Eliciting Affect via Immersive Virtual Reality: A Tool for Adolescent Risk Reduction

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Objective A virtual reality environment (VRE) was designed to expose participants to substance use and sexual risk-taking cues to examine the utility of VR in eliciting adolescent physiological arousal.

Methods 42 adolescents (55% male) with a mean age of 14.54 years (SD = 1.13) participated. Physiological arousal was examined through heart rate (HR), respiratory sinus arrhythmia (RSA), and self-reported somatic arousal. A within-subject design (neutral VRE, VR party, and neutral VRE) was utilized to examine changes in arousal.

Results The VR party demonstrated an increase in physiological arousal relative to a neutral VRE. Examination of individual segments of the party (e.g., orientation, substance use, and sexual risk) demonstrated that HR was significantly elevated across all segments, whereas only the orientation and sexual risk segments demonstrated significant impact on RSA.

Conclusions This study provides preliminary evidence that VREs can be used to generate physiological arousal in response to substance use and sexual risk cues.

Key words adolescents; physiological arousal; sexual risk; substance use; virtual reality.

During adolescence, youth engagement in risk behaviors increases, placing many adolescents at risk for pregnancy and other unwanted health outcomes. Youth Risk Behavior Surveillance (YRBS) data indicate that among adolescents in high school, 71% have tried alcohol and 40% have tried marijuana (CDC, 2012). Initiation of sexual activity also climbs across adolescence, while the trajectory for condom use behavior shows an inverse pattern such that rates decline as adolescents age (CDC, 2009). Therefore, making innovative, adolescent-friendly tools to enhance the capacity of risk prevention interventions is critical.

A number of sexual and substance use prevention interventions have been successful at improving knowledge and behavioral skills (Robin et al., 2004), but knowledge and skills do not always translate into decreased risk behavior (Santelli et al., 2004). This suggests that other processes may interfere with the application of knowledge and skills in real-world situations. Affect management represents an understudied, but potentially meaningful, set of processes that have been linked to adolescent risk-taking behavior. Several studies have documented greater sexual risk among teens with poor affect management, which has been associated with risk taking longitudinally (Brown et al., 2010; Shrier et al., 2009). These relationships may exist because adolescents’ difficulties with affect management increase the likelihood that they will engage in self-soothing behaviors, such as substance use or risky sex, which ultimately increases their odds for sexually transmitted infections or pregnancy. They may also be more reactive to emotional triggers in risky environments, such as parties. This affective dysregulation may impair their ability to use previously learned knowledge and skills.
skills (e.g., assertive communication, proper condom use) to successfully avoid risk.

Fortunately, research has shown that affect management skills can be learned via teaching and modeling (Bell & McBride, 2010; Smyth & Arigo, 2009), and improving affect management skills can reduce both substance use and sexual risk taking. In general, the focus of affect management interventions is to regulate underlying emotions so that one can use protective behavioral skills (e.g., assertive communication). Prior studies of affect management interventions targeting substance use (e.g., alcohol, marijuana) have been able to effectively reduce rates of substance use among adolescents by improving affective coping (Bond et al., 2004; Esposito-Smythers, Spirito, Kahler, Hunt, & Monti, 2011). Similarly, two recent studies targeting affect management skills within the context of sexual risk reduction have both demonstrated that among teens with emotional and behavioral disorders, affect management skills can enhance a sexual risk reduction intervention and increase safer sexual practices (Brown et al., 2011, 2013). Taken together, these studies provide evidence that improving affect management strategies is a viable option for targeting risk reduction.

Across affect management interventions, role-playing is used to elicit emotions and teach affect management skills. However, this approach has limitations with adolescents, for whom the capacity for perspective taking is still developing, making it difficult to imagine or act out a realistic scene that successfully arouses affect. In the absence of affective arousal, the ability to truly learn affect management skills may be limited.

One tool that has been put forward as a means of enhancing the role-play experience and providing contextual cues for affective arousal is virtual reality (VR). Since the early 1990s, VR has been increasingly accepted and adopted by clinicians to intervene with patients presenting with a variety of disorders, including specific phobias, PTSD, substance use, and autism spectrum disorders. Studies have demonstrated that VR can elicit affective responses and/or craving in patients and lead to a reduction in symptoms after treatment (Baumann & Sayette, 2006; Bordnick et al., 2008; Macedonio, Parson, Digiuseppe, Weiderhold, & Rizzo, 2007; Saladin, Brady, Graap, & Rothbaum, 2006). To date, only a few studies have used VR technology as a tool for intervening with children or adolescents (Bordnick, Taylor, Graap, Copp, & Brooks, 2005; Dahlquist et al., 2007; Nemire, Beil, & Swan, 1999), and no study has specifically focused on affective arousal in the context of sexual risk cues among adolescents.

The limited application of VR in adolescent populations is surprising given the previously mentioned developmental challenges of using role-plays with this age-group. VR may be useful in enhancing adolescent learning of affect management, as VR provides several advantages over current methods. First, VR can create important, affect-eliciting contextual cues encountered in the real world (e.g., drugs and alcohol, peers “making out”) that are difficult to simulate in clinical or research settings. Second, immersive virtual reality environments (IVREs) are said to simulate “life-like” environments. This may be due to IVREs’ ability to not only engage the visual sense but also allow for participants to directly interact with the environment and persons within the environment. Tracking sensors within a head-mounted display (HMD) helmet allow the view to change as the participant’s head moves. Creating a sense of “realness” may be critical to evoking the affective responses necessary to providing opportunities for practicing affect regulation. Despite the promise of IVRE use with adolescents, no prior study has examined whether VR can impact physiological arousal.

To address this first, but necessary, question of whether IVR can elicit arousal, we conducted the present study. We also aimed to examine the impact on physiological arousal of an IVR party environment that was specifically developed for adolescents. Arousal was examined through both self-report of somatic sensations and physiological arousal data collection including heart rate (HR) and respiratory sinus arrhythmia (RSA). Numerous studies have demonstrated that HR is a viable measure of physiological arousal and can be used to capture momentary response to stimuli presented in real-world and virtual environments among both clinical and nonclinical samples (Alpers, Wilhelm, & Roth, 2005; Jang et al., 2002; Macedonio et al., 2007; Muhlberger, Bülthoff, Wiedemann, & Pauli, 2007). While HR provides some information about reactivity, recently more emphasis has been placed on looking at variability in cardiac parameters. RSA reflects changes in HR associated with the respiratory cycle. HR slows during expiration and quickens during inspiration. According to Porges’ polyvagal theory (Porges, 1995), the neural basis for this RSA is the rhythmic gating of the vagus nerve’s (the chief nerve of the parasympathetic nervous system) efferents to the heart. Therefore, the amplitude of RSA, as quantified from beat-to-beat heart period data, can be thought of as a reasonably (but not absolutely) pure index of parasympathetic activity (Porter, 2001). For the current study, we chose to examine these physiological indices of arousal as a means of collecting in vivo data and also to reduce the influence of retrospective bias on self-report of arousal.

For the current study, we expected adolescents to report an increase in self-reported somatic symptoms of
arousal following exposure to the developed IVR party. Secondly, we hypothesized that the developed IVR party would be associated with increased HR and decreased RSA relative to a neutral, noninteractive VRE. Changes in RSA, in the context of the proposed research, represent the extent to which RSA is suppressed under conditions of challenge. Lastly, we expected that HR and RSA would return to baseline levels in a neutral postparty VRE. In addition to these hypotheses, we chose to use nonparametric statistical methods to explore the pattern of HR and RSA during different segments of the party, including the party orientation, substance use cues, and sexual risk cues.

Method
Participants
All participants were recruited via flyers from urban high schools and community-based organizations in a northeast city. Adolescents were eligible for participation if they could speak and read in English, were between the ages of 12 and 16 years, were not currently receiving any form of mental health treatment, and reported having been to a party without adult supervision. The latter was included to control for potential novelty effects on adolescent arousal during the VR party. Adolescents cognitively unable to give assent were excluded, as were participants who screened positive for motion sickness susceptibility (which could be triggered by VR exposure) and/or indicated a clinically significant number of symptoms on a brief measure of psychological distress (to minimize the additive effect of VR on already distressed adolescents). Fifty adolescents consented and were enrolled in the project; of those, 46 adolescents were eligible for participation (four were screened out because of motion sickness susceptibility).

All study procedures were approved by the hospital institutional review board. Parents provided consent for their adolescent’s participation and adolescents provided assent. Study measures were completed via paper-and-pencil forms. Adolescents were compensated $50 for their time and travel-associated costs.

VR Party Scene
The IVR party was developed through an iterative process based on feedback from adolescents participating in a series of focus groups (Figure 1). Two cue-specific virtual environments (one male and one female) that represent age-specific party scenarios were designed to expose participants to virtual marijuana and alcohol cues as well as virtual sexual cues (e.g., avatars kissing). The IVR party comprised three segments: party orientation (passive substance use and sexual risk cues), interactive substance use cues, and interactive sexual risk cues.

Party Orientation
The scene begins with two teens walking up a sidewalk to the front door of a home where a party is being held. One is the participant (viewed from a first-person experience); one is a same-sex friend accompanying the participant into the party. The friend chats with the participant about the party. Music and laughter are heard as the teens approach the door. The friend knocks on and opens the door. The dyad is greeted by a partygoer and they enter the living room of the home together. He/she sees other teens standing around in mixed-gender groups. A couple can be seen sitting on the couch talking and flirting but not touching. Adolescents at the party are seen drinking alcohol and smoking marijuana.

Substance Use
As the scene progresses, the subject is offered alcohol and marijuana by the other partygoers. The participant and his/her friend are approached by a male peer and directed to the kitchen for alcohol. The friend retrieves a beer and offers one to the participant. Moments later, the party host walks by and offers the participant marijuana.

Sexual Risk
Next, the couple sitting on the couch begins to kiss and touch one another. The couple then walks into a back room and closes the door. While the couple walks toward the door, catcalls referencing sexual behavior are heard from the others at the party. Afterwards, the friend points to an opposite-sex peer and encourages the participant to talk to him/her. The opposite-sex peers wave/nod at the participant and friend. The friend makes a sexual comment to the participant about the opposite-sex peers as they walk over to where the participant and friend are standing. The friend and one opposite-sex peer begin to flirt openly. After talking, the two walk off together, leaving the participant standing alone with the remaining opposite-sex peer, who becomes more explicit in his/her flirting (e.g., “How come I don’t see you out more often?”). The scene ends with the opposite-sex peer asking the participant to go to a private back room.

Design and Procedures
A within-subject design (baseline, experiment, and baseline) was utilized to examine changes in both self-report of arousal and physiological data. Adolescents completed baseline measures including demographics and a self-report measure of somatic arousal. On completion of the
baseline measures, trained research assistants described the immersive virtual reality protocol and asked participants to remain seated throughout the protocol. Adolescents were then requested to place three sensors on their abdomen to record HR. A respiration belt was placed around the adolescent’s waist to capture respiration rate. Respiration rate and HR were each factored into the algorithm that was used to calculate RSA (see Measures for greater detail). While the adolescent participated in the IVREs, HR and respiration rate were continuously monitored to examine the adolescent’s physiological reactivity to the IVREs.

Once the physiologic sensors were placed, the participant was asked to put on the HMD. The virtual reality software, developed by Virtually Better, Inc., ran on one laptop (HP Elitebook 8540p, Intel Core i7 640M (2.80 GHz), 4 GB of memory, NVIDIA Quadro NVS 5100 M) with the HMD attached via a VGA cable. The HMD used in this study was the eMagin z800 HMD system (eMagin Corp., Bellevue, WA), which delivered a three-dimensional image to the patient with analog super video graphics array resolution (800 × 600) and a 40° field of view. The HMD included built-in head tracking, which replicates the patient’s head movements in the simulated world so the participant can control where he/she looks in the virtual world. Stereo, directional audio was provided to the patient through sound-reducing headphones. Adolescents navigated through the virtual environment on a predetermined path, which included a mix of free-range head movement and fixed views. Fixed views were used to ensure that adolescents were exposed to programmed stimuli that were hypothesized to increase arousal (e.g., flirtatious peer, alcohol), and free range allowed the user to look around the virtual environment. The user interface was developed so that the research team could utilize adolescent-selected music CDs for the party environment. These elements (music and specified intervals of free-range head movement) were allowed to vary across participants to provide the participant with an increased sense of presence in the virtual environment.

The IVR program consisted of three stages. In Stage 1, adolescents viewed neutral IVRE (5 min; aquarium; see

Figure 1. Screenshots from the virtual reality environment. (A) Neutral aquarium environment. (B) Entering the living room of the party. (C) Being offered alcohol by a friend. (D) Couple walking into back room together.
Figure 1). This environment was developed for three purposes: (1) to control for factors related exclusively to experiencing IVR, (2) to measure baseline HR and RSA prior to the introduction of substance use and sexual risk stimuli, and (3) to allow participants to adjust to the VR equipment. In Stage 2, subjects entered the developed IVR party (7 min; see Figure 1) targeting affect-inducing situations related to sexual and substance use risk behavior relevant to adolescents. All stimuli within the IVR party were presented at preset intervals to allow for replication across participants. The research assistant was able to view the virtual scene on a video monitor in an adjacent room throughout the IVR. The IVREs and the physiological data measurement system were synchronized, such that at the moment stimuli were introduced they were marked by the research assistant to allow for examination of affective arousal patterns following each stimulus. After exposure to the IVR party, subjects reentered the neutral VR aquarium environment (Stage 3; 5 min) to complete the study protocol. At the conclusion of the IVR program, participants were directed to remove the HMD, the physiological sensors, and the respiration belt and to complete relevant paper-and-pencil questionnaires.

**Screening Measures**

The Motion Sickness Susceptibility Questionnaire was used to screen out participants who may be at greater risk for developing cybersickness symptoms. In accordance with the protocol of Stanney and colleagues (2002) for managing cybersickness, adolescents with a score of 11.3 or higher (>50th percentile) were eligible for participation in the IVR program.

Global Severity Index (GSI) of the Brief Symptom Inventory (BSI) is a weighted frequency score that assessed adolescent distress. It has excellent test–retest reliability (\(\alpha = 0.90\)) and internal consistency reliability (Derogatis, 1993). Adolescents exceeding the clinical cut-off score or actively involved in mental health treatment were not included in the study because the impact of VR sexual and substance use risk cues on the potential for increasing distress was unknown.

**Assessment Measures**

**Demographics**

Items collected included age, gender, race, ethnicity, and income.

Sensory State Awareness Scale (Monti et al., 1993) comprises 11 items (\(\alpha = 0.91\)) assessing adolescent perception of somatic sensations (e.g., faster HR, sweating hands). Items are rated on a 5-point scale (1 = not at all to 5 = a lot). Adolescents completed this measure prior to entering the VR environments; they also provided retrospective reports of symptoms experienced in the IVR party after completing the scene.

Physiological measures of reactivity and regulation were assessed using a James Long Co. integrated system to examine the physiological arousal response to the VR environments; both sympathetic (HR) and parasympathetic (RSA) indices were measured. HR was measured from two disposable electrodes attached axially on the left and right ribs at the elevation of the heart. Respiration was measured by attaching strain gauge respiration bellows around the adolescents' abdominal area. Electrocardiogram (ECG) data were sampled and digitized at 1 kHz. R-wave times were extracted from the ECG channel and edited manually using ECGRwave software (James Long Company, Caroga Lake, NY, USA). The strain gauge respiration bellows were connected to the bioamplifier for transduction, amplification, and digitization. The RSA program (James Long Company) calculates RSA as the difference between the minimum interbeat interval (IBI) during inspiration and the maximum IBI during expiration (in seconds). This program computes the difference in IBI twice for each respiration cycle, once for inspiration and once for expiration, assigning times of inspiration and expiration as the midpoints of each and calculating the arrhythmia.

Because adolescents reported anticipatory anxiety prior to entering the VR environment, only Minutes 2 and 3 were used to represent baseline arousal. This minimized possible effects associated with the initial setup, as well as anticipatory anxiety related to entering the party environment. For purposes of consistency, this same time frame was extracted from the postparty neutral VR environment for all data comparisons. This data reduction approach resulted in a total of 11 min (2 min baseline, 7–7.5 min party, 2 min postparty) of physiological data across the three stages of the VR program.

**Data Analysis**

Mixed models were used to test the a priori hypotheses that participants would show higher HR and lower RSA during the party relative to the neutral environment. Mixed models were chosen to account for the multiple observations (average observations per participant = 780) nested within participants (n = 42). Because the focus of the investigation was on change in HR and RSA, observations were centered on individual participants’ mean HR and RSA values. To reduce the influence of extreme and potentially anomalous readings from the physiological measures, we removed outliers for participants relative to their own mean and standard deviation. The mixed models allowed both the initial value of HR and RSA and the response to...
the party to vary across participants. Effect sizes were calculated by computing the mean response for each participant during each VR stage and then dividing the mean difference between stages by the standard deviation of the comparison stage. Nonparametric methods were used to explore the pattern of HR and RSA during different segments of the party, including the party orientation, substance use cues, and sexual risk cues. Local regression was used to smooth individual participant trajectories, and penalized regression splines were used to generate the aggregate trajectory accounting for the nesting of observations within participants. Analyses were performed using SAS GLINMIX and SGPLOT.

Results

Background Information

Four of the 46 eligible enrolled participants had unusable data due to hardware failure. The final sample (n = 42) was 55% male, with a mean age of 14.54 years (SD = 1.13). Ethnic composition of the sample was 45% Hispanic. Racial composition was 28% White, 19% multiracial, 17% African American, and 36% did not report a racial identity. The majority of those who did not indicate a racial identity reported being of Hispanic or Latino ethnicity. An annual yearly household income of <$30,000 was reported by 50% of participants.

Self-Report of Physiological Arousal

Adolescents reported a significant decrease in somatic symptoms on the SQL Server Analysis Services from baseline to post-IVRE (pre M = 8.05, SD = 7.68 vs. post M = 3.81, SD = 4.19; t (41) = 3.33, p < .01), with a medium effect size (d = 0.55).

Physiological Data Examining Arousal

Model-predicted responses from the mixed models are depicted in Figure 2. A significant increase in HR was found between the neutral baseline IVRE and the IVR party (F(1, 41) = 2.62; p = 0.01, d = 0.57) and a significant decrease in RSA from baseline IVRE to the IVR party (F(1, 41) = 9.13; p < .01, d = 0.55). Both analyses found a medium effect size for these differences. There were no differences between the IVR party and the neutral postparty stimuli for either HR (F(1,41) = 1.22; p = 0.28, d = 0.17) or RSA (F(1,41) = 0.99; p = .33 d = 0.09), with both producing small effect sizes. Model-predicted responses from the nonparametric regressions are depicted in Figure 3. Based on a visual inspection of these graphs, we decided to test for quadratic trends within each segment of the party. These post hoc models were fit using mixed models and showed a significant quadratic trend for HR during the party orientation segment (F(1,41) = 6.22; p = 0.02), substance use segment (F(1,41) = 7.01; p = 0.01), and sexual risk segment (F(1,41) = 25.91; p < .01). Modeling also showed a significant quadratic trend for RSA during the party orientation segment (F(1,41) = 4.35; p = 0.04) and sexual risk segment (F(1,41) = 5.36; p = 0.03).

Discussion

Consistent with our hypotheses, results demonstrated that the IVR party succeeded in increasing physiological arousal (i.e., both an increase in HR and a decrease in RSA) relative to a neutral IVR environment. Previous studies using IVR to simulate driving, flying, and other phobic cues (e.g., elevators, bridges) have demonstrated similar patterns of increased physiological arousal (Jang et al., 2002; Wilhelm et al., 2005). Notably, all prior studies have focused on adult populations, within the context of addressing phobias (e.g., negative affect), and have used varying measures of physiological arousal (e.g., galvanic skin response, interbeat intervals of HR). Given that this is the first study to examine the impact of sexual and substance use risk cues delivered using VR on HR and RSA with adolescents, comparison with previous studies should be made cautiously. However, these results suggest that IVR may be a viable tool for increasing physiological arousal associated with affective arousal among adolescents in the context of substance use and sexual risk behaviors, thus providing a useful context for affect management skill practice.

In addition to the primary outcomes, interesting results emerged from the post hoc quadratic analyses examining adolescent arousal in response to individual party segments. Rather than a simple linear increase in arousal in response to a new series of cues, the graph took on a nonlinear parabola. The gradual increase in arousal (i.e., increase in HR and decrease in RSA) following exposure, and then a gradual reduction in the arousal response may provide preliminary evidence of adolescents attempting to regulate their affect after the presentation of cues. Alternatively, this pattern may represent the natural waxing and waning of physiological arousal when in a stimulating environment or simply habituation to stimuli. Given that this is the first study to examine physiological arousal in response to risk cues among adolescents, future studies will need to examine this pattern before drawing any firm conclusions.

Although the IVR party led to an increased physiological arousal, as anticipated, several findings were contrary
to our initial hypotheses. First, the significant decrease in self-reported somatic arousal symptoms when comparing measures prior to entering the IVR environments and after exiting the IVR program was contrary to our expectations. However, this outcome is consistent with previous studies demonstrating that adolescents may not be able to reliably report on their somatic arousal (Dorard, Berthoz, Phan, Corcos, & Bungener, 2008). It is also possible that adolescents exhibited a positive cognitive bias about their arousal after successfully completing the IVR party, and therefore were not able to provide accurate retrospective report on their actual arousal when in the IVR party. This finding highlights the importance of measuring self-report of arousal immediately following the delivery of cues to minimize potential bias; however, this may introduce a new stimulus that would impact the sense of presence in the virtual environment. Presence has been shown to be a key feature in determining the experience of participants in virtual environments (Sanchez-Vives & Slater, 2005). Presence is enhanced by the perceived “realness” of

Figure 2. Physiological responses recorded during participants’ virtual reality experience. RSA = respiratory sinus arrhythmia.
objects and persons (e.g., sharpness in details) in the environment (Wirth et al., 2007), which is key to affect recognition tasks.

Second, no significant differences emerged for either HR or RSA in comparisons between the IVR party and the post-VR aquarium. One explanation for the continued elevation in HR is that this was a remnant of adolescent arousal from the IVR party and highlights adolescents’ inability to regulate their affect, even when returning to a neutral stimuli environment. Future studies should consider extending the period of observation following an affectively arousing situation to examine patterns of regulation. As shown in previous studies among adults (Frazier, Strauss, & Steinhauer, 2004), RSA data following

Figure 3. Physiological responses recorded during the presentation of specific cues within the virtual reality environment. Individual trajectories were estimated using local regression. Average trajectory was estimated using penalized spline regression. RSA = respiratory sinus arrhythmia.
*Quadratic effect significant at $p < .05$. 

Neutral Stimuli | Party Introduction | Substance Use | Sexual Risk | Neutral Stimuli
--- | --- | --- | --- | ---
Neutral Stimuli | Party Introduction | Substance Use | Sexual Risk | Neutral Stimuli

Mean Centered Heart Rate

Mean Centered RSA

Time (minutes)
an affectively arousing situation may provide an important insight into an adolescent’s ability to manage their affect. Enhancing an adolescent’s ability to manage their affect in risk situations may increase the chances that they will use previously learned safer sex skills, based on prior research linking affect management abilities and sexual risk (Brown et al., 2012; Raffaelli & Crockett, 2003).

Third, although HR was impacted by the substance use cues, we did not see a concomitant decrease in RSA. There are several possible explanations for this finding. One possibility is that substance use cues were not very novel for this population of adolescents who had prior experience attending a party. In addition, the lesser realism of cues may have impacted adolescents’ arousal levels, whereby in the real world adolescents rely on olfactory cues (e.g., the smell of pot) and visual cues (e.g., smoke) to determine the reality of the cue. The relatively short study timeline and limited resources impacted our ability to devote the necessary time to programming these more challenging cues. As technology continues to advance and tools become less costly, this constraint will likely fade.

The study findings are enhanced by the involvement of a diverse group of youth with prior experience attending an unsupervised party. Likewise, because of the large volume of data generated for each participant (i.e., ~800 observations), we were able to use a sophisticated analytical approach, with a relatively small sample (n = 42), to test our basic assumptions, and explore patterns of response across the three segments of the developed IVR party (orientation, substance use, and sexual risk). Additionally, the use of an ABA design allowed us to explore the general impact of VR on arousal and examine adolescent responding to the VR sexual and substance use risk cues. The combination of thoughtful sampling and design increases our confidence that the results of the current study provide a good representation of an adolescent’s physiological experience when exposed to IVR sexual and substance use cues.

Although this study includes a number of strengths and provides new insight into adolescent arousal when exposed to risk cues, the limitations must be considered. Notably, the developed IVR party presented cues in rapid-fire succession that likely do not simulate real world experience, and therefore may have amplified the physiological arousal data. The true test of this environment will be to examine whether it provides enough similarities to real-world situations that allow adolescents to practice safer sexual practices (e.g., refusal skills, safer sex negotiation) that can then be translated into reductions in adolescent risk behavior and subsequent negative outcomes (e.g., pregnancy). In addition, this study does not directly measure affective arousal state. While physiological arousal has been repeatedly linked to affective arousal (Frazier et al., 2004), the current study does not provide us with specific data on affective state when exposed to sexual and substance use risk factors. The challenge for future studies will be to examine this momentary self-reported affective response while still maintaining adolescent’s sense of presence in VR environments. Finally, the current study results may not generalize to all youth, including adolescents with mental health disorders and/or those older than 16 years, because they were actively screened out of the current study. Given the high rates of risk behavior among youth with mental health problems (Brown, Danovsky, Lourie, DiClemente, & Ponton, 1997) and a decreasing trend in safer sex practices among older adolescents (CDC, 2009), it will be important to examine whether the IVR party has a similar impact for these populations.

In conclusion, this study has provided preliminary evidence that IVREs can be used to generate physiological arousal in response to substance use and sexual risk cues. It also provides some foundational work for the pattern of responses during the VR party that will allow for more confirmatory hypothesis testing in future studies. The next step will be to test this environment within an intervention targeting substance use and sexual risk reduction to determine whether the IVR party provides adolescents with a close-to-real-world environment to practice skills that can be translated into real-world behavior. Future studies will also be necessary to examine the process by which the IVR party impacts how affect regulation varies among individuals. For example, the IVR party might act as an exposure paradigm in which continued exposure would decrease arousal in risky real-life situations, thus improving adolescent’s ability to make more rational decisions. Additionally, this practice might increase self-efficacy for managing affect in such situations, but will need to be explored in future studies using VR to target sexual and substance use risk reduction. The validation and use of these tools will hopefully provide sexual health interventionists with new tools to pursue sexual risk reduction among youth and stem the growing epidemic of HIV, STDs, and unplanned pregnancies.

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References


