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ORIGINAL PAPER

Virtual Reality Erotica: Exploring General Presence, Sexual Presence, Sexual Arousal, and Sexual Desire in Women

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Abstract

Virtual reality (VR) media using a three-dimensional (3D) camera facilitates an immersive experience compared to traditional two-dimensional (2D) formats. In this novel study, we used high quality, women-centered erotica and examined whether stimulus modality (VR vs. 2D) and point of view (POV: first-person vs. third-person) impacted women's feelings of sexual presence (activation of sexual response induced by the perception of being present), sexual arousal, and sexual desire (dyadic and solitary). We also investigated the effects of stimulus modality on feelings of general presence (a sense of "being there"). Results from 38 women indicated that with medium to large effects, general presence, sexual presence, and sexual arousal were significantly higher for VR videos relative to 2D videos. Sexual presence was higher for first-person POV depending on the order of film exposure. A general trend toward increasing dyadic sexual desire over the course of the study was observed. No significant differences were observed for solitary sexual desire. These findings support the adaptability of VR media to sex research and show that it can induce feelings of sexual presence and presence more generally. That sexual arousal was positively impacted by VR erotica may have implications for addressing the limitations that accompany other stimulus modalities used to elicit sexual responses in women.

Keywords Virtual reality · VR erotica · Erotic stimuli · Women's sexual experiences · Pornography

Introduction

Virtual reality (VR), defined as an interactive form of human–computer interface, aims to elicit psychological and behavioral responses in a virtual environment that are analogous to the real world (Bohil et al., 2011). In the past few decades, VR use has increased in many fields varying from scientific use and professional training to the entertainment industry (Wood et al., 2017). The adult film industry has accounted for significant spikes in VR use and is projected to be the third-largest VR entertainment sector (Botoon, 2015). Capturing real sexual scenes using a three-dimensional (3D) camera, VR allows for erotica to be experienced in a more fully immersive format compared to traditional, voyeuristic two-dimensional (2D) media (Elsey et al., 2019). Despite its increasing popularity, few studies have investigated how individuals—particularly women—respond to VR erotica. VR research may have implications for addressing in-laboratory limitations regarding ecological validity and may increase a sense of realness in an inherently artificial setting by engaging the sensorimotor system more fully than other modalities (Bohil et al., 2011; Fromberger et al., 2015; Renaud et al., 2014). This study aimed to examine whether VR is superior to traditional 2D laboratory paradigms in eliciting women's sexual responses.

Immersion, Presence, and Virtual Reality

Researchers distinguish between two main features of VR: immersion and presence. Immersion reflects the objective description of aspects of the technological system (e.g., whether presentation is on a flat screen versus stereoscopic; Schubert et al., 2001). Presence is a psychological phenomenon conceptualized as the subjective experience of being in the virtual environment (Schuemie et al., 2001). As the immersive features of a virtual environment improve (e.g.,

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when using stereoscopic visuals and wide fields of view), levels of presence increase (Cummings & Bailenson, 2016). In turn, subjective sense of presence is associated with emotional responses (e.g., Dores et al., 2013; Fromberger et al., 2015; Gorini et al., 2010; Kim et al., 2014) and affective reactions may be directly enhanced when more immersive technology is used. Sexual response is inherently an emotional response since it is a multifaceted state that encompasses the awareness of autonomic arousal, expectation of reward, and motivated desire (Everaerd, 1989). In this vein, sexual presence is an extension of general presence and is defined as the activation of sexual response induced by the subjective perception of erotic stimuli (Simon & Greitemeyer, 2019).

Previous research exploring sexual experiences using VR technologies is nascent, and only two studies have compared the differential effects of traditional 2D versus 3D VR erotica on presence and arousal. First, Simon and Greitemeyer (2019) compared the effects of viewing sexually explicit films on a conventional 2D desktop monitor and in a 3D immersive VR environment. Films were viewed from a first-person point of view (POV) that showed the sexual acts from the viewer's perspective. Sixty heterosexual men were exposed to the same video twice—once in each modality—with a counterbalanced order of exposure. With medium and large effect sizes ($\eta^2 = 0.12$–0.47), results consistently yielded a stronger effect on physiological and subjective sexual arousal when men viewed videos using VR compared to when videos were viewed using the 2D desktop display, and presence and sexual presence were also fostered in the higher immersive VR condition. Moreover, there was a positive correlation between presence and subjective sexual arousal in the VR condition but not in the desktop condition. For sexual presence and subjective sexual arousal, however, a correlation was found for both conditions. In their analyses, the authors controlled for order of exposure and reported no significant impact of order on the dependent variables—except for physiological arousal, whereby higher levels were seen during the second exposure regardless of stimulus modality. As women were not included in this study, it leaves open the question as to how VR immersion impacts women's sexual response.

A second study evaluated self-reported subjective sexual arousal and sense of general presence induced by VR relative to 2D erotica in 95 heterosexual men and women (Elsey et al., 2019). All participants viewed erotic videos from a first-person POV and a third-person POV. Unlike first-person POV, viewing videos from a conventional third-person POV involves a more passive or voyeuristic experience. With a small effect ($\eta^2 = 0.04$), results indicated a gender and modality (VR vs. 2D) interaction, such that men showed higher subjective sexual arousal to VR relative to 2D, but women did not. Elsey et al. (2019) also found a large effect for general preference for first-person POV relative to third-person POV in men and women, regardless of VR or 2D presentation. A large effect ($\eta^2 = 0.30$) was also noted where both genders reported greater presence in the VR condition compared to the 2D condition, and presence was positively correlated with subjective sexual arousal in both first-person and third-person perspectives. Although results from this study illustrate the importance of the perspective from which erotic stimuli are presented, an important gendered limitation was observed. The authors speculated that due to the scarcity of female-targeted VR content, the videos for women were of relatively poor quality and they were not able to match stimuli across the genders for POV nor across VR and 2D. For instance, while all videos for men included heterosexual intercourse only, first-person POV videos for women contained elements of same-sex intercourse as well as heterosexual intercourse (Elsey et al., 2019). Taken together, these two studies show great promise for the impact of VR erotica on sexual experiences and the limitations point to opportunities to improve stimuli and study methodologies in the future.

Sexual Response in Laboratory Settings

Sexual response is elicited in laboratory settings typically by exposure to sexual stimuli (e.g., images and films depicting sexual activity) in 2D on a computer monitor (Chivers, 2005). Using 2D stimuli, Janssen et al. (2003) found that men's arousal in response to sexual scenes was determined by the attractiveness of the woman performer, the ability to enjoy the scene as an observer, and the ability to imagine themselves in the scene. In contrast, women's responses were only affected by their ability to imagine themselves in the place of the woman featured in the sexual scenes (Janssen et al., 2003). Affect and absorption into a sexual scene are central to Mosher's (1980) involvement theory, according to which sexual arousal consists of an affect–cognition interaction, an awareness of physiological sexual arousal, and sexual affects (sexual interest, sexual enjoyment, sexual pleasure, or anticipatory excitement; Mosher et al., 1988). When viewing erotica, the depth of involvement depends on a goodness of fit such that women reported experiencing a deeper involvement resulting in more sexual arousal, positive affect, and absorption, when viewing erotica intended for women compared to erotica intended for men (Mosher & MacIan, 1994). Taken together, perhaps the use of advanced technology to view 3D erotica and the capabilities of VR that allow viewing sexual scenes from different points of view may facilitate and enhance sexual response in women. Thus, there is a need to explore alternative methodologies that may increase women's depth of involvement and sense of sexual presence (i.e., feeling as if one is involved in a realistic sexual scene) and potentially elicit greater sexual response relative to standard paradigms that employ 2D sexual scenes.

The Current Study

The current study served as a demonstration of a novel protocol in which VR technology was used to deliver high quality, women-centered erotica. Specifically, we compared the effects of stimulus modality (i.e., VR vs. 2D) on women's feelings of general presence, while they viewed erotic videos. We also examined the impact of stimulus modality and POV (i.e., first-person vs. third-person) on women's levels of sexual presence and subjective sexual responses, namely sexual arousal, and dyadic and solitary sexual desire. This study is the first of its kind to use high quality, woman-centered erotica to explore whether VR is superior to traditional 2D laboratory paradigms in eliciting women's sexual responses, shedding light on the potential relationship between sexual response intensity and sexual concordance. We hypothesized that levels of general presence would be greater in the VR condition compared to the 2D condition. We also predicted that sexual presence scores as well as levels of sexual arousal, and sexual desire (dyadic and solitary) would be higher while viewing: (1) VR videos relative to 2D videos; and (2) videos depicting first-person relative to the third-person POV. We also hypothesized an interaction between stimulus modality and POV, such that first-person POV videos in a VR format would elicit the highest levels of sexual response. When hypothesizing two same direction main effects, one must also consider a possibility of a synergistic interaction between stimulus modality and POV, such that first-person POV videos in a VR format would elicit the highest levels of sexual response. We tested such interactions for all relevant outcomes but considered those analyses to be secondary and exploratory and our primary focus remained on the main effects.

Method

Participants

Participants were recruited through the University of British Columbia Human Subject Pool in the Department of Psychology. To be eligible to participate, self-identified women were required to be over 18 years of age and be comfortable viewing erotic videos depicting nude couples engaging in sexual activity. Forty-six women signed up to participate in this study and met inclusion criteria and provided consent. Data from seven women were excluded due to incomplete participation (i.e., did not complete the in-laboratory component) and one woman was excluded due to a technical error. Thirty-eight women, aged 19 to 31 ($M_{age} = 20.79$, SD = 2.23), completed all components of the study and were randomized such that 16 women ($M_{age} = 21.56$, SD = 2.94) viewed VR videos in Block 1 followed by 2D videos in Block 2, and 22 women ($M_{age} = 20.23$, SD = 1.34) viewed 2D videos in Block 1 followed by VR videos in Block 2. The following ethnic backgrounds were reported: 42.1% ($n = 16$) East Asian, 34.2% ($n = 13$) Euro-Canadian, 10.5% ($n = 4$) South Asian, 5.3% ($n = 2$) multiethnic, 2.6% ($n = 1$) African, 2.6% ($n = 1$) Southeast Asian, and 2.6% ($n = 1$) unreported. The majority of our sample was heterosexual (84.2%, $n = 32$), 10.5% ($n = 4$) identified as bisexual, 2.6% ($n = 1$) identified as pansexual, and 2.6% ($n = 1$) did not report their sexual orientation. Half of the participants were single (50%, $n = 19$), 28.9% ($n = 11$) were in a committed relationship, 15.8% ($n = 6$) were dating, and 5.3% ($n = 2$) were common-law.

Materials

Experimental Stimuli

Neutral and erotic audiovisual stimuli were used. Neutral videos included nature scenes taken from freely accessible Internet websites that permitted non-commercial use. All erotic films depicted dyads engaging in consensual sexual activity such as kissing, touching, cunnilingus, and vaginal penetration. Erotic videos did not include depictions of fetish, degradation, and violence. Two erotica film categories were included: (1) videos depicting one female and one male actor, and (2) videos with two female actors. Erotic films were purchased from production companies that focused on women's pleasure and outlined ethical production practices. Terms of Use for erotic videos permitted non-commercial use.

A 1-min nature video served as an adaptation stimulus and was shown first during the practice trial so that participants could acclimate to the testing environment. Neutral stimuli separated each sexual scene and included four 2-min nature videos (two in VR and two in 2D). Erotic stimuli included four 5-min videos (VR first-person, VR third-person, 2D first-person, 2D third-person). For the VR condition, women were immersed in a 180-degree encounter when viewing the videos in the VR headset. Videos for the 2D condition were also presented in the VR headset such that the headset displayed a virtual living room that contained a 2D television screen displaying the 2D videos. For erotic videos shown from a first-person stance, the perspective from which women viewed the scene was through the eyes of the female actor engaging in the aforementioned sexual acts in the scenes. For erotic videos shown from a third-person stance, women watched a couple engage in the sexual activities. Order of erotic video exposure was counterbalanced across participants.

Apparatus

All experimental stimuli were presented using an Oculus Quest VR headset to control for the effect of the headset. The Oculus Quest has a resolution of 1440 × 1600 pixels per eye

with a 360-degree field of view and a refresh rate of 72 Hz. The experiment was built using Unity version 2019.1.7f1, which is a popular software engine for designing 3D environments and video games. Oculus Touch VR controllers were used to control features of the headset (i.e., volume, play/pause, etc.) and to select responses to questions directly in the headset.

Measures

General Presence

The Independent Commission-Sense of Presence Inventory (ITC-SOPI; Lessiter et al., 2001) was used to measure cross-media (VR vs. 2D) experiences of presence by assessing how involved or present participants felt after viewing videos in each modality (i.e., after viewing both videos in VR and after viewing both videos in 2D). The 44-item scale includes four factors: (1) Spatial indicates how individuals are physically involved in a virtual environment (e.g., "I felt I could interact with the displayed environment"), (2) Engagement indicates how individuals are psychologically involved in a virtual environment (e.g., "The content appealed to me"), (3) Naturalness indicates ecological validity and how real a virtual environment is (e.g., "The displayed environment seemed natural"), and (4) Negative Effects indicate adverse physiological reactions (e.g., "I felt nauseous"). A scale ranging from 1 (Strongly disagree) to 5 (Strongly agree) was used and a mean score for each subscale was calculated. The Spatial, Engagement, Naturalness, and Negative Effects factors have high internal consistencies with Cronbach's alphas of 0.94, 0.89, 0.76, and 0.77, respectively (Lessiter et al., 2001). The ITC-SOPI also showed strong internal consistency for each factor in the present sample, with a Cronbach's alpha of 0.90 for Spatial, 0.89 for Engagement, 0.74 for Naturalness, and 0.81 for Negative Effects.

Subjective Sexual Presence

A 10-item measure of subjective sexual presence (SSP; Renaud et al., 2016) was used after each erotic video, with 3 items measuring the level of realism (e.g., "To what degree did you feel sexual arousal similar as one felt in a real sexual situation?") and 7 items assessing levels of involvement (e.g., "To what extent did you have the feeling of witnessing live sexual intercourses taking place in front of you?"). A scale ranging from 1 (Not at all) to 7 (Completely) was used, and a total score was calculated by summing individual items—with higher scores indicating greater sexual presence. Simon and Greitemeyer (2019) utilized this SSP measure in their study and reported a Cronbach's alpha of 0.81 for their sample in the VR condition and 0.78 for the 2D desktop condition. Cronbach's alpha for the SSP in the present sample was 0.91.

Sexual Arousal

After each erotic video, participants provided ratings on two items indicating subjective sexual arousal and self-reported genital arousal (i.e., "During the film, I felt sexually aroused" and "Any genital feelings?") on a scale ranging from 1 (Not at all) to 7 (Intensely). The mean score of those two items was used as the sexual arousal variable. These items were taken from the well-known Film Scale (Heiman & Rowland, 1983) often used in studies of female sexual psychophysiology to assess self-reported sexual response and affect to erotic stimuli.

Sexual Desire

Participants reported the strength of their dyadic and solitary sexual desire before and after each erotic video on a scale ranging from 0 (No desire) to 9 (Maximum desire), and difference scores between these time points were analyzed. For practicality, two items were used (i.e., "How strong is your desire for sex with a partner?" and "How strong is your desire to masturbate?") rather than a more comprehensive desire measure as these two items have previously been used effectively to assess responsive desire (Dawson & Chivers, 2014).

Demographics

Demographic information included age, ethnicity, sexual orientation, relationship status, previous erotica use, and previous VR experience. A variety of other psychological measures were administered along with these measures but were not analyzed as part of the current paper.

Procedure

Participants enrolled in the study using the university human subject pool portal and received an individualized Qualtrics survey link to complete the pre-assessment questionnaire the day before their scheduled in-laboratory assessment. Upon arrival to the laboratory, participants were given a general overview of the study by the researcher and asked to confirm their age and comfort with viewing erotic videos. After providing written consent, participants were seated in a private testing room and provided with instructions about the video paradigm and how to use the VR headset. The researcher helped participants put on the VR headset and demonstrated the controller using a brief practice trial containing a short nature film followed by some practice questions. Participants were instructed to select their preferred erotic film category (choices: heterosexual or lesbian films) in the headset once

the researcher left the room. Videos were viewed in two blocks and the order of videos (VR first-person, VR third-person, 2D first-person, 2D third-person) was counterbalanced across participants, such that participants either viewed the VR videos in Block 1 followed by the 2D videos in Block 2, or vice versa. After each block, participants were instructed to remove the headset and complete the 44-item general presence measure on an iPad. A brief break was also provided between blocks to allow participants to rest without the headset. Each of the 5-min erotic videos was separated by 2-min nature videos to facilitate participants' return to an unaroused baseline (Huberman et al., 2017; Rieger et al., 2015). Questions pertaining to sexual presence, sexual arousal, and sexual desire appeared directly in the headset after each video and participants used a VR controller to provide their answers. After viewing all four videos, participants ranked the videos in the order of their preference from 1 (Most enjoyable) to 4 (Least enjoyable) before removing the headset and using an intercom to inform the researcher that they were finished. The researcher debriefed participants and informed them that they would receive a follow-up survey in 3 days—the follow-up survey contained measures that were not analyzed in this study. Upon completion, participants were granted 2 course credits for their participation. All procedures were approved by the Behavioural Research Ethics Board at the University of British Columbia.

Data Analysis

Given that our general presence measure is modality-specific (i.e., does not measure POV) and was administered after each block to evaluate differences across stimulus modalities, each of the four general presence subscales was subjected to a 2 (Stimulus Modality: VR, 2D) × 2 (Order of Exposure: VR viewed in Block 1, 2D viewed in Block 1) mixed effects ANOVA (modality being within-subject and order being between-subject factor). To examine the effect of stimulus modality and POV on outcomes, each of the remaining dependent variables (sexual presence; sexual arousal; dyadic and solitary sexual desire) was subjected to a 2 (Stimulus Modality: VR, 2D) × 2 (*POV*: first-person, third-person) × 2 (Order of Exposure: VR viewed in Block 1, 2D viewed in Block 1) mixed effects ANOVA, with modality and POV as within-subject factors and order of exposure as a between-subject factor. Significant interactions were further examined using post hoc pairwise comparisons. Statistical significance was adjusted for multiple comparisons (MC) using false discovery rate-based Benjamini–Hochberg (B–H) correction (Benjamini & Hochberg, 1995). The B–H procedure has been recommended as a better alternative to Bonferroni correction and has been increasingly used in behavioral health research (Glickman et al., 2014). Since the main effects of modality and POV were the main hypotheses in this study, the MC adjustment was applied to 12 comparisons (eight main effects of modality and four main effects of POV). While we tested for the interactions of all three independent variables, we did not include interactions in the MC adjustment because the modality by POV interactions was secondary to the main hypotheses and the interactions with order of exposure were done for manipulation check purposes. Accordingly, when we report those interactions, we acknowledge that they should be considered with caution. We allowed for 10% of false positive findings (roughly one significant finding out of the 12 tested models) to assure in this exploratory study that we did not miss potentially interesting findings that may stimulate further inquiry (McDonald, 2014) and taking into consideration the fact that the B–H correction has been found to be conservative under dependency among test statistics (our outcome measures are moderately correlated) (Benjamini & Yekutieli, 2001; Yekutieli & Benjamini, 1999). In the B–H adjustment procedure, the p values obtained in the study are rank ordered from the smallest to the largest, and critical p values for each of them are calculated using a formula. The largest obtained p value that is smaller than or equal to the B–H critical value is considered significant and all obtained p values that are smaller than that p value is considered significant. The B–H critical p values are reported in parentheses next to each finding. We also conducted Pearson correlations to examine associations between sexual presence and each of the sexual response variables. When reporting effect sizes, we used partial eta-squared for the mixed effects ANOVA (0.01 = small, 0.09 = medium, 0.25 = large) and Cohen's d for our post hoc comparisons (0.20 = small, 0.50 = medium, 0.80 = large). We calculated a priori sample size based on the large effect sizes previously reported for sexual presence and sexual arousal when examining stimulus modality (Simon & Greitemeyer, 2019), as well as for general presence when examining POV (Elsey et al., 2019). To detect our predicted effects based on a large effect, we required a total sample size of 24 (power = 0.80, alpha = 0.05). We oversampled to account for any potential data problems. All analyzed data are available on the Open Science Framework (https://osf.io/umvnw/?view_only=b65824c0935b498bb77f5e21fed3f023).

Results

Control Variables

No significant difference was observed in age across the group of women who viewed Block 1 followed by Block 2 compared to women who viewed Block 2 followed by Block 1. All but one woman in our sample (97.4%, $n = 37$) indicated having some previous experience with erotica. For previous experience with VR technology, 71.1% ($n = 27$) indicated

they had not used an experimental VR system in the past. We controlled for previous erotica use and previous experience with VR technology in the following analyses.

Selection of Experimental Stimuli

A Friedman's test showed no differential effects in how the videos were ranked across participants, $\chi^2(3) = 2.59$, $p = .459$, indicating that the content and quality of videos were well selected across each type of video (VR first-person, VR third-person, 2D first-person, 2D third-person). With respect to the selected film category, 78.9% ($n = 30$) of participants selected heterosexual films and 21.1% ($n = 8$) selected lesbian films. No significant differences were detected across participant-selected film category; as such, the current results are collapsed across film category.

Multiple Comparison Adjustment

The obtained p values for 12 hypothesized main effects (Modality impact tested on eight outcomes and POV impact tested on four outcomes) were rank ordered from the smallest ($p < .001$) to the largest ($p = .891$), and B–H critical p values were calculated for each of them. The p value = .042 was the largest obtained p value that was equal or smaller than its B–H critical p value (.05) therefore all the effects in this study that have a p value equal to or less than .042 are considered statistically significant.

General Presence

Results revealed a significant main effect of stimulus modality for three subscales, as presented in Table 1. Regardless of order of exposure, general presence scores were significantly higher for VR videos compared to 2D videos for the Spatial subscale, $F(1, 36) = 83.54$, $p < .001$, $\eta_p^2 = .70$, Engagement subscale, $F(1, 36) = 34.61$, $p < .001$, $\eta_p^2 = 0.49$, and Naturalness subscale, $F(1, 36) = 8.28$, $p = .007$, $\eta_p^2 = 0.19$. All three effects remained significant after adjustment for multiple comparison. As shown in Table 1, the Negative Effects subscale did not show any significant differences across VR and 2D videos, $F(1, 36) = .06$, $p = .805$.

Sexual Presence

A significant effect of stimulus modality was found for subjective sexual presence, $F(1, 36) = 64.75$, $p < .001$, $\eta_p^2 = 0.64$. As shown in Table 1, total sexual presence scores were significantly higher for VR videos compared to 2D videos. There was also a significant effect of POV, $F(1, 36) = 5.76$, $p = .022$, $\eta_p^2 = 0.14$, such that higher sexual presence was reported after watching first-person videos. The effect remained significant after B–H adjustment. This main effect was qualified by a significant interaction between POV and order of exposure as depicted in Fig. 1, $F(1, 36) = 6.05$, $p = .019$, $\eta_p^2 = 0.14$. When 2D videos were viewed in Block 1, total sexual presence scores were significantly higher for videos depicting first-person ($M = 42.71$, SD = 7.69) compared to third-person POV ($M = 37.68$, SD = 6.01), $p = .001$, $d = 0.73$. When VR videos were viewed in Block 1, however, total sexual presence scores were not significantly different across first-person (M = 33.91, SD = 7.69) and third-person POV ($M = 33.97$, SD = 6.01), $p = .969$, $d = 0.01$.

Sexual Arousal

For sexual arousal, there was a significant effect of stimulus modality, $F(1, 36) = 4.43$, $p = .042$, $\eta_p^2 = 0.11$, such that sexual arousal scores were significantly higher when viewing VR films compared to 2D films (Table 1). This result remained significant after B–H adjustment. No significant difference was found across POV ($p = .843$).

Table 1 Mean (plus standard deviation and observed range) scores for sexual presence, sexual arousal, dyadic sexual desire, solitary sexual desire, and the four factors of general presence across stimulus modality (VR vs. 2D)

	VR			2D		
Variable	*M*	SD	Observed range	*M*	SD	Observed range
Sexual presence[a]	42.61	7.0	23–65	31.52	8.08	13–56
Sexual arousal[b]	3.93	1.38	1–7	3.54	1.10	1–7
Dyadic sexual desire[c]	2.49	2.06	− 8–8	2.53	2.14	− 3–8
Solitary sexual desire[c]	2.09	1.93	− 4–8	1.88	1.81	− 2–7
General presence: Spatial[d]	3.32	0.58	1.95–4.37	2.39	0.63	1.05–3.58
General presence: Engagement[d]	3.63	0.63	2.15–4.85	3.09	0.62	1.46–4.38
General presence: Naturalness[d]	3.71	0.65	1.60–4.80	3.36	0.63	1.40–4.40
General presence: Negative Effects[d]	2.51	0.82	1.17–4.50	2.53	0.72	1.00–4.33

VR virtual reality; *2D* two-dimensional stimuli

Scale ranges [a]10-70; [b]1-7; [c]-9–9; [d]1-5. Higher scores indicate greater degrees of the given domain

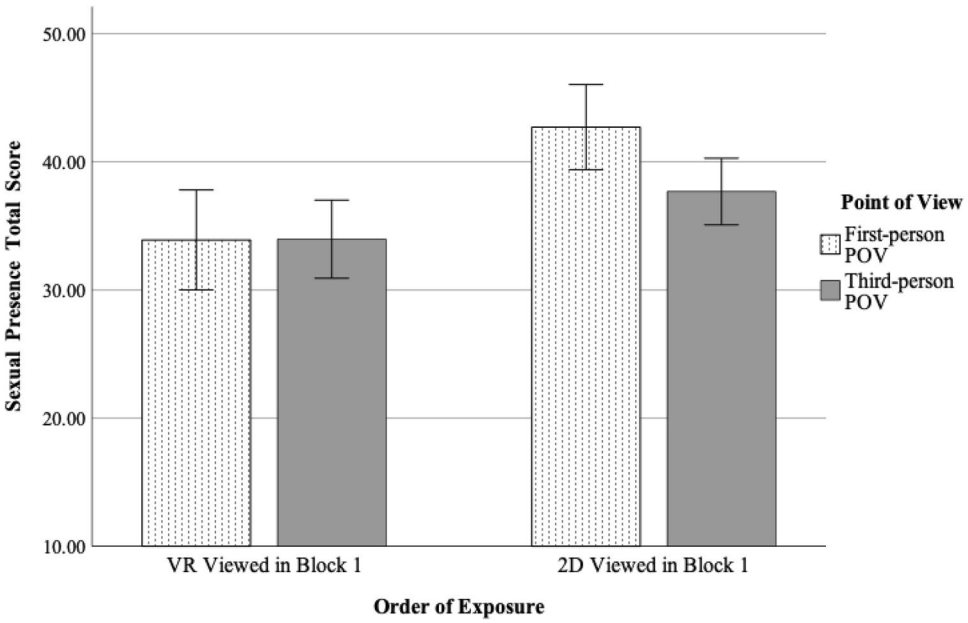

Fig. 1 Mean sexual presence total scores were significantly higher for first-person compared to third-person point of view (POV) only when the 2D videos were viewed in Block 1. When VR videos were viewed in Block 1, no significant differences were observed across POV. Scale range 10–70. Error bars represent 95% CI

Sexual Desire

For dyadic sexual desire, there was no significant main effect of modality ($p = .891$) or POV ($p = .625$). However, there was a significant interaction between stimulus modality and order of exposure, $F(1, 35) = 13.97$, $p = .001$, $\eta_p^2 = 0.29$ (Fig. 2). When VR videos were viewed in Block 1, dyadic sexual desire scores were significantly higher for 2D films appearing in Block 2 ($M = 2.84$, SD = 2.09) compared to VR films viewed in Block 1 ($M = 1.84$, SD = 2.01), $p = .015$, $d = 0.49$. When 2D videos were viewed in Block 1, dyadic desire scores were significantly higher for VR films viewed in Block 2 ($M = 3.14$, SD = 2.01) compared to 2D films viewed in Block 1 ($M = 2.21$, SD = 2.09), $p = .010$, $d = 0.45$. Thus, dyadic sexual scores increased over time leading to higher scores in Block 2. For solitary sexual desire, no significant differences were found across stimulus modality or POV ($ps > 0.472$).

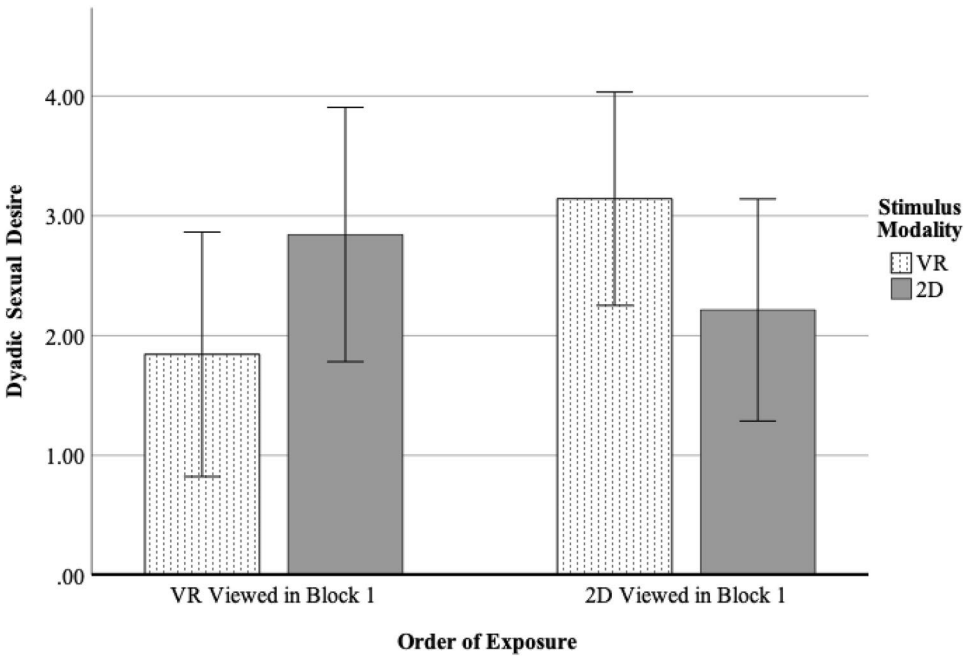

Fig. 2 Mean dyadic sexual desire scores were significantly lower for videos viewed in Block 1. When 3D virtual reality (VR) videos were viewed in Block 1, dyadic sexual desire scores were higher for 2D videos appearing in Block 2. When 2D videos were viewed in Block 1, dyadic sexual desire scores were higher for VR videos appearing in Block 2. Scale range − 9–9. Error bars represent 95% CI

Sexual Presence and Sexual Response

We conducted Pearson correlations between each sexual response variable and total sexual presence scores for all videos (VR first-person, VR third-person, 2D first-person, and 2D third-person), and the results are presented in Table 2. Across all films, we found strong, positive correlations for sexual presence scores and sexual arousal. In examining associations between sexual presence and dyadic sexual desire, we found moderate, positive correlations for VR first-person, 2D first-person, and 2D third-person films. However, sexual presence and dyadic sexual desire were not significantly correlated for VR third-person videos. For solitary sexual desire, moderate positive correlations were found for VR first-person, VR third-person, and 2D third-person videos, but not for 2D first-person films.

Discussion

The goal of this novel study was to explore the use of VR technology as a medium to deliver high quality erotica and evaluate women's experiences. We examined how stimulus modality (VR vs. 2D) and POV (first-person vs. third-person) would influence general presence, sexual presence, sexual arousal, and sexual desire (both dyadic and solitary). As expected, viewing videos in VR resulted in higher general presence scores on the Spatial, Engagement, and Naturalness subscales, but no differences emerged for the Negative Effects subscale across stimulus modality. Replicating previous research in men (Simon & Greitemeyer, 2019), we observed significantly higher feelings of sexual presence for VR videos. Sexual presence was the only variable impacted by POV, with higher scores observed for first-person POV, but only for participants who viewed the 2D videos in Block 1 followed by VR videos in Block 2. Contrary to previous findings (Elsey et al., 2019), we observed higher sexual arousal scores when videos were viewed in VR, regardless of order of exposure and POV. Dyadic sexual desire scores were observed as increasing over the course of the study with higher scores reported in Block 2. Stimulus modality and POV had no differential impact on solitary sexual desire.

Associations Between Presence, Modality, and Point of View

The present findings corroborate existing findings that illustrate the described capability of VR technology to induce feelings of general presence and sexual presence (Elsey et al., 2019; Simon & Greitemeyer, 2019). Results from our general sense of presence measure supported our hypothesis that women felt more physically and psychologically involved and provided higher naturalness ratings for VR videos compared to 2D videos. Our results parallel Simon and Greitemeyer's (2019) findings in men, which showed higher realness ratings for VR as well as feeling more physically present and involved in a virtual environment. As hypothesized, higher feelings of sexual presence were reported when women were exposed to the immersive VR videos relative to the 2D videos, regardless of order of exposure. Taken together, these findings are consistent given that VR videos elicit a sense of "being there" that is characterized as perceiving oneself to be enveloped by and included in the virtual environment (Witmer & Singer, 1998).

Considering sexual presence and POV, our hypothesis was partly supported. Videos depicting first-person POV yielded higher sexual presence scores but only when the 2D videos were viewed in Block 1. We observed no significant differences when VR videos were viewed in Block 1 and novelty of the modality could be a factor influencing this result (Duane & Gurrin, 2020). With 71% of our participants indicating no previous experience with VR technology, the novelty of being exposed to VR videos from the experiment onset may have resulted in experiencing similar levels of sexual presence across VR videos in Block 1, regardless of POV. In contrast, when 2D videos were viewed in Block 1, the first-person POV may have elicited the novelty factor and resulted in the POV effect. Given that the vast majority of mainstream erotica has catered to men, there is a dearth of erotic videos depicting women's first-person perspective (Rubin, 2018). Consequently, women in our study may have been exposed to

Table 2 Pearson correlations between sexual response variables (sexual arousal, dyadic sexual desire, and solitary sexual desire) and sexual presence scores in each film modality

	Sexual presence			
	VR		2D	
Variable	First-person POV	Third-person POV	First-person POV	Third-person POV
Sexual arousal	.744**	.684**	.646**	.682**
Dyadic sexual desire	.524**	.308	.353*	.448**
Solitary sexual desire	.577**	.376*	.300	.490**

VR virtual reality; *2D* two-dimensional stimuli; *POV* point of view

Correlation is significant at the $^{**}p < .01$; $^{*}p < .05$ level (2-tailed)

first-person erotica for the first time and experienced higher levels of sexual presence for videos depicting the more salient first-person POV.

Associations Between Sexual Responses, Modality, and Point of View

Given that a greater sense of presence is related to more intense emotional reactions (Baños et al., 2004, 2008), such that affective responses may be enhanced when one is immersed in a virtual environment, we expected sexual response (i.e., sexual arousal, dyadic sexual desire, and solitary sexual desire) to be greater when erotica was viewed in VR compared to 2D, and also for videos viewed from the first-person POV. We found that women reported more sexual arousal when viewing VR relative to 2D videos but the effect size was small. That women experienced similar levels of sexual arousal across stimulus modality may be explained by the fact that we used high quality, women-centered erotica for both VR and 2D videos. Studies have demonstrated that women experience more sexual arousal and positive affect when viewing female-centered films compared to male-centered films (Laan et al., 1994; Mosher & MacIan, 1994), and this may have increased responses of sexual arousal to the 2D films.

Contrary to our hypotheses, we found no effect of POV on sexual arousal. This stands in contrast to previous research which found that there was a preference for first-person POV in women and men (Elsey et al., 2019). Other research has found that instructing participants to identify with the actors and imagine engaging in the acts being depicted in erotic videos enhances sexual arousal (Both et al., 2011), and we did not provide such instructions in our study. Future research might evaluate differences due to instructions while examining impacts of POV on sexual arousal.

Although our hypotheses for sexual desire (both dyadic and solitary) were not supported, we did observe a general trend that sexual desire for dyadic sexual activity increased as a function of time. That is, regardless of stimulus modality and POV, women indicated higher levels of dyadic sexual desire as the experiment progressed. The incentive motivation model (Toates, 2009) posits that encountering sexual stimuli trigger sexual arousal, which in turn results in sexual desire (Laan & Both, 2008). If the sexual response system can be activated by sexual stimuli, then exposure to four different high quality erotic videos should yield an increase in sexual desire, consistent with our data. The pattern of increasing levels of desire for partnered sexual activity was not replicated for solitary sexual desire: This variable was not impacted by stimulus modality nor POV. This null finding may be due to the nature of the stimuli used in our study—all videos contained dyadic interactions. Investigating the impact of stimulus modality and POV on solitary sexual arousal using erotic videos that depict solitary masturbation may be a fruitful avenue for future investigations of solitary sexual desire.

Associations Between Sexual Presence and Sexual Response

Consistent with findings that show a positive association between sexual presence and sexual arousal in men (Simon & Greitemeyer, 2019), we found moderate to strong positive correlations between sexual presence and our sexual arousal measures. Associations between sexual presence and sexual desire (both dyadic and solitary) were moderate for some videos and weaker for others. Overall, given that women reported feeling sexually present, particularly when viewing videos in VR, our positive associations were consistent with the notion that sense of presence and emotional responses are related to one another for positively arousing stimuli (Elsey et al., 2019). The observed relationship between sexual presence and sexual response in our study illustrates another important aspect, namely selecting erotic stimuli that make women feel involved and sexually present, especially when the aim is to elicit sexual response. Taken together, sex researchers should consider not only the quality and content of the erotic stimuli they are selecting but also the degree of realism and levels of involvement, to allow for optimal conditions to elicit sexual response in women.

Implications

Results from the current study shed light on a novel paradigm involving VR applied within sex research and provide some methodological and clinical implications. Our results show that VR technology has the potential to increase salience of erotic videos and result in higher levels of sexual presence and presence more generally, which in turn may bring about and enhance feelings of sexual arousal. In contrast to traditional modalities (i.e., 2D desktop monitors) that have been used to examine women's sexual response in a laboratory setting, utilizing VR erotica to boost levels of sexual presence may provide an improved alternative to traditional research methods by creating a more realistic experience. Given the levels of realism and engagement that VR offers as a modality, this technology may be used to shed light on aspects of women's sexual response, specifically sexual arousal, outside of a laboratory setting—an important aspect that remains to be explored by future investigations.

Furthermore, illustrating that VR technology used to display erotica may lead to increased feelings of sexual presence and elicit sexual arousal may have important implications for the use of VR in exposure-based treatments of sexual dysfunction. More specifically, research has shown VR to be an effective treatment for phobias and certain anxiety

disorders via gradual exposure to a feared object and the subsequent reduction in the anxiety response (Lafortune et al., 2020). The practical and ethical limitations of conventional exposure-based treatments for sexual dysfunction may be circumvented by the use of VR technology (Lafortune et al., 2020). Such therapeutic applications are possible because of the high degree of ecological validity and control enabled by VR (e.g., tailoring scenarios to an individual's needs and providing therapies that might otherwise be impossible; Bohil et al., 2011). Findings from this study provide a foundation for future studies to explore the development and evaluation of VR-based exposure therapies in sexual dysfunction treatment.

Limitations

While the main focus of the current study was to evaluate VR technology as a potential modality for stimulus presentation, a number of other variables, not measured, may have mediated these effects. For example, it is possible that anxiety, stress, emotional affect, sexual history including past sexual trauma, and attention could have affected the outcomes and should be measured in future trials.

Our decision to use single-item questions to measure dyadic sexual desire and solitary sexual desire was intended to reduce participant fatigue—specifically, to reduce the amount of time participants were required to wear the VR headset (as questions were answered directly in the headset). We acknowledge that the narrow scope of the single-item measures may have impacted our results. There are more comprehensive and multi-item scales available to measure sexual desire, and future studies should seek to include such measures.

We also acknowledge that the generalizability of our findings may be limited. In addition to a small sample size, our sample included young women from a university human subject pool who indicated that they were comfortable viewing erotica. In this regard, we must acknowledge the possibility of volunteer bias given that volunteers of sexuality studies, compared to non-volunteers, typically report more positive sexual attitudes, less sexual guilt, more sexual experience, and more exposure to erotic materials (Strassberg & Lowe, 1995). Indeed, in our sample of 38 women, we only had one participant with no previous erotica exposure. However, we believe that despite the fact almost all of our participants had previous erotica experience, viewing erotica in VR was novel to most of our participants as 71.1% ($n = 27$) indicated that they had no previous VR experience.

Although we aimed to explore the differential impact of POV when viewing erotica, we would be remiss if we did not acknowledge that our videos depicting first-person POV may not have been relatable to some of our participants. Specifically, the first-person POV videos included Caucasian female actors whose features (e.g., body type, skin tone, etc.) may not have matched that of our participants given that less than half of our participants were Euro-Canadian. As a result, taking a first-person perspective of an actor who may not have closely resembled one's own features may have impacted our findings pertaining to POV. It may prove beneficial in the future to customize videos so that specific features of the actors (e.g., body type, skin tone, etc.) match with that of the participants.

Finally, our correlational data are not able to speak to causality. While we have posited that the greater immersion into the films triggered increases in sexual arousal as well as sexual desire (both dyadic and solitary), we cannot rule out the possibility that erotica-induced increases in sexual arousal and desire triggered the increase in sexual presence.

Conclusion

This study adds to the nascent field exploring sexual response using VR technologies as a medium to display erotica. We observed that relative to the traditional 2D modality of stimulus presentation, VR erotica resulted in greater feelings of sexual presence, general presence, and sexual arousal in women. Dyadic sexual desire also increased as a function of time, but no impact of stimulus modality and POV was observed. Using high quality, women-centered erotica that contained features that have been noted to be of importance to women proved to be imperative because women's sexual feelings are more informed by the meaning the sexual stimulus generates. Greater feelings of sexual presence and sexual arousal elicited by the VR videos demonstrate that high-immersive virtual environments are a methodological improvement over the traditional 2D modality. Based on these findings, future investigations can explore VR technology together with additional measures (e.g., eye tracking, vaginal photoplethysmography, etc.) to further elucidate the relationships between sexual experiences and VR technologies, and to also evaluate the utility of VR in the context of sexual dysfunction.

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Availability of Data and Material The experiment reported in this article was not formally preregistered. All analyzed data are available on the Open Science Framework (https://osf.io/umvnw/?view_only=b65824c0935b498bb77f5e21fed3f023).

Declarations

Conflicts of interest All authors declare that they have no conflict of interest.

Ethical Approval The University of British Columbia Behavioural Research Ethics Board approved all procedures for this study.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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