SHORT REPORT

Safety and feasibility of an immersive virtual reality intervention program for teaching police interaction skills to adolescents and adults with autism

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Low-cost, wireless immersive virtual reality (VR) holds significant promise as a flexible and scalable intervention tool to help individuals with autism spectrum disorder (ASD) learn and develop critical practical life skills, including interacting safely and effectively with police officers. Previous research suggests that VR is a motivating intervention platform, but many individuals with ASD also exhibit anxiety and sensory sensitivities which might make it difficult to tolerate VR experiences. Here, we describe the results of a relatively large-scale, National Institutes of Health-funded systematic examination of the safety, feasibility, and usability of an immersive VR training program in adolescents and adults with ASD, aged 12 and older. Sixty verbally fluent individuals with no personal or immediate family history of seizures or migraines participated in either one (n = 30) or three 45-min (n = 30) VR sessions using a lightweight wireless headset, and were monitored for side effects. Participants also reported on system usability, enjoyment, and willingness to engage in further VR sessions. Results confirm that immersive VR is safe, feasible, and highly usable for verbally fluent adolescents and adults with ASD. ***Autism Res*** *2020, 00: 1–7*. © 2020 International Society for Autism Research, Wiley Periodicals, LLC.

Lay Summary: Immersive virtual reality (VR) holds promise as a means to provide social skills interventions for individuals with autism spectrum disorder (ASD), but it is unclear whether associated anxiety and sensory symptoms might limit feasibility. Here, we report data that indicate that immersive VR is both safe and feasible for use in verbally fluent adolescents and adults with ASD, for up to three 45-min sessions.

Keywords: adolescents; adults; autism spectrum disorder; feasibility; immersive virtual reality; intervention; safety

INTRODUCTION

Immersive virtual reality (VR) has become less expensive and more accessible to the general public, and excitement around this technology as a potential intervention tool for meaningful skill development in autism spectrum disorder (ASD) has grown. A handful of studies suggest that VR is highly motivating for this population (Finkelstein, Barnes, Wartell, & Suma, 2013; Josman, Ben-Chaim, Friedrich, & Weiss, 2011; Kandalaft, Didehbani, Krawczyk, Allen, & Chapman, 2012) for a review, see (Turnacioglu, McCleery, Parish-Morris, Sazawal, & Solorzano, 2019). However, it remains unclear whether VR is safe, feasible, and enjoyable for individuals with ASD on a larger scale, particularly across multiple sessions. Here, we describe the results of an National Institutes of Health (NIH)-funded study designed to examine the safety, feasibility, and acceptability of using a wireless immersive VR program for verbally fluent adolescents and adults with ASD to practice interacting with police officers.

Many individuals with ASD have a difficult time with new or novel problem solving, and rapidly processing social situations in real time can be a challenge (Channon, Charman, Heap, Crawford, & Rios, 2001; Vanmarcke et al., 2016). VR allows individuals to practice skills repeatedly under simulated conditions. We chose to study simulated interactions with police officers because they are unscheduled, unplanned interactions that can introduce a high level of stress. They are also interactions that are likely to be experienced by individuals across a wide range of functioning, regardless of whether they work, live independently, drive, or use public transportation. Importantly, VR-based

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interventions focused on improving the *police officer* side of this interaction have been developed (Balsamo, 2019).

The current study is a safety and feasibility trial examining a VR-based police safety interaction training program, which was planned and conducted during Phase I of a National Institutes of Health Science and Technology Transfer Research (STTR) Fast-Track Award. Prespecified inclusion/exclusion criteria included a documented diagnosis of ASD (issued by a licensed medical doctor or clinical psychologist and reviewed by licensed clinical psychologist [J. S. M.]), full-scale and verbal intelligence quotient (IQ) scores greater than or equal to 75 on the Wechsler Abbreviated Scale of Intelligence—second edition (WASI-II, Wechsler, 2011), absence of a known genetic syndrome (e.g., Fragile X syndrome, Down syndrome), no medical history affecting brain functioning or development (e.g., brain surgery, brain injury), and no personal or immediate family history of seizures, migraines, or vertigo. Prespecified Phase I safety and feasibility targets for moving into a Phase II randomized controlled trial (RCT) included: (1) fewer than 10% of participants experience serious adverse effects, and (2) usability scores averaging greater than 70% as measured by the System Usability Scale (SUS; [Sauro, 2011] see Appendix S1). This Phase I Safety and Feasibility Trial, along with associated hypotheses and safety and feasibility targets, underwent peer review as an NIH Science and Technology Transfer Research Award proposal (1R42MH115539–01) and was preregistered on clinicaltrials.gov (Protocol ID: 17–014387).

METHODS

Participants

Individuals with ASD aged 12–38 years participated in either one 45-min VR session (Cycle A) or three 45-min VR sessions (Cycle B; Table 1). This study was prospectively reviewed and approved by the Internal Review Board of Children's Hospital of Philadelphia. Recruitment of participants into Cycle A was initiated and completed first, so that safety and feasibility could be evaluated and confirmed in a single VR session protocol prior to moving on to evaluating a three session VR protocol. No participants from Cycle A were rerecruited into Cycle B. Thirty-six additional participants in Cycle A and 43 additional participants in Cycle B expressed interest in participating but were not enrolled after initial telephone screening. Participants were not enrolled for a variety of reasons, including: intellectual ability levels (A = 6, B = 8), verbal fluency (A = 5, B = 2), chronological age (A = 0, B = 3), presence of a genetic syndrome (A = 1, B = 8), personal or family history of seizures (A = 8, B = 5), personal or family history of migraines (A = 10, B = 10), sensory impairments that impede their ability to engage with VR (A = 1, B = 2), medical history affecting brain functioning or development (A = 0, B = 1), reported vertigo (A = 2, B = 0), severe behavioral issues (A = 1, B = 0), or meeting multiple exclusionary criteria (A = 2, B = 4). Eight participants did not continue the study after laboratory-based IQ testing revealed verbal or nonverbal IQ estimates below 75 (A = 3, B = 5). While this first study excluded individuals with known physiological risks (e.g., seizure risk, migraine risk), we take the responsiveness from families as a promising sign of interest in VR within the ASD community (see Discussion). For this study, groups of participants in Cycles A and B did not differ on age, IQ estimates, sex ratio, racial/ethnic background, autism symptoms, sensory sensitivities, or prior VR experience (Table 2). Participants and their parents also completed parent- and self-report questionnaires for characterization, which are listed in Tables 1 and 2.

Measures of safety, feasibility, and usability

Safety was measured by recording serious adverse effects (serious events requiring an emergency room visit, such as a seizure) and mild side effects due to VR use, as reported by participants or caregivers during or after each VR session. In particular, mild side effects (e.g., headache, dizziness, disorientation, nausea, fear, anxiety) were assessed at the end of each VR session, using a semi-structured qualitative interview in which participants were asked both open-ended and specific questions about their experiences and possible side effects (see Appendix S2). If mild side effects were reported, study staff followed up with participants the following day, to check whether side effects dissipated. This interview was conducted by the same clinical research assistant who administered the VR session. Given the line of questioning in the interview, interviewers were not blinded to the potential outcome of the study (see Appendix S2). Feasibility was measured by assessing the percentage of participants who successfully completed an entire VR session (Cycle A) or three sessions (Cycle B). At the end of the final session, usability was assessed via the SUS (Sauro, 2011) modified for use with verbally fluent adolescents and adults on the spectrum (SUS-ASD; Parish-Morris et al., 2018). Although not a primary outcome measure, participant feedback about the VR experience was elicited after every session; this direct stakeholder feedback was vital for further development of the VR intervention.

VR tool: Floreo Police Safety Module

The Floreo Police Safety Module (PSM; Floreo, Inc.) is an immersive mobile VR tool designed to train police safety in adolescents and adults with ASD. The PSM tool is based completely in computer-generated 3D graphics and runs through an application (i.e., "app"), which links an iPhone in a lightweight headset worn by the participant to an iPad held by the intervention provider via wireless

TABLE 1. Demographics and characterization data for Cycles A and B; mean (SD), min–max

	Cycle A $N = 30$	Cycle B $N = 30$	Difference
Age	17.20 (5.99)	16.60 (4.86)	$t = -0.43$
	12–38	12–37	$p = 0.67$
Sex	26 male	26 male	$\chi^2 = 0.00$
	4 female	4 female	$p = 1.00$
Race	0 American Indian	1 American Indian	$\chi^2 = 8.47$
	2 Asian	0 Asian	$p = 0.13$
	4 Black	0 Black	
	0 Native American or Other Pacific Islander	0 Native American or Other Pacific Islander	
	22 White	25 White	
	0 Other	1 Other	
	2 Biracial	1 Biracial	
	0 Not reported	2 Not reported	
Full-scale IQ	101.70 (13.70)	107.07 (16.26)	$t = 1.38$
	76–125	75–132	$p = 0.17$
Verbal IQ	101.00 (11.95)	106.67 (13.78)	$t = 1.70$
	82–126	75–129	$p = 0.09$
SRS-2	81.33 (28.43)	88.30 (22.95)	$t = 1.04$
	11–144	26–133	$p = 0.30$
SCQ—lifetime	19.1 (7.76)	17.69 (5.45)	$t = -0.81$
	7–36	9–29	$p = 0.42$
AQ	26.53 (7.88)	26.07 (7.36)	$t = -0.23$
	12–41	14–41	$p = 0.82$
Sensory profile—sensitivity	38.17 (7.72)	38.72 (9.98)	$t = 0.24$
	22–56	20–59	$p = 0.81$
VR experience?	Yes = 18	Yes = 21	$\chi^2 = 0.29$
	No = 12	No = 9	$p = 0.59$

Notes: IQ was estimated using the WASI-II (four subscales; Wechsler, 2011), SRS-2 was the informant version (Constantino, 2012).

Abbreviations: AQ, Autism Quotient (Baron-Cohen et al., 2001; 2006); IQ, intelligence quotient; SCQ, Social Communication Questionnaire; SRS-2, Social Responsiveness Scale, second edition; VR, virtual reality; WASI-II, Wechsler Abbreviated Scale of Intelligence—second edition. Sensory profile (Brown & Dunn, 2002).

internet (wifi) connection (see also Appendix S3 for additional technical details. While the iPhone presents the immersive VR scene experience to the participant, the iPad presents the intervention monitor with both the visual scene displayed to the participant and several control buttons, along with a text-based instruction window. In this way, the intervention monitor is able to initiate each VR experience for the participant, monitor the participant's performance while interacting with police officers, and control changes in the police officers' behavior in real time (Figures 1 and 2). The intervention monitor also provides direct feedback and instructions to the participant based on the participant's behavioral performance. For example, the monitor observes the participant's verbal responses to officer questions, behaviors including having their hands in or out of their pockets, and orienting their gaze toward the officer. The PSM is implemented using a cognitive-behavioral therapy approach, which includes communicating with the participant about the nature and importance of police interactions and police safety, agreeing on participant-specific targets for skill improvement, skill practice through VR, behaviorally focused progress evaluation, and postsession planning and discussion. The VR application itself involves a number of training trials in which one or two virtual police officers approach the participant and ask several different types of questions, which include asking for the participant's name, where they live, what they are doing, and whether or not they have personal identification (ID) on them, among others.

Procedure

After screening, participants or parents provided written informed consent to participate in the study. Participants and parents then completed a series of online demographic, medical, and family history, and clinical characterization questionnaires (Table 2). Participants made either one (Cycle A) or three (Cycle B) visits to the Center for Autism Research at Children's Hospital of Philadelphia during which they received IQ testing, filled out additional study-specific questionnaires, and engaged in immersive VR. Participants in both cycles completed a brief questionnaire about prior technology use and experience. Participants in Cycle B were also asked to complete a questionnaire about their familiarity with police officers, and prior interactions with law enforcement. Participants in Cycle A then completed one VR session, and participants in Cycle B completed a total of three VR sessions. For each participant, sessions were completed within a 6-week period. During VR sessions, participants interacted with virtual law enforcement officers for approximately 8 min (four 2-min interactions, with a break in between each trial) while wearing a lightweight headset. After each session, safety and usability were assessed and recorded.

RESULTS

Cycle A

Thirty participants with ASD successfully completed one session of VR. *Safety*: No serious adverse events occurred, although some mild side effects were reported (Figure 3). *Feasibility*: One session of immersive VR is highly feasible; 100% of participants who began a VR session completed the entire session. *Usability*: SUS-ASD scores averaged 83.58% (SD: 12.49%; range: 52.5–100%), indicating good usability for this population.

Cycle B

Thirty out of 31 participants with ASD successfully completed three sessions of VR. *Safety*: No serious adverse events

TABLE 2. Measures and questionnaires

	Adolescents	Adults
Demographics/history/IQ		
Medical and family history	×	×
Family demographic form	×	
Adult demographic form		×
WASI-II	×	×
Autism/Social Symptoms		
SCQ: lifetime	×	×
Autism Quotient	×	×
SRS-2: school age (parent report)	×	
SRS-2: adult (self-report)		×
SRS-2: adult (informant report)		×
Behavioral/Sensory Symptoms		
CBCL: Ages 6–18	×	
ABCL: ages 18–59		×
ASR: ages 18–59		×
Sensory Profile Adolescent/Adult Self Questionnaire	×	×
Primary study measures		
Police Knowledge and Experience Questionnaire (Cycle B, visit 1 pre-VR)	×	×
Technology and VR Experience Questionnaire (visit 1 pre-VR)	×	×
Post-VR qualitative interview (all visits, post-VR)	×	×
SUS-ASD (final visit, post-VR)	×	×

Abbreviations: ABCL, Adult behavior checklist; ASD, autism spectrum disorder; AQ, Autism Quotient; ASR, Adult self-report; CBCL, Child behavior checklist; IQ, intelligence quotient; SCQ, Social Communication Questionnaire (Rutter et al., 2003); SRS-2, Social Responsiveness Scale, second edition; SUS, System Usability Scale; VR, virtual reality; WASI-II, Wechsler Abbreviated Scale of Intelligence—second edition. CBCL, ABCL and ASR (Achenbach & Rescorla, 2001; 2003).

occurred, although some mild side effects were reported (Figure 3). Critically, the number of mild side effects reported dropped from 30% in session one to 7% in sessions two and three, suggesting that experiencing a mild side effect in one's first immersive VR experience does not mean that side effects will be experienced in future VR sessions. *Feasibility*: Three sessions of immersive VR are highly feasible; 97% of participants who began a VR session completed the entire session. One participant decided to discontinue the study due to mild side effects, with the participant reporting that the movement very close to their face caused shakiness and nausea. After removing the VR headset, sitting for approximately one to 2 min, and having a drink of water, the participant reported feeling better. However, the participant decided to discontinue participation. This participant did not complete the SUS and thus no scores are included for this participant. *Usability*: SUS-ASD scores averaged 87% (SD: 7.89%; range: 67.5–100%), indicating good usability for this population, even across three sessions. Overall, 80% percent of participants in both cycles reported that they "would like to use this VR again," suggesting that this type of VR is both feasible and desirable for use by verbally fluent adolescents and adults with ASD.

User experience

Although this was a safety and feasibility trial, we purposefully solicited feedback about the user experience via qualitative interviews after each session. This step was important due to the design of our study, which involved

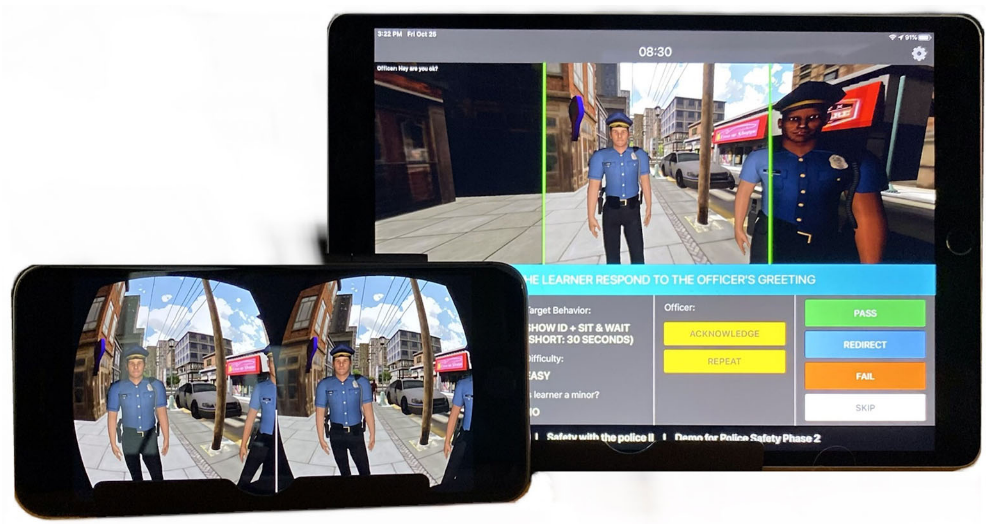

FIGURE 1. Floreo, Inc., Police Safety Module. Presented is the monitor (therapist) controlled iPad screen presentation. Through a wifi connection, this monitor's iPad is linked to the iPhone which presents the learner's immersive VR experience. The portion of the screen between the green vertical lines is what the learner sees via their head-mounted iPhone. The blue window presents instructions to the monitor, and the monitor is able to progress and monitor the learner's experience through the control panel buttons toward the bottom of the iPad screen. VR, virtual reality

FIGURE 2. The virtual reality intervention is administered by a therapist who monitors the learner's responses and behavior, collects data, and provides feedback in vivo

a development phase before beginning our Phase II RCT. Comments from users (positive and negative) were therefore incorporated into Phase II product development efforts. Positive comments included, "It felt like I was in that part of the world," "I feel like I have improved in how I'm feeling every time I've been here," "I was a little scared of police officers at first but then got used to it and felt good," "I think this is a very important topic," "It was beneficial and I feel a bit more prepared now." Suggestions included, "Change the voices," "Make different police officers," "Add other responses, like if I ask a question have them answer it," "Mixing up scenes, scenarios, and questions," "Change their tones to be more intimidating in higher levels," "Other types of confrontations with police officers." The wide variety of useful suggestions that were offered by participants are being incorporated into Phase II development.

DISCUSSION

The goal of this study was to systematically examine the safety, feasibility, and usability of an immersive VR tool designed to improve the ability of adolescents and adults with ASD to interact safely and effectively with police officers. The VR program met or exceeded all prespecified targets, including no serious adverse events, very few nonserious side effects that dissipated quickly, an extremely low participant dropout rate (one from Cycle B), and favorable system usability scores, following both single and multiple VR session protocols. These data represent the first experimental examination of the safety, feasibility, and usability of immersive VR for adolescents and adults with ASD, including across multiple VR sessions, and thereby provide critical evidence to support both clinical and research developments and applications of this technology for the benefit of individuals with ASD.

Limitations of the current study include the potential for participant self-selection bias, whereby the participant pool may have been biased toward those with more positive views of VR and against those who might have increased sensitivity to negative effects such as nausea or disorientation. Therefore, clinicians and educators should use caution and respect individual differences in participant interest and willingness to participate in VR. In addition, the current study utilized only a single VR situation: a relatively calm interaction with virtual police officers. Therefore, the results of the current study may not

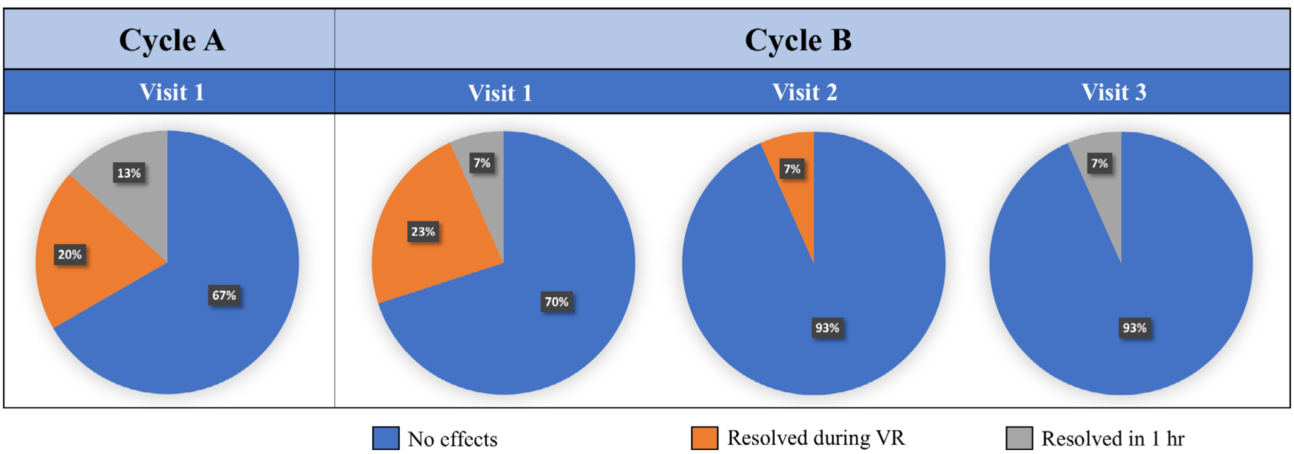

FIGURE 3. Percent of participants experiencing mild side effects in Cycles A and B. One participant in Cycle B experienced mild side effects that resolved within the hour during Visits 1 and 3—All other side effects were experienced by participants at one visit only. No serious side effects (e.g., seizures, migraines) were observed or reported. Participants were asked how they felt periodically during the VR exposure (e.g., after each VR trial). If a participant reported a side effect during VR use, we also followed up at the end of the visit during the qualitative interview, as well as over the phone the next day. VR, virtual reality

generalize to other forms of VR, including forms that include complex or rapid motion, or flickering lights. These features could increase the likelihood of participant experiences of nausea, disorientation, anxiety, or confusion. Finally, although the current study employed a combination of both direct interview-based questioning about specific negative effects and experiences and open-ended questions which were designed to encourage participants to report adverse effects and feelings, we did not examine potential longer-term effects such as negative impacts on physical activity, sleep, or academic performance. Relatedly, the current study only utilized a maximum of three VR sessions, completed in a laboratory setting. Therefore, future research should focus on examining potential longer-term impacts of more intensive VR completed in community-based settings (e.g., schools, homes).

With regard to the efficacy of the current Police Safety VR intervention itself, one barrier to VR-based intervention will be generalization of skills learned in VR to real-world situations. As such, it will be critical for future researchers to collect quantitative measures of safe and effective interactions with police officers following intervention. For example, the primary outcome measure in an ongoing RCT directly comparing VR-based police safety training to an established video modeling curriculum (BE SAFE; Iland, 2014) includes a police interaction score behaviorally coded from a video-recorded live interaction with a police officer (clinicaltrials.gov ID: 17-014387). This police interaction score is derived from coding variables that include orienting to the officer, fidgeting, appropriateness of verbal responses, and an overall behavioral interaction quality rating. In order to increase the likelihood of learning skills that generalize to live police interactions and other real-world scenarios, the VR-based police safety intervention has been revised to incorporate virtual police officers who are more varied in both their physical appearance and interaction style, produce more complex questioning and conversations, and are more emotionally responsive to the VR participant's behavioral and conversational responses.

CONCLUSIONS

In this study, we demonstrated the safety, feasibility, and usability of a wirelessly linked VR application in a large sample of verbally fluent adolescents and adults with ASD with no personal or family history of seizures or migraines, across one and three sessions of VR. No serious adverse events or side effects (e.g., seizures, migraines) occurred. Some mild side effects were reported for a small percentage of participants, but these mild side effects resolved within the hour. Future research should examine the safety and feasibility of more intense and longer-term VR-based interventions and exposures in real-world contexts, and should include measures of other aspects of functioning, including physical activity, sleep, and academic performance, in addition to the more direct physical experiences and psychological effects examined in the current study.

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CONFLICT OF INTEREST

R. S. and S. T. receive financial compensation as employees of Floreo, Inc. V. R. receives financial compensation and royalties as Co-Founder and Chief Executive Officer of Floreo, Inc. J. M. receives financial compensation from Floreo, Inc., as consultant to the clinical development team. We thank the research participants and their families for their participation in this study.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1. See attached SUS-ASD. The original SUS was accessed from https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html. After pilot testing revealed inconsistent answering due to negatively worded questions (Parish-Morris et al., 2018), the SUS-ASD was developed for use with individuals on the autism spectrum

Appendix S2. See attached semi-structured qualitative interview in which participants were asked both open-ended and specific questions about their experiences and possible side effects associated with the virtual reality intervention

Appendix S3. See attached technical details for Floreo, Inc. Virtual Reality Setup utilized in the current study