf & Butler, 2013). This could be one possible explanation of why few people have memories before the age of 2 (Nelson & Fivush, 2004). Autobiographical memory is still developing during the preschool years, during a time in which children are learning to develop a sense of self over time. IVR can create virtual scenarios of different places and different time periods (Blascovich & Bailenson, 2011; Lombard & Ditton, 1997), and if children don't have a fully developed sense of self, they may confuse IVR experiences of occurring in the physical world (see Segovia & Bailenson, 2009). In addition, children would need to know that the self exists and have a grasp of dual representation to understand that they can be represented in virtual spaces (i.e., via an avatar). However, what could happen when the virtual self deviates from the appearance or behavior of the user, potentially making it challenging for children to recognize it as an avatar or an embodied agent? Two examples of how virtual environments challenge the self and how it can be represented in real time are exemplified via virtual doppelgangers and the Proteus effect.

A virtual doppelganger is a special type of an embodied agent: It is a virtual representation that looks like an actual person that exists (or existed) in the physical world, but is controlled by a computer. A virtual doppelganger blurs the line between an avatar and an embodied agent: It looks like the user, but a computer algorithm controls it. Through virtual doppelgangers, users can see themselves from a third-person point of view, perform novel acts that they otherwise could not or would not perform. For example, children could see their photorealistic representation performing or saying things they never did in the physical world such as walking on the moon or consuming a specific brand of sports drink. Importantly, users highly identify with their virtual doppelgangers even when they know that computer algorithms control them (Blascovich & Bailenson, 2011; Fox, Bailenson, & Binney, 2009). Viewing the behaviors of their virtual doppelganger in IVR affects user's attitudes, physiological responses and behaviors more than seeing a virtual character that does not look like them engage in the same behaviors (Blascovich & Bailenson, 2011). Users in IVR have been shown to prefer product brands they see their virtual doppelganger use over those endorsed by a virtual other (Ahn & Bailenson, 2011), have increased skin conductance when they see their virtual doppelganger running (compared with standing; Fox, Bailenson, & Ricciardi, 2012), and were more likely to invest in their future after seeing an aged version of themselves (Hershfield et al., 2011).

Another way that digital representations can influence people is through the appearance of their avatar. The Proteus effect refers to the notion that an avatar's appearance can affect the user's behaviors and attitudes in the real world (e.g., Fox, Bailenson, & Tricase, 2013). The user controls the actions of the avatar, but the avatar's appearance differs from the user's appearance. Research shows that the body types people assume in IVR affect their attitudes and behaviors such as behaving more confidently during a negotiation task when embodying a taller avatar (Yee & Bailenson, 2007), feeling self-objected after controlling a hypersexualized female avatar (Fox et al., 2013), or decreasing implicit race bias after embodying an avatar of a different race (Peck et al., 2013). The Proteus effect differs from the virtual doppelgangers in two ways: (1) the Proteus effect involves an avatar and a virtual doppelganger is a type of embodied agent, and (2) users see their virtual doppelganger, from a third-person view, engage in behaviors outside of their control (that may or may not have happened). This is similar to users watching themselves act in a movie. In contrast, the Proteus effect is about how the appearance of users' avatar (typically controlled from a first-person point of view) influences their behaviors.

THE FLUIDITY OF THE COGNITIVE SELF IN IVR

Imagine being a young child, having developed a sense of self for only a few years, and then being immersed in a virtual space where self-representation remains fluid; a new developed sense of self may lower the threshold for responding to one's avatar and embodied agents, as if they were real. In the past, self-recognition tests have manipulated real time (i.e., via a mirror or live video feed) versus delayed time (i.e., video recording). However, virtual doppelgangers push the self-recognition test to the limit: it is a mirror image of the self, but the child never had control of it at any point in time. With virtual doppelgangers, children can see themselves engage in behaviors that never happened. For example, Segovia and Bailenson (2009) found that when young elementary children (i.e., 6- to 7-years old) watched their virtual doppelganger swim with orca whales, they confused that as happening in real life. They were more likely to have "false memories" in these contexts compared with a no exposure control group or seeing another virtual child swimming with whales. Through immersion, children's sense of self through time was altered.

Surprisingly, in Segovia and Bailenson's (2009) study, there were no significant differences between conditions among preschool age children (i.e., 4- to 5-year olds). During the preschool years, children's dual representation and sense of self in media is still maturing, which could explain why this group was susceptible to creating false memories after all conditions (i.e., imagining swimming with whales, seeing the self-swim with whales in IVR, seeing another child swim with whales in IVR). In contrast, the older children (6- to 7-year olds) may have had a stronger understanding of self-recognition, but understanding how the self was represented in IVR may have been particularly challenging. IVR provides immersion that allows virtual content and digital representations to appear real even when the virtual scenario is impossible in the physical world. How children experience IVR and how immersion affects children may vary according to age, cognitive abilities, and type of immersive media-technology used.

TRENDS IN RESEARCH WITH IVR AND CHILDREN

Although there have been a number of studies and examples of children using virtual environments via low immersive technology such as using a 2D computer or television screen, there are few empirical studies that include children (e.g., under the age of 18) and IVR, specifically using an

HMD or CAVE. There are even fewer studies with children under the age of 7 (possibly due to the limited availability of IVR to the public or the large size and heaviness of past IVR technology). An overview of the literature shows four broad research topics: (1) IVR as a pain distraction tool, (2) IVR as a learning environment, (3) IVR for assessment and measurement, and (4) IVR's affect on child development. Studies included both clinical and nonclinical populations.

As a pain distraction tool, IVR has been used successfully to help with pain management for a multitude of medical procedures such as for burn wound cleaning (e.g., Das, Grimmer, Sparnon, McRae, & Thomas, 2005; van Twillert, Bremer, & Faber, 2007), cancer treatment (e.g., Gershon, Zimand, Pickering, Rothbaum, & Hodges, 2004; Schneider & Workman, 1999), and dental work (e.g., Aminabadi, Erfanparast, Sohrabi, Oskouei, & Naghili, 2012). IVR has been used as a distraction tool both from emotional and physical pain. In fact, research suggests that IVR has special qualities that help with pain distraction: With little to no interactivity (i.e., passively viewing the prerecorded actions of a video game or a film), patients report less pain compared with usual care (e.g., Dahlquist et al., 2007; Law et al., 2011). A review of VR as a pain distraction tool is found in Shahrbanian et al. (2012).

IVR has also been used as a tool for education. It has been used to facilitate learning for various skills and content areas such as visualizing fractions (Roussou, Oliver, & Slater, 2006), learning about gorilla behaviors (Allison & Hodges, 2000), and cognitive training for children with ADHD (Cho et al., 2002) or with Autism Spectrum Disorder (ASD; Jarrold et al., 2013). Several studies exist that use nonimmersive virtual environments for teaching children with ASD (e.g., teaching and practicing social cognition skills; Parsons, 2015; Wass & Porayska-Pomsta, 2014). However, few studies exist specifically using IVR to teach children with ASD. For a review of research on children with ASD using IVR and nonimmersive VR see the work of Bellani, Fornasari, Chittaro, and Brambilla (2011), and for a review of nonclinical educational virtual environments that include both IVR and nonimmersive VR refer to Mikropoulos and Natsis (2011) and Hew and Cheung (2010).

IVR can track where participants look and how they move their bodies, collecting thousands of data points. Researchers have used this capability to capture large amounts of data as a method for assessment and measurement. For example, researchers have used IVR as a tool to effectively measure the attention patterns of children with brain injuries (Gilboa et al., 2015) and to identify children with ADHD by measuring their attentional focus and performance on cognitive tasks (e.g., Bioulac et al., 2012). Although IVR has been used for pain distraction, education, and assessment with children, little is known about the effects of IVR as a technology on child development (for a general discussion of children's use of online virtual worlds and some of the developmental implications, see Subrahmanyam, 2009). The few studies that have explored issues of IVR and child development have examined the effect of IVR on children's visual system and memories. More specifically, one study examined the short-term use of IVR on fatigue related to the visual system (Kozulin, Ames, & McBrien, 2009) and another study examined IVR's impact on children believing that events in IVR happened in the physical world (Segovia & Bailenson, 2009).

CONCLUSIONS AND FUTURE DIRECTIONS

IVR is a system that blocks out the physical world, providing rich sensory fidelity wherein the user feels and responds to the virtual world, as if it were real. However, little is known about how IVR relates to child development. The little research examining young children and IVR suggests that they may have experiences unique to their age range. Brain development, EF, dual representation, and self-recognition (i.e., avatars, virtual doppelgangers, and TSI) in virtual environment may be important topics to consider regarding research on children's experiences in IVR. Basic questions related to presence, safety, and virtual characters in IVR also need to be answered before taking the steps to create effective content. For example, in IVR, virtual characters can mimic the child's behaviors, provide varying degrees of eye contact, or vary in size, with each of these factors potentially influencing the child's social behavior and learning. While television research provides the foundation for children's VR research, IVR can create content not possible in the physical world, and could elicit unknown reactions (i.e., emotional responses to standing in front of a virtual character 3 times the child's size).

Children may have strong reactions to IVR because they are still developing the skill of experiencing fully immersive technologies. For instance, there is some speculation that older children's attention to television content is less susceptible to formal features (e.g., cuts, zooms, music) because through experience, they have learned when and how to watch content based on those features (Anderson & Kirkorian, 2013). Perhaps, as children gain more experience with IVR, they will learn a type of immersive "formal feature" skill that could help them navigate in and out of immersive technologies. How children experience IVR may relate to their higher-order cognitive skills such as EF and dual representation, because the salient sensory feedback in IVR could challenge their behavioral and emotional regulation. If IVR could easily pull children into the content and elicit automatic responses related to attention and action, it may be a platform to develop new ways of measuring EF skills such as inhibitory control.

On November 8, 2015, the New York Times gave their Sunday print subscribers access to VR (Somaiya, 2015; Wohlsen, 2015). Placed neatly and easily in their newspapers, more than a million people had an inexpensive piece of cardboard in which after just a couple of minutes they could fold into an HMD that uses their phone as the screen. For the first time, millions of people had access to VR at the same time. Wired magazine writer, Wohlsen (2015), highlighted the potential implications of children having greater access to IVR, he writes, "But for good or ill, [the cardboard HMD] is just good enough to imprint a new paradigm on a nation of 8-year-olds. From now on, kids who've had the VR experience have a new set of expectations of what it should mean to interact with a computer. Imagine what they'll expect by the time they're 18." Although it had limited content and on the lower end of some immersive features (i.e., level of tracking), the New York Times roll out of VR demonstrated the children's access to immersive technologies is here.

Research with adult populations has shown IVR to have powerful effects on attitudes, behaviors, and physiology. IVR can be a technology that provides high degrees of immersion placing users directly into digital content, creating the illusion that the experience is real. Some research suggests that young children may experience virtual content differently from adults. Researchers, scholars, and VR developers need to examine the developmental issues related to the intersection of the immersive features and content of IVR further to determine what use of the technology are appropriate for which ages and how IVR can be used to enhance youth's lives. Children and adolescents are avid and early adopters of media. With broad access to VR breaching the horizon, it is expected that all ages will be interacting with immersive virtual environments. More than ever, it is a time to understand what these technological experiences mean for being a kid and what it means for human development.

REFERENCES

Ahn, S. J., & Bailenson, J. N. (2011). Self-endorsing versus other-endorsing in virtual environments. *Journal of Advertising*, *40*(2), 93–106. http://dx.doi.org/10.2753/JOA0091-3367400207.

Allison, D., & Hodges, L. F. (2000). Virtual reality for education? *Presented at the proceedings of the ACM symposium on virtual reality software and technology*, ACM, pp. 160–165. http://dx.doi.org/10.1145/502390.502420.

Aminabadi, N. A., Erfanparast, L., Sohrabi, A., Oskouei, S. G., & Naghili, A. (2012). The impact of virtual reality distraction on pain and anxiety during dental treatment in 4–6 year-old children: A randomized controlled clinical trial. *Journal of Dental Research, Dental Clinics, Dental Prospects*, *6*(4), 117–124.

Anderson, D. R., & Kirkorian, H. L. (2013). In J. Bryant & P. Vorderer (Eds.), *Psychology of entertainment* (pp. 35–51). Mahwah, NJ: Routledge.

Bailenson, J. N., Beall, A. C., Loomis, J., Blascovich, J., & Turk, M. (2004). Transformed social interaction: Decoupling representation from behavior and form in collaborative virtual environments. *Presence Teleoperators and Virtual Environments*, *13*(4), 428–441. http://dx.doi.org/10.1162/1054746041944803.

Bailenson, J. N., Yee, N., Blascovich, J., Beall, A. C., Lundblad, N., & Jin, M. (2008). The use of immersive virtual reality in the learning sciences: Digital transformations of teachers, students, and social context. *Journal of the Learning Sciences*, *17*(1), 102–141. http://dx.doi.org/10.1080/10508400701793141.

Bailey, J. O., Bailenson, J. N., Flora, J., Armel, K. C., Voelker, D., & Reeves, B. (2015). The impact of vivid messages on reducing energy consumption related to hot water use. *Environment and Behavior*, *47*(5), 570–592. http://dx.doi.org/10.1177/0013916514551604.

Bainbridge, W. S. (2007). The scientific research potential of virtual worlds. *Science*, *317*(5837), 472–476. http://dx.doi.org/10.1126/science.1146930.

Banakou, D., Groten, R., & Slater, M. (2013). Illusory ownership of a virtual child body causes overestimation of object sizes and implicit attitude changes. *Proceedings of the National Academy of Sciences*, *110*(31), 12846–12851. http://dx.doi.org/10.1073/pnas.1306779110.

Baumgartner, T., Speck, D., Wettstein, D., Masnari, O., Beeli, G., Jäncke, L., et al. (2008). Feeling present in arousing virtual reality worlds: Prefrontal brain regions differentially orchestrate presence experience in adults and children. *Frontiers in Human Neuroscience*, *2*, 8. http://dx.doi.org/10.3389/neuro.09.008.2008.

Baumgartner, T., Valko, L., Esslen, M., & Jäncke, L. (2006). Neural correlate of spatial presence in an arousing and noninteractive virtual reality: An EEG and psychophysiology study. *CyberPsychology & Behavior*, *9*(1), 30–45. http://dx.doi.org/10.1089/cpb.2006.9.30.

Bellani, M., Fornasari, L., Chittaro, L., & Brambilla, P. (2011). Virtual reality in autism: State of the art. *Epidemiology and Psychiatric Sciences*, *20*(03), 235–238. http://dx.doi.org/10.1017/S2045796011000448.

Bioulac, S., Lallemand, S., Rizzo, A., Philip, P., Fabrigoule, C., & Bouvard, M. P. (2012). Impact of time on task on ADHD patient's performances in a virtual classroom. *European Journal of Paediatric Neurology*, *16*(5), 514–521. http://dx.doi.org/10.1016/j.ejpn.2012.01.006.

Blakemore, S. -J., & Mills, K. L. (2014). Is adolescence a sensitive period for sociocultural processing? *Annual Review of Psychology*, *65*(1), 187–207. http://dx.doi.org/10.1146/annurev-psych-010213-115202.

Blanke, O. (2012). Multisensory brain mechanisms of bodily self-consciousness. *Nature Reviews Neuroscience*, *13*(8), 556–571. http://dx.doi.org/10.1038/nrn3292.

Blascovich, J., & Bailenson, J. (2011). *Infinite reality: Avatars, eternal life, new worlds, and the dawn of the virtual revolution*. New York, NY: William Morrow & Co.
Blascovich, J., Loomis, J., Beall, A. C., Swinth, K. R., Hoyt, C. L., & Bailenson, J. N. (2002). Immersive virtual environment technology as a methodological tool for social psychology. *Psychological Inquiry*, *13*(2), 103–124. http://dx.doi.org/10.1207/S15327965PLI1302_01.
Bowman, D. A., & McMahan, R. P. (2007). Virtual reality: How much immersion is enough? *Computer*, *40*(7), 36–43. http://dx.doi.org/10.1109/MC.2007.257.
Cho, B. -H., Ku, J., Jang, D. P., Kim, S., Lee, Y. H., Kim, I. Y., et al. (2002). The effect of virtual reality cognitive training for attention enhancement. *CyberPsychology & Behavior*, *5*(2), 129–137. http://dx.doi.org/10.1089/109493102753770516.
Claxton, L. J., & Ponto, K. C. (2013). Understanding the properties of interactive televised characters. *Journal of Applied Developmental Psychology*, *34*(2), 57–62. http://dx.doi.org/10.1016/j.appdev.2012.11.007.
Courage, M. L., & Howe, M. L. (2002). From infant to child: The dynamics of cognitive change in the second year of life. *Psychological Bulletin*, *128*(2), 250–277.
Cruz-Neira, C., Sandin, D. J., DeFanti, T. A., Kenyon, R. V., & Hart, J. C. (1992). The CAVE: Audio visual experience automatic virtual environment. *Communications of the ACM*, *35*(6), 64–72. http://dx.doi.org/10.1145/129888.129892.
Cummings, J. J., & Bailenson, J. N. (2016). How immersive is enough? A meta-analysis of the effect of immersive technology on user presence. *Media Psychology*, *19*(2), 272–309. http://dx.doi.org/10.1080/15213269.2015.1015740.
Dahlquist, L. M., McKenna, K. D., Jones, K. K., Dillinger, L., Weiss, K. E., & Ackerman, C. S. (2007). Active and passive distraction using a head-mounted display helmet: Effects on cold pressor pain in children. *Health Psychology*, *26*(6), 794–801. http://dx.doi.org/10.1037/0278-6133.26.6.794.
Das, D. A., Grimmer, K. A., Sparnon, A. L., McRae, S. E., & Thomas, B. H. (2005). The efficacy of playing a virtual reality game in modulating pain for children with acute burn injuries: A randomized controlled trial. *BMC Pediatrics*, *5*(1), 1. http://dx.doi.org/10.1186/1471-2431-5-1.
DeLoache, J. S. (2000). Dual representation and young children's use of scale models. *Child Development*, *71*(2), 329–338. http://dx.doi.org/10.1111/1467-8624.00148.
DeLoache, J. S. (2004). Becoming symbol-minded. *Trends in Cognitive Sciences*, *8*(2), 66–70. http://dx.doi.org/10.1016/j.tics.2003.12.004.
Fivush, R. (2011). The development of autobiographical memory. *Annual Review of Psychology*, *62*(1), 559–582. http://dx.doi.org/10.1146/annurev.psych.121208.131702.
Flavell, J. H., Flavell, E. R., Green, F. L., & Korfmacher, J. E. (1990). Do young children think of television images as pictures or real objects? *Journal of Broadcasting & Electronic Media*, *34*(4), 399–419. http://dx.doi.org/10.1080/08838159009386752.
Fox, J., Bailenson, J., & Binney, J. (2009). Virtual experiences, physical behaviors: The effect of presence on imitation of an eating avatar. *Presence Teleoperators and Virtual Environments*, *18*(4), 294–303. http://dx.doi.org/10.1162/pres.18.4.294.
Fox, J., Bailenson, J. N., & Ricciardi, T. (2012). Physiological responses to virtual selves and virtual others. *Journal of CyberTherapy & Rehabilitation*, *5*(1), 69–72.
Fox, J., Bailenson, J. N., & Tricase, L. (2013). The embodiment of sexualized virtual selves: The Proteus effect and experiences of self-objectification via avatars. *Computers in Human Behavior*, *29*(3), 930–938. http://dx.doi.org/10.1016/j.chb.2012.12.027.
Fox, S. E., Levitt, P., & Nelson, C. A., III (2010). How the timing and quality of early experiences influence the development of brain architecture. *Child Development*, *81*(1), 28–40. http://dx.doi.org/10.1111/j.1467-8624.2009.01380.x.
Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin*, *134*(1), 31–60. http://dx.doi.org/10.1037/0033-2909.134.1.31.

Gershon, J., Zimand, E., Pickering, M., Rothbaum, B., & Hodges, L. (2004). A pilot and feasibility study of virtual reality as a distraction for children with cancer. *Journal of the American Academy of Child & Adolescent Psychiatry*, *43*(10), 1243–1249. http://dx.doi.org/10.1097/01.chi.0000135621.23145.05.

Gilboa, Y., Kerrouche, B., Longaud-Vales, A., Kieffer, V., Tiberghien, A., Aligon, D., et al. (2015). Describing the attention profile of children and adolescents with acquired brain injury using the virtual classroom. *Brain Injury*, *29*(13–14), 1691–1700. http://dx.doi.org/10.3109/02699052.2015.1075148.

Hershfield, H. E., Goldstein, D. G., Sharpe, W. F., Fox, J., Yeykelis, L., Carstensen, L. L., et al. (2011). Increasing saving behavior through age-progressed renderings of the future self. *Journal of Marketing Research*, *48*, S23–S37.

Hew, K. F., & Cheung, W. S. (2010). Use of three-dimensional (3-D) immersive virtual worlds in K-12 and higher education settings: A review of the research. *British Journal of Educational Technology*, *41*(1), 33–55. http://dx.doi.org/10.1111/j.1467-8535.2008.00900.x.

Hoffman, H. G., Patterson, D. R., Seibel, E., Soltani, M., Jewett-Leahy, L., & Sharar, S. R. (2008). Virtual reality pain control during burn wound debridement in the hydrotank. *The Clinical Journal of Pain*, *24*(4), 299–304. http://dx.doi.org/10.1097/AJP.0b013e318164d2cc.

Jarrold, W., Mundy, P., Gwaltney, M., Bailenson, J., Hatt, N., McIntyre, N., et al. (2013). Social attention in a virtual public speaking task in higher functioning children with autism. *Autism Research*, *6*(5), 393–410. http://dx.doi.org/10.1002/aur.1302.

Kozulin, P., Ames, S. L., & McBrien, N. A. (2009). Effects of a head-mounted display on the oculomotor system of children. *Optometry and Vision Science*, *86*(7), 845–856. http://dx.doi.org/10.1097/OPX.0b013e3181adff42.

Lamkin, P. (2015, June 18). Virtual reality devices: $4 billion+business by 2018. Retrieved September 11, 2016 from http://www.forbes.com/sites/paullamkin/2015/06/18/virtual-reality-devices-4-billion-business-by-2018/#53d8c14cfd92.

Law, E. F., Dahlquist, L. M., Sil, S., Weiss, K. E., Herbert, L. J., Wohlheiter, K., et al. (2011). Videogame distraction using virtual reality technology for children experiencing cold pressor pain: The role of cognitive processing. *Journal of Pediatric Psychology*, *36*(1), 84–94. http://dx.doi.org/10.1093/jpepsy/jsq063.

Lauricella, A. R., Cingel, D. P., Blackwell, C., Wartella, E., & Conway, A. (2014). The mobile generation: youth and adolescent ownership and use of new media. *Communication Research Reports*, *31*(4), 357–364. https://doi.org/10.1080/08824096.2014.963221.

Lee, K. M. (2004). Presence, explicated. *Communication Theory*, *14*(1), 27–50. http://dx.doi.org/10.1111/j.1468-2885.2004.tb00302.x.

Lombard, M., & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication*. *3*(2). http://dx.doi.org/10.1111/j.1083-6101.1997.tb00072.x.

Mikropoulos, T. A., & Natsis, A. (2011). Educational virtual environments: A ten-year review of empirical research (1999–2009). *Computers & Education*, *56*(3), 769–780. http://dx.doi.org/10.1016/j.compedu.2010.10.020.

Nelson, K., & Fivush, R. (2004). The emergence of autobiographical memory: A social cultural developmental theory. *Psychological Review*, *111*(2), 486–511. http://dx.doi.org/10.1037/0033-295X.111.2.486.

Nielsen, M., Suddendorf, T., & Slaughter, V. (2006). Mirror self-recognition beyond the face. *Child Development*, 77(1), 176–185. http://dx.doi.org/10.1111/j.1467-8624.2006.00863.x.

Obradović, J., Portilla, X. A., & Boyce, W. T. (2012). Executive functioning and developmental neuroscience: Current progress and implications for early childhood education. In R. C. Pinta, L. Justice, W. S. Barnett, & S. Sheridan (Eds.), *Handbook of early childhood* *education* (pp. 324–351). New York, NY: Guilford. Retrieved from http://cepa.stanford.edu/content/executive-functioning-and-developmental-neuroscience-current-progress-and-implications-early-childhood-education.

Parsons, S. (2015). Learning to work together: Designing a multi-user virtual reality game for social collaboration and perspective-taking for children with autism. *International Journal of Child-Computer Interaction*, *6*, 28–38. http://dx.doi.org/10.1016/j.ijcci.2015.12.002.

Peck, T. C., Seinfeld, S., Aglioti, S. M., & Slater, M. (2013). Putting yourself in the skin of a black avatar reduces implicit racial bias. *Consciousness and Cognition*, *22*(3), 779–787. http://dx.doi.org/10.1016/j.concog.2013.04.016.

Petkova, V. I., & Ehrsson, H. H. (2008). If I were you: Perceptual illusion of body swapping. *PLoS ONE*, *3*(12), e3832. http://dx.doi.org/10.1371/journal.pone.0003832.

Reeves, B. (1989). Theories about news and theories about cognition: Arguments for a more radical separation. *The American Behavioral Scientist*, *33*(2), 191–198.

Reeves, B., & Nass, C. I. (1996). *The media equation: How people treat computers, television, and new media like real people and places: (Vol. xiv)*. New York, NY, US: Cambridge University Press.

Richert, R. A., Robb, M. B., & Smith, E. I. (2011). Media as social partners: The social nature of young children's learning from screen media. *Child Development*, *82*(1), 82–95. http://dx.doi.org/10.1111/j.1467-8624.2010.01542.x.

Rideout, V. (2013). *Zero to eight: Children's media use in America 2013*. Common Sense Media. Retrieved from https://www.commonsensemedia.org/research/zero-to-eight-childrens-media-use-in-america-2013.

Roussou, M., Oliver, M., & Slater, M. (2006). The virtual playground: An educational virtual reality environment for evaluating interactivity and conceptual learning. *Virtual Reality*, *10*(3–4), 227–240. http://dx.doi.org/10.1007/s10055-006-0035-5.

Salomon, R., Lim, M., Pfeiffer, C., Gassert, R., & Blanke, O. (2013). Full body illusion is associated with widespread skin temperature reduction. *Frontiers in Behavioral Neuroscience*, 7, 65. http://dx.doi.org/10.3389/fnbeh.2013.00065.

Schneider, S. M., & Workman, M. L. (1999). Effects of virtual reality on symptom distress in children receiving chemotherapy. *CyberPsychology & Behavior*, *2*(2), 125–134. http://dx.doi.org/10.1089/cpb.1999.2.125.

Segovia, K. Y., & Bailenson, J. N. (2009). Virtually true: Children's acquisition of false memories in virtual reality. *Media Psychology*, *12*(4), 371–393. http://dx.doi.org/10.1080/15213260903287267.

Shahrbanian, S., Ma, X., Aghaei, N., Korner-Bitensky, N., Moshiri, K., & Simmonds, M. J. (2012). Use of virtual reality (immersive vs. non immersive) for pain management in children and adults: A systematic review of evidence from randomized controlled trials. *European Journal of Experimental Biology*, *2*(5), 1408–1422.

Sharar, S. R., Carrougher, G. J., Nakamura, D., Hoffman, H. G., Blough, D. K., & Patterson, D. R. (2007). Factors influencing the efficacy of virtual reality distraction analgesia during postburn physical therapy: Preliminary results from 3 ongoing studies. *Archives of Physical Medicine and Rehabilitation*, *88*(12 Suppl. 2), S43–S49.

Skouteris, H., & Robson, N. (2006). Young children's understanding of photo self-representations. *Australian Journal of Educational & Developmental Psychology*, *6*, 50–59.

Slater, M. (2009). Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *364*(1535), 3549–3557. http://dx.doi.org/10.1098/rstb.2009.0138.

Slater, M., Antley, A., Davison, A., Swapp, D., Guger, C., Barker, C., et al. (2006). A virtual reprise of the Stanley Milgram obedience experiments. *PLoS ONE*, *1*(1), e39. http://dx.doi.org/10.1371/journal.pone.0000039.

Slater, M., Spanlang, B., Sanchez-Vives, M. V., & Blanke, O. (2010). First person experience of body transfer in virtual reality. *PLoS ONE*, *5*(5), e10564. http://dx.doi.org/10.1371/journal.pone.0010564.

Slater, M., & Wilbur, S. (1997). A framework for immersive virtual environments (five): Speculations on the role of presence in virtual environments. *Presence Teleoperators and Virtual Environments*, *6*(6), 603–616. http://dx.doi.org/10.1162/pres.1997.6.6.603.

Solomon, B. (2014, March 25). Facebook buys oculus, virtual reality gaming startup, for $2 billion. Retrieved August 15, 2016, from http://www.forbes.com/sites/briansolomon/2014/03/25/facebook-buys-oculus-virtual-reality-gaming-startup-for-2-billion/.

Somaiya, R. (2015, October 20). The times partners with google on virtual reality project. *The New York Times*. Retrieved from http://www.nytimes.com/2015/10/21/business/media/the-times-partners-with-google-on-virtual-reality-project.html.

Steptoe, W., Steed, A., & Slater, M. (2013). Human tails: Ownership and control of extended humanoid avatars. *IEEE Transactions on Visualization and Computer Graphics*, *19*(4), 583–590. http://dx.doi.org/10.1109/TVCG.2013.32.

Steuer, J. (1992). Defining virtual reality: Dimensions determining telepresence. *Journal of Communication*, *42*(4), 73–93. http://dx.doi.org/10.1111/j.1460-2466.1992.tb00812.x.

Subrahmanyam, K. (2009). Developmental implications of children's virtual worlds protecting virtual playgrounds: Children, law, and play online. *Washington and Lee Law Review*, *66*, 1065–1084.

Suddendorf, T., & Butler, D. L. (2013). The nature of visual self-recognition. *Trends in Cognitive Sciences*, *17*(3), 121–127.

Suddendorf, T., Simcock, G., & Nielsen, M. (2007). Visual self-recognition in mirrors and live videos: Evidence for a developmental asynchrony. *Cognitive Development*, *22*(2), 185–196. http://dx.doi.org/10.1016/j.cogdev.2006.09.003.

Troseth, G. L. (2003). TV guide: Two-year-old children learn to use video as a source of information. *Developmental Psychology*, *39*(1), 140–150. http://dx.doi.org/10.1037/0012-1649.39.1.140.

Troseth, G. L., & DeLoache, J. S. (1998). The medium can obscure the message: Young children's understanding of video. *Child Development*, *69*(4), 950–965. http://dx.doi.org/10.1111/j.1467-8624.1998.tb06153.x.

van Twillert, B., Bremer, M., & Faber, A. W. (2007). Computer-generated virtual reality to control pain and anxiety in pediatric and adult burn patients during wound dressing changes. *Journal of Burn Care & Research: Official Publication of the American Burn Association*, *28*(5), 694–702. http://dx.doi.org/10.1097/BCR.0B013E318148C96F.

Wass, S. V., & Porayska-Pomsta, K. (2014). The uses of cognitive training technologies in the treatment of autism spectrum disorders. *Autism*, *18*(8), 851–871. http://dx.doi.org/10.1177/1362361313499827.

Wohlsen, M. (2015, November 9). Google cardboard's New York Times experiment gave a bunch of kids their first glimpse of the future. Retrieved September 11, 2016, from https://www.wired.com/2015/11/google-cardboards-new-york-times-experiment-just-hooked-a-generation-on-vr/.

Yee, N., & Bailenson, J. (2007). The proteus effect: The effect of transformed self-representation on behavior. *Human Communication Research*, *33*(3), 271–290. http://dx.doi.org/10.1111/j.1468-2958.2007.00299.x.

You, S. H., Jang, S. H., Kim, Y. -H., Hallett, M., Ahn, S. H., Kwon, Y. -H., et al. (2005). Virtual reality–induced cortical reorganization and associated locomotor recovery in chronic stroke an experimenter-blind randomized study. *Stroke*, *36*(6), 1166–1171. http://dx.doi.org/10.1161/01.STR.0000162715.43417.91.