The Disconnect between Real and Virtually Real Worlds: The Challenges of Using VR with Adolescents

1 Introduction

Industry projections suggest the commercial usage of virtual reality (VR) headsets will increase steadily over the next five years, with more immersive, stand-alone headsets representing the bulk of purchases by consumers (Bolkan, 2018; Taylor, 2017; Lamkin, 2017; Orland, 2017). Whether individuals are watching 360° videos on smartphone-based headsets or using stand-alone head-mounted displays (HMDs), virtual reality is becoming more widespread in healthcare, education, business, entertainment, and industry (CB Insights, 2017; Mujber, Szecsi, & Hashmi, 2004; Pantelidis, 2009; Psotka, 2013; Rizzo et al., 2013; Rizzo, Rizzo, Schultheis, Kerns, & Mateer, 2004). Increasingly, concerns have been brought up about the ethical usage of VR, both with vulnerable groups as well as the general population (Madary & Metzinger, 2016; Southgate, Smith, & Scevak, 2017). It is clear that the adolescent brain has unique features including heightened neuroplasticity, increased emotional intensity and reactivity, and increased ability to learn (Casey, Jones, & Hare, 2008; Jensen & Nutt, 2015; Southgate et al., 2017; Steinberg, 2014). Though age recommendations are given by all manufacturers of VR hardware, they vary from child-appropriate to those recommended for age 13 years or above due to concerns about effects on ocular development and maturity of content (Gent, 2016); yet at the same time, VR headsets are being marketed as educational tools for children. Often, users disregard the warnings and allow younger children to engage with content and hardware that may not be recommended for their age group. We believe there is a gap in understanding between the potential psychological, physiological, and emotional impact of virtual reality hardware on children and adolescents, and what research actually makes its way to developers, users, parents, and guardians.

Through four years of applied research on learning and VR, VR focus groups with adolescents, and experimental work with adults, we have observed thousands of people using and interacting with commercial content in VR, often in everyday settings such as schools or clubs. In our work with virtual reality, particularly with adolescents, we have observed some interesting disconnects between the expected outcome of particular pieces of content versus the actual experience of the adolescent user in VR. VR presents a number of innovative elements that provide rich opportunities for the medium to be an effective learning tool including simulations, exposure to novel situations, and engagement with learners in ways not allowed for by traditional mediums (Castaneda, Cechony, Bautista, & Pacampara, 2017). At the same time, our data also suggest that research done in applied settings may usefully supplement laboratory findings by revealing validation of experimental findings, or inconsistencies which can recommend further areas for investigation in real-world environments.

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Lisa M. Castaneda
100 NE Northlake Way
Suite 100
Seattle, WA 98105
lisa@foundry10.org

Samantha W. Bindman
foundry10

Anna Cechony
foundry10

Manrita Sidhu
Radia

In this article, we draw from research and programs that explore how youth (and sometimes adults) respond to virtual reality experience, with a focus on ways that VR can be used to enhance education. The main study, from 2016–2017, involved more than 1,500 middle and high school students from the United States and Canada who used virtual reality technology in school settings across a variety of subject areas. We have worked with an additional 2,500 students in successive years as part of a related applied VR study. All students completed surveys including both open-ended and forced-choice questions before and after their VR use. Teachers were interviewed before, during, and after the semester or year-long course. The study was reviewed by an Institutional Review Board and all participating students (parents, for those under age 18) and teachers provided informed consent. Our work in VR extends beyond classroom studies, and pertinent information about adolescents using VR has come from these additional projects. Therefore, this article also shares findings from interviews with focus groups of students ages 7–11 enrolled in an after-school technology program, a focus group of high school students, ages 13–18, involved in a research program at foundry10, and an experimental study of adults viewing 360° video on an HMD (see Bindman, Castaneda, Scanlon, & Cechony, 2018). Here, we synthesize data from these varied sources to point to research questions and design problems that should be tackled to make VR a viable learning tool for youth at appropriate ages, particularly in educational contexts. We focus in four areas: the inherent challenges of behavioral realism and immersion, the complexity of empathy, issues with proximity, and perspective-taking.

2 Inherent Challenges of Behavioral Realism and Immersion

VR has the potential to transport students to different places, allowing them to have experiences they might not otherwise encounter, such as being in an historical event or being inside a live volcano. The majority of students (78%) in our large-scale study of VR in schools reported that they believed VR has the potential to take people to a different time or place after having exposure to the technology. Research has demonstrated that it is of primary importance for viewers (and their perceptual systems) while in VR that objects and characters behave as they should in the real world, versus simply having high levels of photorealism (Blascovich et al., 2002). VR users can experience the illusion of presence, or the feeling of actually being in the virtual world, even if the graphical quality of the virtual images is not high (Bailenson, Blascovich, Beall, & Loomis, 2001). This idea of accurately representing real world behaviors, even in fantastical settings, in a simulated environment is termed *behavioral realism* (Blascovich et al., 2002). The inherent plausibility of the scenario also matters when one is considering whether or not something feels "real." For example, in a VR experience with dinosaurs it is more important that the dinosaurs move like the observer thinks they should move, rather than being entirely photorealistic. If the content is just right, individuals will feel both that they are present in the virtual environment and that the events they see are happening *to them*—referred to as the plausibility illusion (Slater, 2009). Though our research provides evidence to support the importance of both behavioral realism and plausibility in VR, we argue that we need a better understanding of how both are shaped by individuals' lived experiences, particularly among adolescents. We will illustrate why a more nuanced understanding of the possible role of individuals' life experiences in conjunction with behavioral realism and plausibility in VR would be useful both for developers and researchers to consider.

In many cases, students in our programs experience presence in VR through the plausibility illusion. However, in some cases plausibility and behavioral realism can interact in ways that make presence more difficult to achieve. Many students in our study have encountered the limits of behavioral realism in content like *Remembering Pearl Harbor* (LIFE VR, 2016). In this experience, the user is encouraged to pick up objects of particular relevance to the time period such as newspapers, photographs, or other relics as they learn about what happened during the event. However, students quickly noticed that they could very easily pick up tables, chairs, and all sorts of other objects with a simple click of the trigger, and some students proceeded to lose focus on the intended targets of their attention. Intended visual elements were sometimes difficult to view and, of the 15 students in our focus group, six felt frustrated by on-screen captions or text that diminished their experience of being present (and several couldn't figure out how they even turned captioning on in the first place). Thus, the extraneous objects like the tables and chairs became the focus rather than the intended visual cues. Interestingly, the narrator's voice, which was audio laid over the visual experience, did not serve to break immersion in the VR setting, and, for a third of the students, it actually added to their understanding of the scenes they were exploring. It seemed as though the text served as a visual distraction while the voice of a survivor of Pearl Harbor, though not actually present as a visual character in the experience, was plausible and provided a benefit. Perhaps a narrator is a more familiar device for storytelling, as opposed to the ability to touch everything or have captioning in the room, and thus serves to enhance rather than detract from the experience.

An interesting effect we have observed in VR experiences with adolescents, including *Remembering Pearl Harbor*, is that some of the most profound moments for students seem to arise from times when they had a break from the action and were given opportunities to reflect within the experience. One student noted, "It's a challenge when you create an experience like that. Instead of putting you right in the action, it gave you time to reflect. You were in the home where it was quiet and then were taken to the action in the middle of one of the worst scenes in history." Another said, "The house was my favorite. I could compare my day-to-day when I was in the house; I did not have to deal with losing my friends or dying. Being in the house, to be at home with those thoughts. . . very different than my thoughts at home." The scenario of being in a home in 1941 was both plausible and relatable for students but the opportunities for interactivity and the text used to guide students through the experience distracted them from the intended purpose of the experience. Gaining a clearer understanding of what is plausible in scenarios such as this (e.g., a narrator versus useless assets with which one can interact) may help us design experiences that are both immersive and educational.

The degree to which virtual reality is a truly immersive and sometimes very realistic medium is still challenging for adults and children to comprehend. There can be a disconnect between an individual's understanding of what "immersive" means, compared to the actual virtual experience. In one case, middle school students were using an immersive VR roller coaster experience. All students had an understanding of the concept of a roller coaster and most found the real-life experience to be enjoyable. Interestingly, even though roller coasters were considered extremely aversive stimuli for several students, they still chose to put on the advanced headset and immerse themselves in roller coaster VR. Some of these students had negative reactions, such as fear and nausea, in the VR simulation, similar to their reactions on real-life roller coasters. It was apparent that they were unable to anticipate in advance that something they did not like in real life would likely be something they did not like in VR, and, in fact, a few expressed surprise by their own negative reaction. As one middle schooler observed, "My understanding of the VR has changed, because before taking this class, I didn't know what being in a virtual reality world was like. I thought that it would be very unrealistic and not look very good but after experiencing it, I realized that it is extremely realistic. . ." It is important that we understand how adolescents conceptualize the "realness" of VR and how this is altered by repeated exposure. We know from direct experience with students in classrooms that trailers previewing VR content can help students better comprehend what the virtual experience will entail in terms of the scope of content. However, we also know that trailers on a 2D screen do not adequately simulate the immersive experiences and numerous students have felt uncomfortable when they realized how intense the "real" VR experience could be. Perhaps we could look to other fields like medicine, where kids receive gradual exposure to new experiences, such as an MRI, to prepare them for the real experience as potential guides for introducing VR (Raschle et al., 2012).

Some students have expressed that they consider VR content to be useful for addressing their own fears. They would intentionally immerse themselves into experiences involving insects or heights in order to confront their fears. In these cases, they essentially utilized a cognitive behavioral exposure paradigm as they attempted to address their own fears. We highlight this for two reasons. One, researchers are still learning about how VR can be effectively used as an actual treatment for phobias (Gebara, de Barros-Neto, Gertsenchtein, & Lotufo-Neto, 2016; Parsons & Rizzo, 2008), and it is reasonable to assume that adolescents who self-select to undergo VR experiences for these purposes may not have the training and understanding necessary to make this an effective solution for themselves. Second, we believe it is of immense importance that educators, even using cartoonish experiences in VR with children, should engage in dialogue with students beforehand regarding the role immersive experiences might have in triggering aversive responses. As one high school student reflected when asked to advise other new users about VR, "Take it slow at first! It can be quite shocking to go from a classroom to the top of a mountain. . . if you feel uncomfortable with the simulation, don't do it. My fear of falling for example has made me feel very uneasy in some situations, and VR is supposed to be enjoyable."

3 The Complexity of Empathy

In designing virtual experiences, content creators often try to tap into the elements of emotions and empathy for the purposes of helping people learn and relate in VR (Milk, 2015). Through repeated observations of adolescents in content designed to evoke empathetic responses, we note inconsistencies in their experiences that give us pause as we consider how best to tap into feelings of empathy in learning environments. In one scenario, adolescents (and adults) interacted with an imaginary creature that had real, relatable emotions and thus the behavioral realism worked as one would anticipate. The idea that there are basic, universal "human" emotions (Ekman, 1992) seems particularly relevant when considering this example. The piece of content utilized was called *Henry* (Oculus Story Studio, 2015) and involves a personable computer-generated hedgehog who is alone on his birthday. Though we wondered in advance if an animated hedgehog would be an effective tool for eliciting empathy, we were pleasantly surprised to find that it was. The feeling of sadness is a universal emotion that resonated with the majority of our participants. Children would reach out to try and hug him, adolescents would sometimes cry, and adults would reflect on times of loneliness in their lives. In fact, more than 80% of adult participants in our experimental study reported feeling sad after watching the 360° video. The scenario seemed plausible and relatable even though it involved a hedgehog and was a far cry from some of the more human-centered pieces of VR content available today.

Our observations with *Henry* were quite different compared to other content that was specifically designed to elicit strong emotions using human characters but failed to do so in consistent ways, particularly with adolescents. In scenarios where adolescents in a focus group were placed in a VR Syrian refugee experience (Aora & Milk, 2015), they responded more strongly to the dust kicked up by a bomb explosion that obscured their vision than they did to the people in the experience. In another classroom, a teacher placed students in a 9/11 simulation where the user has to try to get out of one of the Twin Towers (08:46; WEARVR, 2015). Much to our surprise, the students did not have the strong emotional response to the content typically reported by adults we have placed in the experience. Instead, they talked about how they had never considered 9/11 from that perspective before and previously had only thought about the planes crashing into the building. Those students were not alive during 9/11, and thus their conceptualization and emotional reaction to that event is likely different than that of adults.

We know from research that sometimes empathetic responses are mediated by an individual's capacity to find a clear analog to his or her own life (Slater, Johnson, Cohen, Comello, & Ewoldsen, 2014). A teacher in our study had success using the solitary confinement VR experience *6 x 9* (Guardian News Media, 2016) with her middle school Prisons and Protests class. Students clearly articulated why the virtual experience was so helpful to their conceptualization of the inhumanity of solitary confinement and they could clearly relate to the idea of being in an unpleasant, enclosed environment. When we left, we were struck by the fact that this was a wealthy school where students' lives may be largely untouched by the penal system; thus their experience of discomfort may have been rooted in something very different than students whose life experiences brought them in closer contact to the prison system. How would that content have resonated with students who have family members in prison? In what ways would the lived experiences of those adolescents possibly have exaggerated the effects of the plausibility of that content?

In considering these questions, it is important to investigate the potential value of students engaging in these experiences and possible disconnects that may occur. While there are merits to allowing students to expand their understanding of the world through content that is meant to induce empathy, it is crucial to be aware that some studies have shown counterproductive effects of these experiences. Empathetic 360° and VR content can overwhelm students or lead them to feeling hopeless (Bloom, 2017), which can reduce the chance of them taking empathetically driven action. Additionally, in content simulating disabilities like blindness, users experience *becoming* rather than *being* blind and often leave with a negatively skewed perception of living as a blind person, which is incongruent with many lived experiences (Silverman, 2015). Lastly, appeals to empathy can increase rather than reduce prejudice in some instances (Silverman, 2015; Southgate et al., 2017). In this way, it is crucial to validate empathy-inducing content prior to release, and to host discussions with students about this content, finding analogues to user experience, and accepting that one virtual experience will not give users a full picture of life in someone else's shoes.

4 Physical Distance

VR has the potential to give students a close-up view of objects and people—to understand size and scale—in ways not possible in the real world. Though we did not set out to specifically study physical proximity in VR, issues surrounding violations of personal space in VR arose in all of our research. This is largely because in many pieces of VR content, users cannot easily regulate their distance from approaching assets. Due to this lack of control, there may be a disconnect between the way space is conceptualized by designers versus how it is experienced by adolescents in VR.

Research in proxemics, the study of personal space, has demonstrated that when one's personal zone is violated, such as by having another person come too close, feelings of discomfort emerge which often then evoke compensatory behaviors such as withdrawal or flight from the intruder (Brozzoli, Makin, Cardinali, Holmes, & Farne, 2011; Hall, 1963; Lloyd, 2009; Sommer, 1959). The realm of peri-personal space, the assessment of the comfortable area surrounding the body (Rizzolatti, Fadiga, Fogassi, & Gallese, 1997), may vary between individuals and in different scenarios. A person's peri-personal space is likely different with their partner than a stranger, but when an individual feels the space is violated, negative emotions are elicited. Recent research suggests that some viewers of 360° video feel discomfort from being close to other people in virtual experiences, whereas other viewers may enjoy the feeling of seeing someone else's work up close (Passmore et al., 2016).

In VR, the idea of personal space is often violated intentionally. A character may come close to a user to elicit surprise, or, because the user can look in all directions, an object may approach while the user is not looking and therefore may give the illusion of very quickly entering the peri-personal zone. This violation of proximity may prove to be a distraction from the expected VR experience when it unintentionally triggers a negative response. We saw this with children playing a game called *Fantastic Contraption* (Radial Games, 2015). After the tutorial, a green cat with giant wide eyes appears right behind the user to bring them tools. The cat is supposed to be helpful, but the proximity of the cat to the user led many of the children to jump across the room or to ask, "Why is that cat so close to me?" or "Can you make the cat move away from me?" Compensatory behaviors, such as moving away, jumping, shifting position, or trying to use the controllers to move the cat were observed. Research has suggested that being looked at triggers different responses than not having eye-contact and although these responses are largely prosocial, the presence of eyes has been shown to make people more conscious of their activities and likely to conform to societal norms (Bateson, Nettle, & Roberts, 2006; Francey & Bergmüller, 2012; Powell, Roberts, & Nettle, 2012). This can be particularly jarring in a virtual space because up until this point, the user has been in a constructed environment in which they were the only person (or thing with eyes). When something shows up that is watching them, it can be alarming. *Fantastic Contraption* has since been updated so that the cat's eyes are no longer always open upon approach and we are curious to explore this effect with future users of this experience.

Similar responses happened when both children and adults were approached by a friendly bunny who comes right up and "sniffs" them in *Invasion!* (Baobab Studios, 2016). Both children and adults moved back, leaned away, or at times commented afterwards that the bunny was too close, even though it was just for a short time period and the bunny was a friendly character. Though not necessarily a reason to remove the headset, in both cases, it pulled focus away from the task at hand and created a sense of unease in users that may diminish their sense of presence. This effect occurred repeatedly with adolescents using *The Blu Encounter* (Wevr, 2016), an ostensibly peaceful, underwater CGI simulation. One of the highlights of the experience is that a gigantic blue whale quietly swims past the user. However, the whale approaches the user (versus the user approaching it) and one of its giant eyes appears to be looking directly at them. We had many adolescents tell us the experience of the whale was frightening for them and a small subset of those students refused to try VR again; these were adolescents within the age-range specifications of the manufacturer. The whale does not interact with the user, it is not designed to be a scary experience, and many people find it wonderful and a great way to understand the scale of the world's largest mammal, so we were surprised by the idiosyncratic negative reactions this content sometimes elicited. These observations may be related to adolescent brain development characteristics such as increased emotional response to events and incomplete frontal lobe development, which together may lead to what appear to adults to be "irrational" responses (Casey et al., 2008; Jensen & Nutt, 2015; Southgate et al., 2017; Steinberg, 2014).

Interestingly, in VR, it does not have to be a person or even an animate object that approaches in order for a user to feel that their space is invaded. Llobera and colleagues (Llobera, Spanlang, Ruffini, & Slater, 2010) demonstrated that even large cylinders moving toward users, when they moved into the peri-personal zone, were off-putting, mainly because the users were approached by objects and not approaching the objects themselves. This violation of personal proximity can make users uncomfortable regardless of what violates that space. Considering this fact, and that there can be a variety of useful purposes for invading space in VR (e.g, scale, surprise, empathy, interaction), it is useful for researchers and developers to consider ways in which the user can exert more control over these types of interactions. One mechanic we have observed that seems to help with this proximal approach, with both adults and younger users, is seen in the commercial game *SuperHot VR* (Superhot Team, 2017). In this game, the characters and assets move only when the user moves. This allows the user to move slowly and thus slow the characters down, or for the user to freeze completely, thus essentially pausing the action and controlling proximity without removing the headset. Investigating whether or not these types of mechanics inhibit physiological arousal would be a worthwhile endeavor. Additionally, virtual spaces such as *Tilt Brush* (Google, 2016b) and *CoSpaces* (Delightex GmbH, 2017) allow the user to crawl inside of things and get very close or not, as they see fit, as they work within the space. The element of choice in terms of proximity and pacing seems to be a beneficial addition for adolescent, and likely adult, users. Better understanding the scenarios in which proximity is most effective as an educational tool is important for researchers and developers to consider so that we can limit the distraction or deterrence that may occur when it is used ineffectively.

5 Time Travel and Perspective

Through our applied work with teachers and adolescents we consistently see interesting applications for learning and skill acquisition that leave us feeling optimistic about the use of immersive technology in educational settings. Students in our research repeatedly cite history as one of the more enticing subjects to experience in VR because they strongly desire to see events through various perspectives and to "travel back in time to see what it was really like." When asked what they want to do in VR, 56% ($n = 851$) of students in our study wanted to try new things and 44% ($n = 669$) wanted to experience historical events or places. Students have consistently expressed that they believe they will understand events and places more thoroughly if they could experience them in VR. What has been confusing to us as researchers is how adolescents will use language about traveling back in time and "reliving" those experiences. One student said, "They can go back to different time periods and be able to experience it themselves." This answer was not unique and 73% ($n = 1110$) of the students in that study thought VR could be used to take people to a different time or place.

We know from discussions that adolescents, when directly asked outside of VR, do not really believe that time travel is possible, yet they seem to believe that someone could simply virtually recreate the events. This type of belief brings up major questions about the adolescent skepticism about content creators' biases. These virtual experiences are created by developers and represent a very specific viewpoint or perspective on how an event unfolded. History teachers in our study have been very clear that they consider VR to be a secondary source of information that students should be trained to question and think critically about. Interestingly, 73% of students said they either agreed or strongly agreed with the statement "Professional developers are knowledgeable about the content that they are trying to create in VR." Some developers most certainly are; yet because there is no process for vetting VR content in this way, assessment of accuracy is really a function of an individual's content knowledge.

Google Earth VR (Google, 2016a) in VR is a piece of content that has been extremely positively received by students and teachers alike. Although the content itself is designed to showcase geographical locations, we have seen adolescents make very personal connections with places. An exchange student from Germany took his classmates on a tour of his home neighborhood and actually became quite emotional about how homesick he was. Interestingly, though VR is touted as an excellent vehicle for developing empathy (Milk, 2015) we have repeatedly heard from students that VR is a better tool for understanding places versus people (Castaneda et al., 2017). Our data suggest that they are less certain about their ability to understand and relate to people through VR, though we have seen numerous instances (such as the example of the German student) where students have used places as a mechanism for connecting to very human emotions. Strategically exploring how these types of content work, whether or not they have the intended effect on a wide array of users and what the user takes away from the experience, is an imperative step.

6 Final Thoughts

As virtual reality becomes more ubiquitous in the home, workplace, and classroom, it is imperative that we look at commercially available content, and do more work to understand the implications of VR use with a wider age range of users. Understanding how everyday adolescent users experience and interpret commercial content can help us design more effective experiences and perhaps better gauge user reactions. As researchers, we feel there is great potential for VR use in education. Students and teachers in our studies feel the same way. The question is, how do we encourage educators, parents, consumers, and developers to consider the important possible disconnect between expected experience and actual experience of VR content? How can educators and parents bridge the gap to effectively mediate the experience for adolescents? We have introduced several ideas from different areas of VR research and its impact on adolescents. Table 1 provides a summary of the key ideas we have presented.

As researchers, in focusing our studies on the exposure of adults to VR content, we may be missing key elements regarding the role of behavioral realism and its interpretation by developing minds. For a variety of reasons, including brain development and life experiences, adolescent responses may be very different than those of adults with whom content is play-tested. In addition, there is evidence from many arenas that adolescents may

Table 1. *Considerations for Using Virtual Reality as an Educational Tool for Adolescents*

Findings	Preliminary Recommendations
Behavioral realism (objects and characters behave as they do in the real world) is often more effective in creating a sense of presence in VR than photorealism (images look as they do in the real world). Therefore, if objects, people or environments in VR behave or respond to stimuli unrealistically, presence is difficult to achieve. Objects and their unexpected behavior or attributes (e.g., you are able to pick up a large table and throw it) can be distracting, as can overlaid text. The **plausibility illusion** refers to the feeling of being present in the virtual environment and feeling as if the events occurring are actually happening to you. Adolescents don't always understand that many VR experiences have high behavioral realism, potentially making viewers feel present in the experiences even though the events aren't "real." Takeaways • VR gives students experiences they wouldn't otherwise have • Students may not understand or be prepared for the level of realism • Inadequate behavioral realism and other design elements may distract from the experience	Developers • Test responses from a diverse group of participants prior to release to exclude distracting or counterintuitive elements Educators • Provide an introduction to the HMD itself, such as through a practice experience • Preview experience with students by viewing a trailer and facilitating discussion to mentally prepare them and mitigate aversive responses • Be aware of life experiences or fears that may make experiences more intense • Allow students to opt out or leave a VR experience without negative consequences • Debrief after experience All Users • These experiences are not designed for self-treatment of phobias outside of a clinical setting • Take time to reflect before, during and after a virtual experience
Empathy, or understanding and feeling someone else's emotions, may be strongly elicited while immersed in VR, which is why some feel it is such a powerful tool. Although there are many similarities between VR experiences and real life, there are crucial disconnects to consider, including the user's lived experiences, emotional state, attention and focus. Takeaways • VR can be used as a tool to experience a moment of another's lived experience • Sometimes experiences designed to elicit empathy can backfire, overwhelming emotions, resulting in decreased empathy or action, and providing a skewed perception of what it's like for someone else	Developers • Test before deployment as attempts to increase empathy can sometimes backfire Educators • Be mindful of the content choice, making sure to balance the benefits and risks of emotional connection • Introduce such VR only within a larger context/curriculum to help students connect to larger ideas • Discuss the strengths and limitations of VR All Users • Understand that VR offers opportunities for intersection with someone else's experience but doesn't automatically provide understanding and, at times, may even be counterproductive

Table 1. *(Continued)*

Findings	Preliminary Recommendations
Physical distance/proxemics – Findings with adolescents suggest that closer is not always better with younger users in VR. When individuals of all ages perceive objects or creatures to be infringing on their personal space in VR, that violation of proximity, though often by design, can pull them out of and detract from the experience. Takeaways • Viewers can appreciate size and scale to a degree not possible in everyday life • Viewers usually don't have control over approaching objects and characters	Developers • Allow subjects to approach objects in VR rather than having objects approach them • If objects are going to approach the viewer, develop mechanics to give the viewer some control and choice Educators • Inform students of objects and characters that come close • Provide explicit procedures and opportunities to stop if they are uncomfortable All Users • Keep in mind that personal space varies • The ability to manipulate space in VR can provide the benefits of seeing something up close but can also elicit the negative effects of fear or social discomfort
Time travel/perspective – Advances in CGI and film technology allow viewers to be transported to different times and places in immersive experiences. A fair number of students think of this as a form of time travel. Takeaways • VR has the potential to teach students about historical places and events • Visiting places can also create unexpected emotional connections • Adolescents can have trouble distinguishing fantasy versus reality	Developers • Be aware that people utilize VR content in learning environments and may accept it as being an accurate representation • Acknowledge potential personal or source biases in creating VR experiences and take steps to mitigate that effect Educators • Have discussions with students about VR as a secondary source and ask them how content may represent a developer's point of view (just as much as any written document, account, media, site or image) All Users • Consider where content comes from; who created it? Why did they pick this piece of content? What kind of response do they want you to have?

struggle more than expected in distinguishing reality from created reality. In a study of students experiencing augmented reality where computer generated multisensory input was overlaid on a screen while viewing a real environment, 11–16 year olds played a game called *Alien Contact* (Dunleavy, Dede, & Mitchell, 2009). Researchers noted that the students became so immersed in the AR environment that they asked researchers if aliens really had crashed at the school and whether the researchers were in fact affiliated with the FBI. This suggests some confusion on the part of the students and their ability to distinguish between what is real and what is pretend (Southgate et al., 2017).

Recently, we were speaking with an educator who used a wonderful example to illustrate the challenges of immersive technology with adolescents. He heard his middle school students having a real debate about the existence of zombies. He had assumed that by middle school, students would no longer hold those fantastical beliefs. His question to us was, "What is the impact of putting an adolescent who still believes zombies might be real in a virtual experience where they actually interact with behaviorally real zombies?" This is the type of question that researchers, developers, parents, and educators need to consider. As we continue this work with adolescents and VR, we encourage others to consider questions such as the ones below which we are also grappling with.

7 Research Questions for Further Study

- What are steps that should be taken to help adolescents prepare for immersive experiences?
- What role do pre-conversation and post-experience debriefing have in adolescent understanding/internalization of virtual immersive experiences?
- Are there specific strategies we can utilize to promote empathy before, during, and after a VR experience?
- How do participants understand empathy and how does that relate to their emotional response while using VR?
- What are the limits of VR and how do we understand when students have hit their capacity for emotional understanding in this medium?
- What are ways that we can minimize proximal disturbances or distractions for users in VR?
- Are there particular mechanisms that provide users a sense of control over distance and/or impending interaction such that they feel more comfortable within the VR experience?

References

Aora, G., & Milk, C. (2015). *Clouds over Sidra: A virtual reality experience* [video file]. Retrieved from https://with.in/watch/clouds-over-sidra/

Bailenson, J. N., Blascovich, J., Beall, A. C., & Loomis, J. M. (2001). Equilibrium theory revisited: Mutual gaze and personal space in virtual environments. *Presence: Teleoperators and Virtual Environments, 10*(6), 583–598. Retrieved from https://doi.org/10.1162/105474601753272844

Baobab Studios. (2016). *Invasion!* [video file]. Retrieved from http://www.baobabstudios.com/invasion/

Bateson, M., Nettle, D., & Roberts, G. (2006). Cues of being watched enhance cooperation in a real-world setting. *Biology Letters, 2*(3), 412–414. Retrieved from https://doi.org/10.1098/rsbl.2006.0509

Bindman, S. W., Castaneda, L. M., Scanlon, M., & Cechony, A. (2018). Am I a bunny? The impact of high and low immersion platforms and viewers' perceptions of role on presence, narrative engagement, and empathy during an animated 360° video. *Proceedings of SIGCHI Human Factors in Computing Systems (CHI 2018)*. New York: ACM.

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. Retrieved from https://doi.org/10.1207/S15327965PLI1302_01

Bloom, P. (2017). Against empathy: The case for rational compassion [video file]. *Aspen Ideas Festival 2017*. Retrieved from https://www.aspenideas.org/session/against-empathy-case-rational-compassion

Bolkan, J. (2018). Forecast: AR and VR headset sales to return to strong growth following lackluster 2017. *The Journal*. Retrieved from https://thejournal.com/articles/2018/03

/20/report-ar-and-vr-headset-sales-to-return-to-strong -growth-following-lackluster-2017.aspx

Brozzoli, C., Makin, T., Cardinali, L., Holmes, N., & Farne, A. (2011). Peripersonal space: A multisensory interface for body-object interactions. In M. M. Murray & M. T. Wallace (Eds.), *The neural bases of multisensory processes* (pp. 449–466). London: Taylor & Francis.

Casey, B. J., Jones, R. M., & Hare, T. A. (2008). The adolescent brain. *Annals of the New York Academy of Sciences, 1124*, 111–126. Retrieved from https://doi.org/10.1196/annals.1440.010

Castaneda, L. M., Cechony, A., Bautista, A., & Pacampara, M. (2017). *All-school aggregated findings 2016–2017 VR*. Retrieved from http://foundry10.org/wp-content/uploads/2018/03/All-School-Aggregated-Findings-2016–2017.pdf

CB Insights. (2017). *13 Industries That Will Be Transformed by Virtual Reality*. Retrieved from https://www.cbinsights.com/research/ar-vr-industries-disrupted-beyond-gaming/

Delightex GmbH. (2017). *CoSpaces Edu: Make VR in the classroom* [video file]. Retrieved from https://cospaces.io/edu/

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology, 18*(1), 7–22. Retrieved from https://doi.org/10.1007/s10956-008-9119-1

Ekman, P. (1992). An argument for basic emotions. *Cognition and Emotion, 6*(3–4), 169–200. Retrieved from https://doi.org/10.1080/02699939208411068

Francey, D., & Bergmüller, R. (2012). Images of eyes enhance investments in a real-life public good. *PLoS ONE, 7*(5), e37397. Retrieved from https://doi.org/10.1371/journal.pone.0037397

Gebara, C., de Barros-Neto, T., Gertsenchtein, L., & Lotufo-Neto, F. (2016). Virtual reality exposure using three-dimensional images for the treatment of social phobia. *Revista Brasileira de Psiquiatria, 38*(1). Retrieved from https://doi.org/10.1590/1516-4446-2014-1560

Gent, E. (2016). Are virtual reality headsets safe for kids? *Live Science*. Retrieved from https://www.livescience.com/56346-are-virtual-reality-headsets-safe-for-kids.html

Google. (2016a). *Google Earth VR* [computer software]. Retrieved from https://vr.google.com/earth/

Google. (2016b). *Tilt Brush by Google* [computer software]. Retrieved from https://www.tiltbrush.com/

Guardian News Media. (2016). *6x9: A virtual experience of solitary confinement* [video file]. Retrieved from https://www.theguardian.com/world/series/6x9–a-virtual-experience-of-solitary-confinement

Hall, E. T. (1963). A system for the notation of proxemic behavior. *American Anthropologist, 65*(5), 1003–1026. Retrieved from https://doi.org/10.1525/aa.1963.65.5.02a00020

Jensen, F. E., & Nutt, A. E. (2015). *The teenage brain: A neuroscientist's survival guide to raising adolescents and young adults*. New York: HarperCollins.

Lamkin, P. (2017). Virtual reality headset sales hit 1 million. *Forbes*. Retrieved from https://www.forbes.com/sites/paullamkin/2017/11/30/virtual-reality-headset-sales-hit-1-million/#1f0747712b61

LIFE VR. (2016). *Remembering Pearl Harbor* [computer software]. Retrieved from http://time.com/4583817/remembering-pearl-harbor-virtual-reality/

Llobera, J., Spanlang, B., Ruffini, G., & Slater, M. (2010). Proxemics with multiple dynamic characters in an immersive virtual environment. *ACM Transactions on Applied Perception, 8*(1), 1–12. Retrieved from https://doi.org/10.1145/1857893.1857896

Lloyd, D. M. (2009). The space between us: A neurophilosophical framework for the investigation of human interpersonal space. *Neuroscience & Biobehavioral Reviews, 33*(3), 297–304. Retrieved from https://doi.org/10.1016/J.NEUBIOREV.2008.09.007

Madary, M., & Metzinger, T. K. (2016). Recommendations for good scientific practice and the consumers of VR-technology. *Frontiers in Robotics and AI, 3*, 3. Retrieved from https://doi.org/10.3389/frobt.2016.00003

Milk, C. (2015). How virtual reality can create the ultimate empathy machine [video file]. *TED*. Retrieved from https://scholar.google.com/scholar?q=milk+2015+virtual+reality+empathy&btnG=&hl=en&as_sdt=0%2C48

Mujber, T. S., Szecsi, T., & Hashmi, M. S. J. (2004). Virtual reality applications in manufacturing process simulation. *Journal of Materials Processing Technology, 155–156*, 1834–1838. Retrieved from https://doi.org/10.1016/J.JMATPROTEC.2004.04.401

Oculus Story Studio. (2015). *Henry* [video file]. Retrieved from https://www.oculus.com/story-studio/films/henry/

Orland, K. (2017). VR headset sales are slowly rising out of the doldrums. *Ars Technica*. Retrieved from https://arstechnica.com/gaming/2017/11/more-than-a-fad-vr-headset-sales-are-slowly-creeping-higher/

Pantelidis, V. S. (2009). Reasons to use virtual reality in education and training courses and a model to determine when to use virtual reality. *Themes in Science and Technology Education, 2*(1–2), 59–70.

Parsons, T., & Rizzo, A. (2008). Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: A meta-analysis. *Journal of Behavior Therapy and Experimental Psychiatry, 39*, 250–261. Retrieved from https://doi.org/10.1016/j.jbtep.2007.07.007

Passmore, P. J., Glancy, M., Philpot, A., Roscoe, A., Wood, A., & Fields, B. (2016). Effects of viewing condition on user experience of panoramic video. *Eurographics Proceedings.* Retrieved from https://doi.org/10.2312/EGVE.20161428

Powell, K., Roberts, G., & Nettle, D. (2012). Eye images increase charitable donations: Evidence from an opportunistic field experiment in a supermarket. *Ethology, 118*, 1096–1101. Retrieved from doi: 10.1111/eth.12011

Psotka, J. (2013). Educational games and virtual reality as disruptive technologies. *Educational Technology & Society, 16*(2), 69–80.

Radial Games. (2015). *Fantastic Contraption* [computer software]. Retrieved from http://fantasticcontraption.com/

Raschle, N., Zuk, J., Ortiz-Mantilla, S., Sliva, D. D., Franceschi, A., Grant, P. E., . . . & Gaab, N. (2012). Pediatric neuroimaging in early childhood and infancy: Challenges and practical guidelines. *Annals of the New York Academy of Sciences, 1252*, 43–50. Retrieved from https://doi.org/10.1111/j.1749-6632.2012.06457.x

Rizzo, A., John, B., Newman, B., Williams, J., Hartholt, A., Lethin, C., & Buckwalter, J. G. (2013). Virtual reality as a tool for delivering PTSD exposure therapy. *Military Behavioral Health, 1*(1), 52–58. Retrieved from https://doi.org/10.1080/21635781.2012.721064

Rizzo, A., Rizzo, A. A., Schultheis, M., Kerns, K. A., & Mateer, C. (2004). Analysis of assets for virtual reality applications in neuropsychology. *Neuropsychological Rehabilitation, 14*(12), 207–239. Retrieved from https://doi.org/10.1080/09602010343000183

Rizzolatti, G., Fadiga, L., Fogassi, L., & Gallese, V. (1997). The space around us. *Science, 277*(5323), 190–119.

Silverman, A. (2015). The perils of playing blind: Problems with blindness simulation and a better way to teach about blindness. *Journal of Blindness Innovation and Research, 5*(2).

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

Slater, M. D., Johnson, B. K., Cohen, J., Comello, M. L. G., & Ewoldsen, D. R. (2014). Temporarily expanding the boundaries of the self: Motivations for entering the story and implications for narrative effects. *Journal of Communication, 64*(3), 439–455. Retrieved from https://doi.org/10.1111/jcom.12100

Sommer, R. (1959). Studies in personal space. *Sociometry, 22*, 247–260.

Southgate, E., Smith, S. P., & Scevak, J. (2017). Asking ethical questions in research using immersive virtual and augmented reality technologies with children and youth. *2017 IEEE Virtual Reality,* 12–18. Retrieved from https://doi.org/10.1109/VR.2017.7892226

Steinberg, L. (2014). *Age of opportunity: Lessons from the new science of adolescence*. New York: Mariner Books, Houghton Mifflin Harcourt.

Superhot Team. (2017). *SUPERHOT—The FPS where time moves only when you move* [computer software]. Retrieved from https://superhotgame.com/

Taylor, H. (2017). More than one million VR headsets sold last quarter. *Gamesindustry.biz*. Retrieved from https://www.gamesindustry.biz/articles/2017-11-28-vr-headset-sales-exceed-one-million-units-last-quarter

WEARVR. (2015). *08:46* [video file]. Retrieved from https://www.wearvr.com/apps/eightfoursix

Wevr. (2016). *theBlu VR* [video file]. Retrieved from https://wevr.com/project/theblu-vr