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Examining Erectile Disorder Manifestations and the Impact of Point-Of-View in Virtual Reality Erotica

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ABSTRACT

A growing body of research utilizes virtual reality (VR) in the field of mental health. Yet, the potential of this technology for sexual dysfunctions remains underexplored. This study focused on erectile disorder (ED) and evaluated the ability of virtual three-dimensional sexual scenarios to elicit ED manifestations (e.g. sexual performance anxiety, low sexual response). It further investigated the influence of viewer perspective in VR – first-person point of view (POV) versus third-person POV – on the activation of ED manifestations. Sixty adults (30 with ED; 30 without ED) viewed three virtual sexual scenarios (oral sex, masturbation, penetrative sex) in the laboratory. Measures of fear, catastrophizing, sexual arousal, and sexual presence were collected throughout the scenarios. Mixed repeated-measures ANOVAs revealed no differences between ED and non-ED groups in levels of fear and catastrophizing; however, individuals with ED reported significantly lower sexual arousal scores during the oral sex and masturbation scenarios. The POV modality had no effect on the examined outcomes among individuals with ED. These findings suggest that VR sexual stimuli may hold promise for examining impaired sexual responses in ED, while highlighting the need for future research evaluating the efficacy of more interactive and realistic virtual environments in eliciting sexual performance anxiety.

Introduction

From sex toys and artificial partners (*erobots*) to teledildonics and virtual reality (VR) pornography, the global *sextech* market is expected to reach 100 billion dollars by 2030 (Grand View Research, 2023). Our knowledge of the scientific applications of these technologies in the domain of sexual health research remains largely theoretical and speculative, underscoring a significant lack of empirical evidence (Döring et al., 2020, 2021; Dubé et al., 2022). The last three decades have seen a growing number of studies in psychology employing VR to enhance our understanding of the mechanisms involved in mental health disorders (Freeman et al., 2017; Rizzo & Bouchard, 2019). However, little attention has been given to the use of VR in research on sexual difficulties, despite its ability to experimentally examine the processes underlying sexual dysfunctions (Freeman et al., 2017; Lafortune, Lapointe, et al., 2023).

Erectile disorder (ED) is characterized by a marked, persistent, and distressing difficulty to achieve and maintain a satisfying erection for sexual activities (American Psychiatric Association, 2022; World Health Organization, 2019). Common among the adult population (Lewis et al., 2010; Nguyen et al., 2017), ED is associated with decreased quality of life, as well as lower sexual and relational satisfaction (Boddi et al., 2012; Dewitte et al., 2021; Huri et al., 2016; McCabe & Althof, 2014), with transnational studies reporting

annual prevalence rates between 6.1% to 23.8% (Lafortune, Girard, et al., 2023; Mitchell et al., 2013; Quinn-Nilas et al., 2018; Richters et al., 2003; Selvin et al., 2007).

Performance anxiety – a combination of fear and anxious anticipation (catastrophizing) – is a key mechanism explaining the impaired sexual response associated with psychogenic ED (Gambescia & Weeks, 2006; Pyke, 2020; Wincze & Weisberg, 2015). Given the complexity of safely recreating sexual situations associated with ED in a laboratory setting, studies on performance anxiety predominantly rely on observational cross-sectional designs using retrospective questionnaires or experimental conditions featuring non-immersive sexual stimuli (e.g., explicit sexual videos presented on a computer screen; Chivers et al., 2010; Kane et al., 2019). This highlights the need for advanced research tools that enable a more naturalistic exploration of the emotional, cognitive, and sexual experiences of individuals with ED during sexual interactions, while maintaining both ecological and ethical validity (Dubé et al., 2022). VR could help mitigate these limitations. Although recent studies indicate that VR can activate the emotional manifestations (e.g., fear) of certain sexual difficulties, such as vaginismus and sexual aversion (Brown & Brotto, 2023; Lafortune et al., 2022; Lafortune, Dubé, et al., 2023), there is little research using VR to examine ED clinical features (Huang et al., 2024)

Cognitive-Emotional Conceptualization of Erectile Disorder

Psychological factors are predominant in the development of many ED cases (McCabe & Althof, 2014; Nobre, 2010; Nobre & Pinto-Gouveia, 2006). Accordingly, the biopsychosocial models of ED emphasize the inhibitory effect of performance anxiety on erectile response (Bancroft et al., 2009; Berry & Berry, 2014; Nobre, 2010; Wiegel et al., 2007). For instance, the Dual Control Model (Bancroft & Janssen, 2001; Bancroft et al., 2009) conceptualizes sexual response as the result of a balance between excitatory and inhibitory mechanisms (e.g., performance anxiety). Two distinct types of sexual inhibitions have been identified (Bancroft et al., 2009): (1) the *fear of performance failure*, characterized by negative expectations regarding one's ability to exhibit sexual responses, maintain an erection, and concerns about disappointing one's sexual partner; (2) the *fear of performance consequences*, involving anticipation that sexual interactions could result in negative outcomes (e.g., contracting a sexually transmitted disease; Janssen & Bancroft, 2007). Empirical studies have supported this model for ED. Compared to individuals without ED, those living with this condition report greater performance anxiety related to the rigidity of their erection and stronger inhibition of their sexual response (Bancroft et al., 2005; McCabe, 2005; Nobre, 2010; Quinta-Gomes et al., 2018, 2022; Telch & Pujols, 2013), the latter being associated with lower sexual arousal and reduced erectile function (Bancroft et al., 2009; Quinta-Gomes et al., 2018, 2022).

Similarly, the Cognitive-Affective Model of sexual dysfunctions (Barlow, 1986; Wiegel et al., 2007) suggests that psychogenic ED is primarily caused by anxious apprehension. This involves feelings of anxiety or discomfort when facing signs of sexual interest or expectations from a partner, as well as cognitive biases that manifest as a tendency to imagine the worst possible outcomes during sexual encounters (i.e., catastrophizing), such as the belief that one will lose an erection or disappoint their partner. For instance, Nobre (2010) found that low erectile functioning was moderately to strongly associated with elevated tendencies to experience catastrophizing thoughts related to erectile difficulties. Moreover, performance anxiety related to ED tends to increase depending on the perceived importance of the erectile response in sexual intercourse and the partner's sexual satisfaction. Thus, offering cunnilingus is usually perceived as less anxiety-inducing than being masturbated by the partner or penetrating them, situations that require adequate penile rigidity (Coyne et al., 2010; Kaplan, 2013; Selke, 2003). An integrative investigation of the clinical expression of ED should therefore include an examination of its related manifestations of fear, catastrophizing, and sexual response. That said, it is important to recognize that most cases of ED result from a complex interplay between biogenic factors (e.g., vasculogenic, neurogenic, endocrinological) and psychogenic factors (e.g., performance anxiety, depression, negative body image). Even when organic causes predominate, psychological factors often coexist, exacerbating clinical manifestations (e.g., negative expectations, reduced sexual responsiveness) and contributing to associated distress

(Kalogeropoulos & Larouche, 2020; Shamloul & Ghanem, 2013; Wincze & Weisberg, 2015).

Virtual Reality to Explore Erectile Disorder Manifestations

VR refers to computer-generated simulation designed to immerse individuals in an environment that provides multi-sensory information, mimicking stimuli from the physical world (e.g., audiovisual, haptic; Kardong-Edgren et al., 2019; Slater, 2018). This technology is frequently used to study the symptoms of mental health conditions (e.g., phobias, eating disorders; Bell et al., 2020; Freeman et al., 2017; Riva & Serino, 2020; Skurla et al., 2022) as it can activate emotional, cognitive, and behavioral responses comparable to those observed in real-life situations (Bell et al., 2020), while offering standardized and safe experimental conditions (Roberts et al., 2019). In their systematic review of the use of VR in the field of mental disorders, Freeman et al. (2017) identified 285 empirical studies published between 1996–2016. Of these, two-thirds (67%) focused on anxiety disorders, while only 1% targeted sexual dysfunctions.

A recent systematic review of VR research in sexual health (1993–2023; Lafortune, Lapointe, et al., 2023) identified three VR studies on ED conducted in the late 1990s (Optale et al., 1997, 1998, 2003) by an Italian research team. These studies focused on the pre-post effectiveness of a VR-assisted psychoanalytic therapy for ED. Although innovative, these studies did not examine cognitive-emotional and sexual responses during the simulation, nor did they include non-clinical control groups of individuals without ED. Three decades later, two papers published in 2024 investigated VR use for ED treatment and assessment (Huang et al., 2024; Rodríguez Martínez et al., 2024). In one pilot study ($n = 6$), individuals with psychogenic ED underwent an 8-week VR intervention that consisted of one educational session and five VR audio exercises utilizing a masturbation aid device (Rodríguez Martínez et al., 2024). The treatment yielded a significant reduction in ED symptoms after the intervention. Another study (Huang et al., 2024) evaluated the effectiveness of a virtual audiovisual sexual simulation in aiding the diagnosis of ED. During a 60-min session, participants with ($n = 301$) and without ED ($n = 100$) watched four 10-min erotic VR videos depicting heterosexual activity—i.e., petting, foreplay, and intercourse – while their genital sexual response was monitored. Individuals with ED exhibited significantly lower penile rigidity and shorter duration of erectile response compared to the non-ED group. While there has been a renewed interest in using VR in ED research recently, the capability of VR to activate the emotional, cognitive, and sexual manifestations of ED has yet to be explored. Such an examination is crucial for uncovering the full potential of VR in comprehensively exploring these manifestations and key components of ED experience.

VR represents a promising tool for studying ED and its manifestations. The literature on performance anxiety in ED predominantly consists of clinical case reports, theoretical reviews, and cross-sectional data, with limited experimental designs (e.g., Laja et al., 2017). For instance, observational studies on ED often rely on self-reported questionnaires

about past or current sexual activities with a partner (Chivers et al., 2010; Kane et al., 2019; Quinta-Gomes et al., 2022). Their data are thus influenced by recall biases and are not representative of the experiences of individuals with ED who do not have sexual partners or who avoid sexual interactions with their partner due to performance anxiety or fear of judgment (Kalogeropoulos & Larouche, 2020). Using immersive sexual scenarios in experimental designs could facilitate the real-time exploration of cognitive, emotional, and sexual symptoms of ED in a more standardized, naturalistic, and inclusive manner. VR can indeed generate highly realistic socio-sexual situations that are more immersive than explicit 2D sexual videos or pictures, and as such, more closely approximate real-life sexual contexts related to ED (e.g., partner's sexual interest, genital touch or penetration). VR can also help to overcome the ethical and methodological limitations of research on ED. For instance, by using laboratory simulations rather than sexual interactions with a partner, VR allows for the controlled, safe exploration of the experience of individuals living with ED (Dubé et al., 2022).

Beyond clinical populations, several studies have examined sexual response when viewing sexual scenarios in VR. Their results reveal that VR generates higher levels of sexual arousal and sexual presence (i.e., the feeling of being involved in a realistic sexual scenario and experiencing sexual arousal similar to that felt in a real-life situation) than non-immersive control conditions (e.g., pornographic videos on a computer screen; Dekker et al., 2021; Elsey et al., 2019; Milani et al., 2022). Higher levels of sexual presence are linked to stronger subjective and genital sexual arousal in VR sexual environments (Simon & Greitemeyer, 2019). This suggests that VR represents both an ethical and scientifically valid method for studying low sexual response in ED.

In addition, VR allows users to embody a character (avatar) involved in sexual interactions, thereby increasing the sense of intimacy, realism, and engagement compared to watching erotic interactions in pornographic videos, for instance (Dekker et al., 2021; Milani et al., 2022). To date, two studies have examined whether viewing two-dimensional erotic videos from a first-person point of view (POV; i.e., participating as a role-player in simulated sexual interactions) or third-person POV (i.e., observing sexual interactions between virtual characters) influences reported sexual arousal and presence in non-clinical samples (Elsey et al., 2019; Milani et al., 2022). Milani et al. (2022) found that sexual presence was greater when viewing erotic content from a first-person POV compared to a third-person POV, while there was no significant difference in sexual arousal between the POVs. In contrast, Elsey et al. (2019) found that viewing erotic stimuli from a first-person POV elicited greater sexual arousal than from a third-person perspective regardless of gender, while presence did not vary based on POV.

These mixed results highlight the need for further research on perspective-taking and its effect on sexual response and presence when exposed to VR erotic stimuli. To our knowledge, no studies have investigated the influence of perspective – first- vs. third-person POV – on the emotional, cognitive, and sexual experiences of individuals with sexual

dysfunctions while viewing VR erotica, and prior research on non-clinical samples have not utilized three-dimensional virtual simulations (e.g., Elsey et al., 2019). Examining POV effect during three-dimensional erotica is particularly relevant in sex research because, unlike 2D videos, 3D VR scenarios allow for immersive character embodiment and the modulation of spatial perspectives, offering a unique framework to investigate sexual experiences. Although speculative, it is plausible that, based on the biopsychosocial models of ED, individuals with ED could experience heightened performance anxiety and a reduced sexual response when embodying an avatar engaged in sexual interactions rather than passively observing sexual interactions between virtual characters.

The Current Study

This quasi-experimental study examined the potential of three-dimensional VR sexual scenarios in eliciting the cognitive-emotional and sexual manifestations of ED. Specifically, levels of fear, catastrophizing, sexual response, and sexual presence in individuals with and without ED were compared when viewing three VR sexual scenarios with increasing emphasis on the importance of erectile response (i.e., performing oral sex, being masturbated, and penetrating the partner). It was hypothesized that individuals with ED would exhibit greater fear and catastrophizing as well as lower sexual arousal and sexual presence as the importance of the erectile response in the VR sexual scenarios increased, compared to individuals without ED (H_1).

This study's secondary aim was also to explore the influence of viewer perspective – first-person vs. third-person POV – on ED manifestations. Despite the mixed results of prior research (Elsey et al., 2019; Milani et al., 2022), it was expected that higher involvement in the sexual scenarios (first-person POV) would be associated with higher sexual arousal and sexual presence (H_2), and that the ED group would experience higher fear and catastrophizing as well as lower sexual arousal and presence than in the low involvement condition (third-person POV; H_3).

The results of this study could provide critical data on the potential of VR erotica to elicit ED manifestations and serve as an experimental paradigm to strengthen the empirical foundation of the theoretical framework for ED mechanisms. Additionally, research on POV effects is crucial for examining how varying levels of involvement in virtual sexual scenarios contribute to symptom activation.

Method

This study used a quasi-experimental design in which individuals with and without ED were randomly assigned to either a first-person or a third-person POV condition when viewing three erotic scenarios.

Participants

Sixty adults with ($n = 30$) and without ED ($n = 30$) were recruited in Quebec (Canada) using social media

advertisements (Facebook and Instagram). Sample size was estimated based on an *a priori* power analysis (Cohen's $f = 0.25$; $\alpha = .05$; $1 - \beta = 0.80$) for $2 \times 2 \times 3$ mixed ANOVAs (G*Power 3.1; Faul et al., 2007), suggesting a minimal total sample size of 40 individuals to examine main and interaction effects and conduct post hoc contrasts. The inclusion criteria were: (a) being ≥ 18 years old; (b) being a male; (c) having sufficient knowledge of French to complete the questionnaires and protocol; (d) being able to come to the laboratory. The exclusion criteria were: (a) completing $< 80\%$ of the pre-experimental questionnaire, (b) having missing data on the ED measure (cf. Measures); (c) reporting cyber-sickness during immersion (cf. Procedure); (d) reporting suicidal ideation; (e) taking psychoactive substances on the day of the laboratory visit.

VR System and Sexual Scenarios

The Meta Quest 3 wireless headset was used to display the simulation as it offers high graphic quality (resolution of 2064×2208 pixels per eye), procuring a heightened immersed sense of realism in virtual environments.

The simulation comprises three sexual scenarios, each with an increasing emphasis on erectile response, where a male character is: (a) performing oral sex, (b) being masturbated, (c) penetrating his partner. The three-dimensional sexual scenarios were designed based on the biopsychosocial conceptualization of ED outlined in the Introduction. Each scenario lasted three minutes. Two sets of sexual scenarios were developed to reflect the participant's sexual orientation: male-female or male-male (see Image 1 for a visualization of the scenarios). In the male-male scenarios, phallovaginal penetration were replaced with anal sex. In the first-person POV condition, the participant embodied a male avatar in the male-female scenarios or its equivalent in the male-male scenarios. For the third-person POV, participants were statically positioned to the side of the characters, at a sufficient distance to provide an overall view of the sexual behaviors (see Image 1). Before presenting the sexual scenarios, a familiarization condition was used where participants were alone in the Meta Quest 3 introductory environment (a simulation of a virtual living room; 3 minutes; see Procedure).

The sexual scenarios were created using the open-access Virt-A-Mate game engine (Meshed VR), which supported the VR simulation. Virt-A-Mate was chosen for its photorealistic characters and ease of use in adapting preprogrammed 3D sexual animations and rigged characters. Once downloaded from Virt-A-Mate, the male and female characters were then configured to fit sexual animations in each scenario. In the sexual scenario, characters were placed in an empty space with no environmental elements (e.g., furniture) to focus the user's attention on the characters' sexual behaviors and to avoid interference with their movements (e.g., characters' body parts passing through objects). The animations were then edited to keep only smooth, consistent motion loops related to the targeted sexual behaviors (e.g., masturbation, oral sex) to minimize visual artifacts. Although participants remained seated during the simulation, they could move their head and upper body to visually explore and engage with the environment.

Measures

Sociodemographics

The sociodemographic questionnaire was based on the Statistics Canada census (Statistics Canada, 2021), which collects information on age, sex/gender, sexual orientation, employment status, education level, annual income, and ethnicity to describe the sample. Participants were also questioned about the presence of diagnoses such as hypertension, diabetes, prostate cancer, neurological diseases (i.e., Parkinson's disease, spinal cord injury, multiple sclerosis), medications (i.e., anti-hypertensives, psychotropics, serotonin-specific inhibitors, hormonal treatments), or elevated use of tobacco or alcohol (i.e., >15 cigarettes per day or 15 drinks per week), given their associations with biogenic ED (Berookhim et al., 2016; Wincze & Weisberg, 2015).

Erectile Disorder

The presence of ED was assessed using the French-version of the International Index of Erectile Function (IIEF-5; 5 items; $\alpha = .83$; Dargis et al., 2013; Rosen et al., 1999), a widely used measure to determine the presence and severity of ED. On a 5-point Likert scale, participants evaluated the rigidity of, and satisfaction with their erection (e.g., "How confident are you that you can get and maintain an erection?"). This measure shows good test-retest reliability ($r = .88-.92$; Neijenhuijs et al., 2019; van Kollenburg et al., 2019) and a score of 16 adequately discriminates individuals with or without ED (sensitivity = .85, specificity = .96; Vallejo-Medina et al., 2022). We opted for a more conservative cutoff of 16, compared to the previously reported threshold of 21 (Rosen et al., 1999), to better distinguish individuals with distressing erectile impairment from those without and to align with findings showing that lower thresholds improve specificity and compatibility with the criteria for ED in the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 2022; Vallejo-Medina et al., 2022). This scale showed good internal consistency in the current sample ($\alpha = .84$).

Sexual Performance Anxiety: Trait

Two 4-item subscales of the French version of the Sexual Inhibition/Sexual Excitation Scales-Short Form (SIS/SES-SF; Janssen et al., 2020; Nolet et al., 2021) were used to assess sexual performance anxiety trait based on the Dual Control model (Bancroft et al., 2009): the sexual inhibition due to threat of performance failure (SIS1) and fear of performance consequences (SIS2) subscales ($\alpha = .66-.68$; Nolet et al., 2021). Participants were asked how they may react to hypothetical scenarios leading to an increase/loss of sexual arousal (e.g., "When I have a distracting thought, I easily lose my erection/my arousal") using a four-point Likert scale ranging from 1 (Strongly agree) to 4 (Strongly disagree). In the current sample, these subscales demonstrated similar internal consistency ($\alpha = .56-.67$) to previous research (Nolet et al., 2021) and were used to confirm elevated performance anxiety as a psychogenic factor in the ED group compared to their non-ED counterparts.

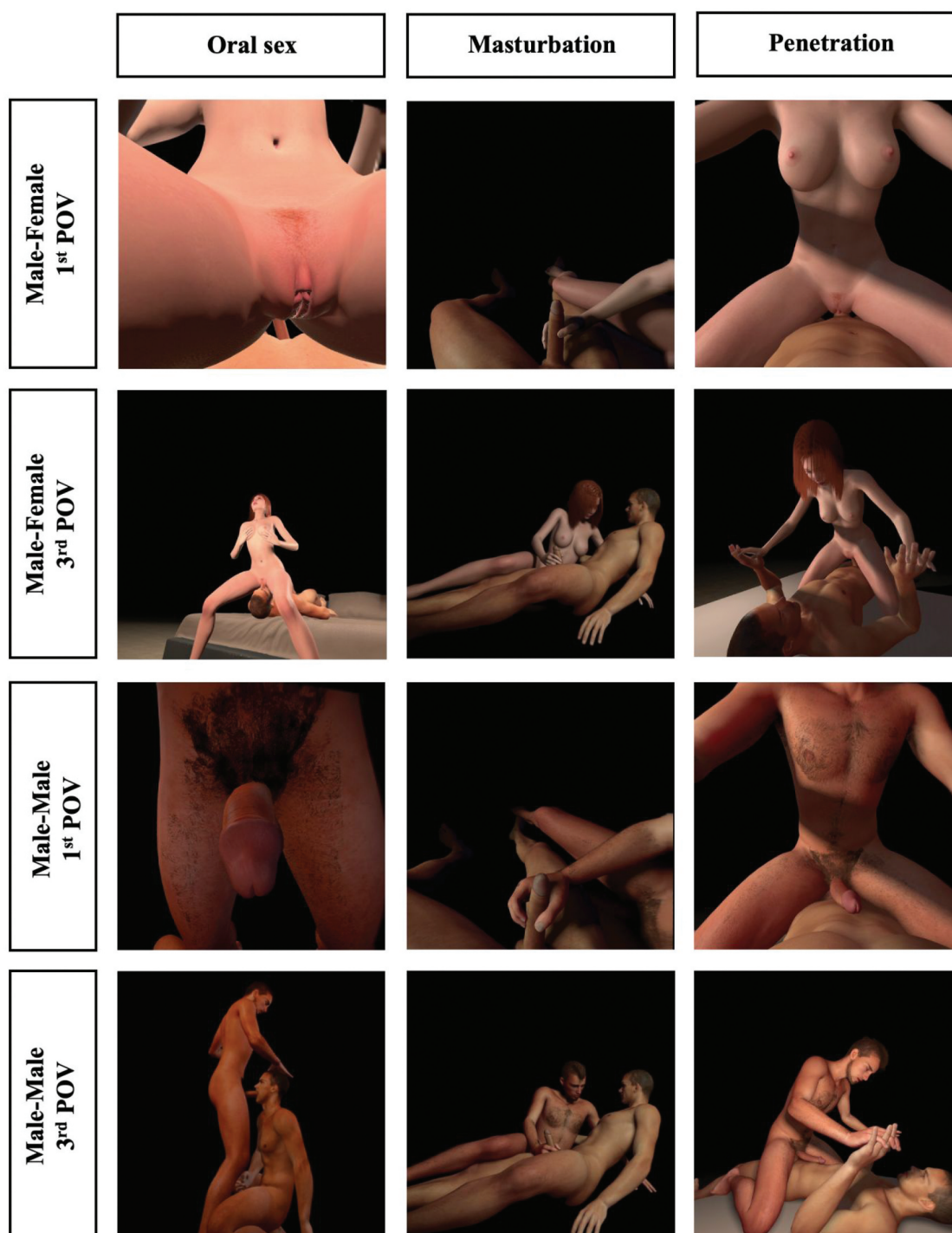


Image 1. The male-female and male-male series of the three virtual sexual scenarios for the first-person POV and third-person POV conditions.

Sexual Performance Anxiety: State

The following measures were employed to assess fear and catastrophizing associated with each sexual scenario. Fear was assessed using the classical Subjective Units of Distress Scale (1 item; Wolpe, 1990), evaluating the level of fear on a scale from 0 (No fear) to 100 (Extreme fear). This scale is widely used to measure emotional responses in VR research on mental disorders (e.g., Owens & Beidel, 2015; Reger et al., 2019; Takac et al., 2019). Catastrophizing was

assessed with two items employed in clinical research (Miloff et al., 2019; Öst, 2012). The first identified the type of catastrophic beliefs using an open-ended question (e.g., “In the following scenario, you will be performing cunnilingus on a woman. What is the worst thing you fear experiencing or seeing happen in this situation?”). The second assessed the degree of certainty regarding this belief on a scale from 0 to 100% (e.g., “How likely do you think this scenario is to occur?”).

Sexual Arousal

Sexual arousal was measured using one item commonly used in studies examining subjective sexual responses to sexual stimuli (Heiman & Rowland, 1983; Milani et al., 2022), which evaluates the level of sexual arousal felt on a scale from 0 (Not at all aroused) to 10 (Extremely aroused).

Sexual Presence

Sexual presence was assessed using the French version of the Subjective Sexual Presence Questionnaire (10 items; $\alpha = .91$; Milani et al., 2022; Renaud et al., 2016), which measures the level of sexual presence on a 7-point Likert scale ranging from 1 (Not at all) to 7 (Completely) with questions such as “To what extent did you feel sexual arousal similar to that felt in a real sexual situation?” This subscale showed satisfactory internal consistency in the current study ($\alpha = .77-.78$).

Procedure

Interested participants were directed to the secure online platform Qualtrics, where they were invited to review and sign the consent form and complete a pre-experimental questionnaire. This questionnaire included a measure of erectile functioning (IIEF-5), performance anxiety (SIS/SES-SF), filter questions to ensure eligibility for the study (cf. inclusion/exclusion criteria), and a section to provide contact details for scheduling the laboratory visit (1.5 hours). Participants scoring < 16 on the IIEF-5 were assigned to the ED group, while those scoring ≥ 16 were assigned to the non-ED group (Vallejo-Medina et al., 2022). Participants were randomly assigned to either the first-person POV or third-person POV condition using the Research Randomizer software.

In the laboratory, an experimenter seated the participant in a chair designated for the VR simulation and asked them to select one of the two scenario series (male-female or male-male). The experimenter then set up and calibrated the VR headset, after which the simulation was launched. In the familiarization condition (virtual living room), the participant was invited to visually explore the environment and familiarize themselves with VR. Next, the participant was asked to remove the headset and the experimenter provided information about the upcoming sexual scenario to measure catastrophizing (i.e., “. . . you will perform cunnilingus/fellatio on a woman/man;” cf. Measures). The participant was then exposed to the oral sex scenario. After viewing this scenario, the participant was invited to remove the headset again, during which the levels of fear, sexual arousal, and sexual presence elicited by the viewed scenario were measured. The same procedure was followed for the other two sexual scenarios, with prompts adjusted to measure catastrophizing (i.e., “. . . a woman/man will masturbate you” and “. . . you will have sexual intercourse with penetration”). To control for order effects, the three sexual scenarios were presented randomly. All data were collected on an iPad which was provided to the participants. At the end of the laboratory session, all participants received a CAD \$40 gift card as compensation.

It should be noted that right after the familiarization condition (virtual living room), cybersickness (i.e., dizziness, nausea) was assessed using a Likert scale ranging from 0 (No

discomfort) to 10 (Severe discomfort; Keshavarz & Hecht, 2011). The VR simulation was interrupted if a participant scored ≥ 4 to minimize the adverse effects of immersion (Stanney et al., 2020); however, the protocol did not need to be stopped for any participant.

The Institutional Research Ethics Board of the Université du Québec à Montréal approved this study procedure (ethics certification number: 2024-6106).

Data Analysis

All statistical analyses were performed using SPSS, version 29.

Comparison analyses (i.e., *t*-test, chi-square) were conducted using sociodemographic and SIS1/SIS2 variables to identify significant preexisting differences between the ED and non-ED groups.

Mixed repeated measures ANOVAs were performed with the two groups (ED vs. non-ED) and two conditions (first-person POV vs. third-person POV) as between-subjects factors and the three scenarios (oral sex, masturbation, and penetration) as within-subjects factors for each of the following outcomes: fear, catastrophizing, sexual arousal, and sexual presence. When Mauchly's test indicated a violation of the sphericity assumption, the appropriate correction was applied (i.e., Huynh-Feldt). Post hoc comparisons were reported for main or interaction effects significant at *p*-values $< .05$, with Bonferroni adjustments applied for multiple comparisons. Given the sample size, post hoc comparisons for effects significant at $p < .10$ were provided to indicate potential trends and inform future research (Giner-Sorolla, 2012). Effect sizes were reported for each analysis (i.e., η_p^2). The dataset contained no missing values.

Exploratorily, responses to the open-ended question on catastrophic beliefs were analyzed using inductive qualitative content analysis (Elo & Kyngäs, 2008). Chi-square analyses were then performed using SPSS 29 to compare the ED and non-ED groups on categories of catastrophic beliefs reported for each sexual scenario. Bonferroni corrections were applied to each significant omnibus chi-square test ($p < .05$).

Results

Sample Characteristics

The ED and non-ED groups did not differ significantly in demographic characteristics (see Table 1) or on any of the factors associated with biogenic ED (e.g., hypertension, diabetes, neurological diseases). The level of sexual performance anxiety trait was higher in the ED group, as reflected in greater scores on sexual inhibition due to the threat of performance failure (SIS1; $p < .001$) or consequences (SIS2; $p = .007$).

Fear

There was a significant main effect of POV modality on fear, $F(1, 56) = 5.76$, $p = .020$, $\eta_p^2 = .09$ (see Figure 1). Fear scores in the third-person POV condition for the penetration scenario were significantly lower compared to the first-person POV condition, $p = .014$, $\eta_p^2 = .10$, with a non-significant trend for

Table 1. Demographic characteristics and sexual inhibition scores of ED and non-ED groups.

Variables	ED (n = 30)		Non-ED (n = 30)		Statistical test
	M (SD)	%	M (SD)	%	
Age in years (range = 24–73)	50.77		47.47		$t = .98, ns$
Gender	(13.77)		(12.20)		
Cis men		93.3		86.7	$\chi^2 = .74, ns$
Non-binary/queer individuals		6.7		13.3	
Sexual orientation				56.7	$\chi^2 = .40, ns$
Heterosexual		53.3		26.7	
Homosexual		33.3		13.3	
Bi/pansexual		10.0			
Other (e.g., questioning)		3.3		3.3	
Relationship status		46.7		40.0	$\chi^2 = .27, ns$
Not in a relationship		53.3		60.0	
In a relationship					
Employment status					$\chi^2 = 3.16, ns$
Employed or self-employed		66.7		65.5	
Unemployed		0		3.4	
Student		6.7		6.9	
Retired		23.3		13.8	
Other (e.g., sick, parental leave)		3.3		6.9	
Prefer not to answer		0		3.4	
Annual income (CAD)					$\chi^2 = 2.13, ns$
< \$44,999		36.7		30.0	
\$50,000–\$99,999		50.0		46.7	
> \$100,000		10.0		20.0	
Prefer not to answer		3.3		3.3	
Education degree					$\chi^2 = 5.51, ns$
Elementary		3.3		0	
Secondary		13.3		16.7	
Professional or college		33.3		26.7	
Undergraduate		16.7		10.0	
Graduate		33.3		46.6	
Ethnicity					$\chi^2 = 5.84, ns$
Caucasian		90.0		73.3	
Middle Eastern/African		0		10.0	
Asian		6.7		3.3	
Latin-American		3.3		10.0	
Indigenous		0		3.3	
SIS1	11.93 (2.73)		8.67 (2.17)		$t = 5.13^{***}$
SIS2	11.70 (2.81)		9.80 (2.40)		$t = 2.82^{**}$

** $p < .01$, *** $p < .001$; ns: not significant; SIS1: sexual inhibition due to threat of performance failure; SIS2: sexual inhibition due to performance consequences.

the oral sex, $p = .077$, $\eta_p^2 = .06$, and masturbation scenarios, $p = .057$, $\eta_p^2 = .06$ (see Supplementary materials for descriptive data). There was no significant effect of scenarios on fear, nor were there effects of ED status, scenario $\times$ ED status interaction, scenario $\times$ POV modality interaction, or ED group $\times$ POV condition interaction (see Table 2 for details on ANOVAs results).

Catastrophizing

The main effect of scenarios on catastrophizing scores was significant, $F(2, 112) = 4.05$, $p = .020$, $\eta_p^2 = .07$. As depicted in Figure 2, catastrophizing scores tended to be significantly lower in relation to the masturbation scenario compared to the penetration scenario, $p = .008$, with no other significant differences. Catastrophizing scores were not significantly different between the oral sex and masturbation scenarios. No significant effects were found for ED status, POV modality, scenario $\times$ ED status interaction, scenario $\times$ POV modality interaction, or ED group $\times$ POV condition interaction.

Five categories of catastrophic beliefs were found across sexual scenarios: 1) disgust (i.e., anticipating disgust or poor hygiene in the VR character), 2) pain (i.e., causing or

experiencing pain), 3) low attractiveness (i.e., the character's disinterest or lack of attraction toward the character), 4) ejaculatory latency (i.e., experience premature or delayed ejaculation), and 5) erectile functioning (i.e., being unable to have or maintain an erection). The frequencies of catastrophic beliefs are presented in Table 3. Although erectile functioning anticipation was more prevalent in the ED group across scenarios, the omnibus chi-square test was only significant for the penetration scenario, $\chi^2(4) = 10.22$, $p = .037$, with the ED group reporting significantly more anticipation regarding erectile functioning (58.8%) than the non-ED group (22.2%). Interestingly, 76.2% of participants with ED reported anticipating feelings of disgust before the oral sex scenario, and 44.4% anticipated pain during the masturbation scenario.

Sexual Arousal

As depicted in Figure 3, there was a significant main effect of scenarios on sexual arousal scores, $F(2, 112) = 5.42$, $p = .006$, $\eta_p^2 = .09$. Sexual arousal scores in the penetration scenario were higher than in the oral sex ($p = .020$) and the masturbation scenarios ($p = .021$), with non-significant differences between the oral sex and masturbation scenarios. There was

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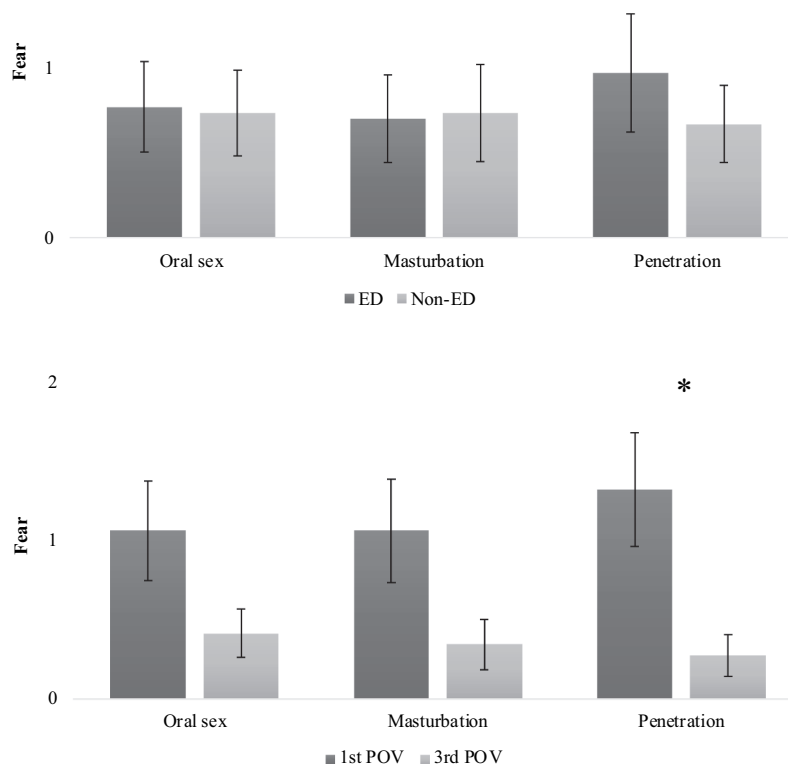


Figure 1. Fear ratings for each scenario for both groups (ED vs. Non-ed) and conditions (first-person POV vs. third-person POV). Error bars represent standard errors of the means. * $p < .05$.

Table 2. Mixed ANOVA results by outcomes.

Variables	df	F	p	η_p^2
Fear				
Scenario	1.85–103.58	.13	.878	.00
ED status	1–56	.01	.922	.00
POV modality	1–56	5.76	.020	.09
Scenario $\times$ ED status	1.85–103.58	.40	.654	.01
Scenario $\times$ POV modality	1.85–103.58	.69	.493	.01
ED status $\times$ POV modality	1–56	.03	.858	.00
Catastrophizing				
Scenario	2–112	4.05	.020	.07
ED status	1–56	.28	.598	.00
POV modality	1–56	.69	.410	.01
Scenario $\times$ ED status	2–112	.17	.847	.00
Scenario $\times$ POV modality	2–112	.05	.953	.00
ED status $\times$ POV modality	1–56	.20	.656	.00
Sexual arousal				
Scenario	2–112	5.42	.006	.09
ED status	1–56	4.16	.046	.07
POV modality	1–56	1.26	.266	.02
Scenario $\times$ ED status	2–112	2.71	.071	.05
Scenario $\times$ POV modality	2–112	1.48	.233	.03
ED status $\times$ POV modality	1–56	.14	.706	.00
Sexual presence				
Scenario	2–112	5.01	.008	.08
ED status	1–56	2.69	.106	.05
POV modality	1–56	3.36	.072	.06
Scenario $\times$ ED status	2–112	2.47	.089	.04
Scenario $\times$ POV modality	2–112	.33	.722	.01
ED status $\times$ POV modality	1–56	.59	.558	.01

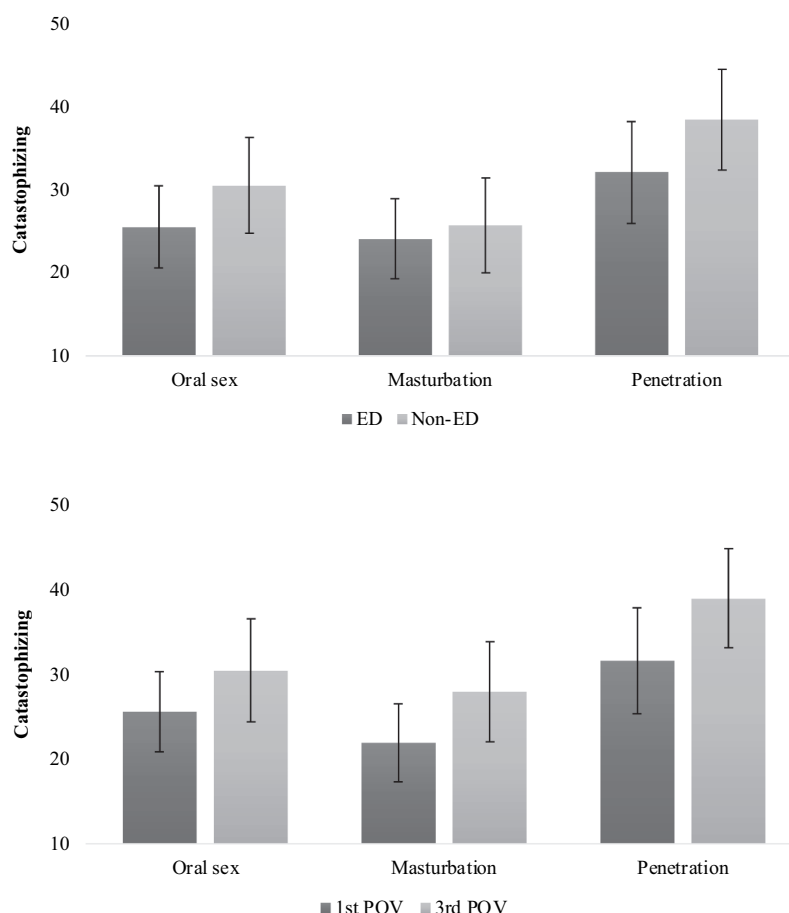


Figure 2. Catastrophizing ratings for each scenario for both groups (ED vs. Non-ed) and conditions (first-person POV vs. third-person POV). Error bars represent standard errors of the means. * $p < .05$.

Table 3. Prevalence of catastrophic beliefs by sexual scenario for ED and non-ED groups.

Categories	Oral sex (%)			Masturbation (%)			Penetration (%)		
	ED	Non-ED	χ^2	ED	Non-ED	χ^2	ED	Non-ED	χ^2
Disgust	76.2	44.4	8.82, <i>ns</i>	5.6	5.3	8.71, <i>ns</i>	23.5	11.1	10.22*
Pain	9.5	5.6		44.4	15.8		11.8	16.7	
Low attractiveness	9.5	33.3		5.6	15.8		5.9	22.2	
Ejaculation latency	0	16.7		11.1	47.4		0	27.8	
Erectile functioning	4.8	0		33.3	15.8		58.8	22.2	

* $p < .05$, *ns*: not significant. Between 30.0% and 43.3% of responses regarding catastrophic beliefs were not interpretable for each sexual scenario (e.g., "none").

a significant main effect of ED status on sexual arousal, $F(1, 56) = 4.16$, $p = .046$, $\eta_p^2 = .07$. Individuals with ED reported significantly lower sexual arousal scores in the oral sex, $p = .037$, $\eta_p^2 = .08$, and masturbation scenarios, $p = .011$, $\eta_p^2 = .11$, than their non-ED counterparts, but no significant differences were found for the sexual intercourse scenario. No significant effects were found for POV modality, scenario $\times$ POV modality interaction, or ED group $\times$ POV condition interaction, although a non-significant trend was observed for scenario $\times$ ED status interaction effect, $F(2, 112) = 2.71$, $p = .071$, $\eta_p^2 = .05$. Sexual arousal scores were lower for the oral sex ($p = .006$) and masturbation scenarios ($p = .003$) compared to the penetration scenario for the ED group, while levels of sexual arousal did not differ across scenarios for non-ED participants.

Sexual Presence

For sexual presence, there was a significant main effect of scenarios, $F(2, 112) = 5.01$, $p = .008$, $\eta_p^2 = .08$ (see Figure 4). Sexual presence scores were globally higher in the penetration scenario than in the oral sex ($p = .022$) and the masturbation scenarios ($p = .021$), but levels of sexual arousal did not significantly differ between the oral sex and masturbation scenarios. There was a non-significant trend of POV modality on sexual presence scores, $F(1, 56) = 3.36$, $p = .072$, $\eta_p^2 = .06$, but post hoc contrasts revealed only one significant difference: sexual presence scores in the masturbation scenario were lower than in the penetration scenario when viewed from a third-person POV perspective ($p = .042$). No significant effects were found for ED status, scenario $\times$ POV modality

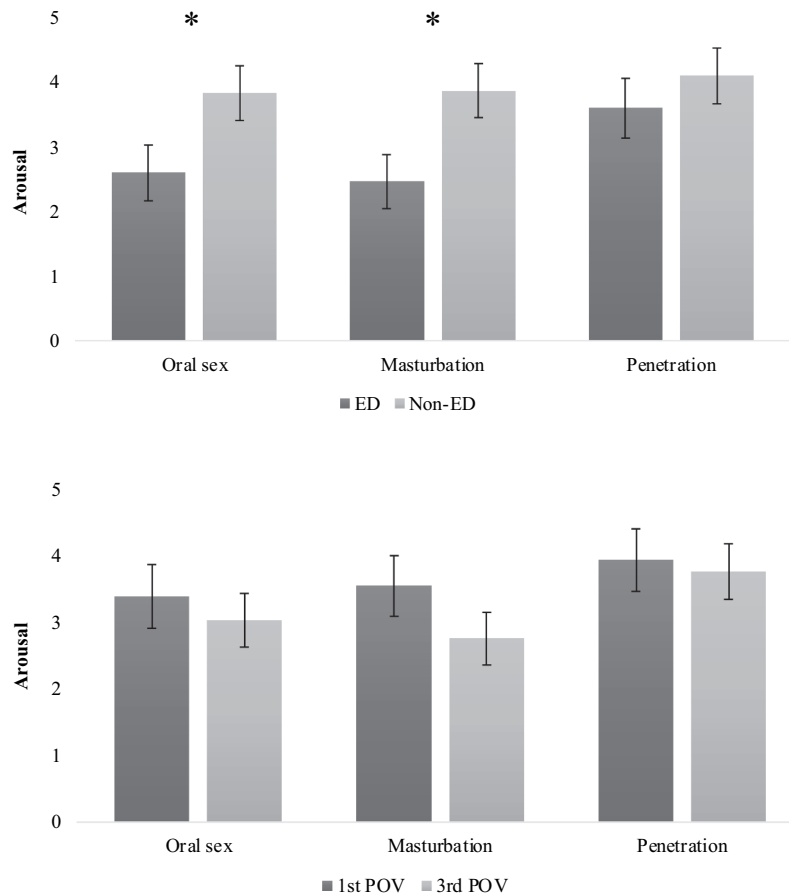


Figure 3. Sexual arousal ratings for each scenario for both groups (ED vs. Non-ED) and conditions (first-person POV vs. third-person POV). Error bars represent standard errors of the means. * $p < .05$.

interaction, or ED group $\times$ POV condition interaction. However, a non-significant trend was observed for a scenario $\times$ ED status interaction effect, $F(2, 112) = 2.47$, $p = .089$, $\eta_p^2 = .04$. Sexual presence scores were lower for the oral sex ($p = .009$) and masturbation scenarios ($p = .003$) compared to the penetration scenario for the ED group, while levels of sexual presence did not differ across scenarios for non-ED participants.

Discussion

This experimental study explored ED using three-dimensional VR sexual scenarios and examined the impact of viewpoint on ED manifestations among a sexually diverse sample of men. The data partially supported our hypotheses.

Regarding the primary aim, the ED and non-ED groups did not differ significantly in their levels of fear and degree of certainty regarding catastrophic beliefs. However, catastrophic beliefs about low erectile response were significantly more prevalent in the ED group in relation to the penetration scenario. Additionally, individuals with ED reported significantly lower sexual arousal scores in the oral sex and masturbation scenarios compared to their non-ED counterparts. In these scenarios, sexual arousal and sexual presence scores within the ED group were lower compared to the penetration scenario, while they did not differ across scenarios for the non-ED

group (H_1). With regard to the secondary aim, results revealed that first-person POV was not associated with higher sexual arousal and sexual presence than third-person POV (H_2), nor did POV modality affect the expression of fear, catastrophizing, sexual arousal, or sexual presence among individuals with ED (H_3). Furthermore, the study provided new findings: (1) the POV condition appeared to affect reported fear (in the penetration scenario), (2) catastrophizing scores varied by scenario, being lower in the masturbation scenario compared to oral sex and penetration, and (3) sexual arousal and presence scores were higher in the penetration scenario compared to the oral sex and masturbation scenarios.

The observation that individuals with ED reported significantly lower sexual arousal scores in the oral sex and masturbation scenarios compared to their non-ED counterparts aligns with the findings of Huang et al. (2024). They found that individuals with ED exhibited lower erectile rigidity and duration when viewing virtual erotica compared to control patients. However, since their study did not measure arousal responses to specific sexual behaviors displayed in VR, we cannot ascertain whether the low sexual arousal observed was linked to specific sexual practices, as identified in our study (i.e., oral sex and masturbation versus penetration). Our results also concur with the experimental study by Laja et al. (2017), which demonstrated that individuals with ED exhibited lower physiological and subjective sexual arousal to erotic

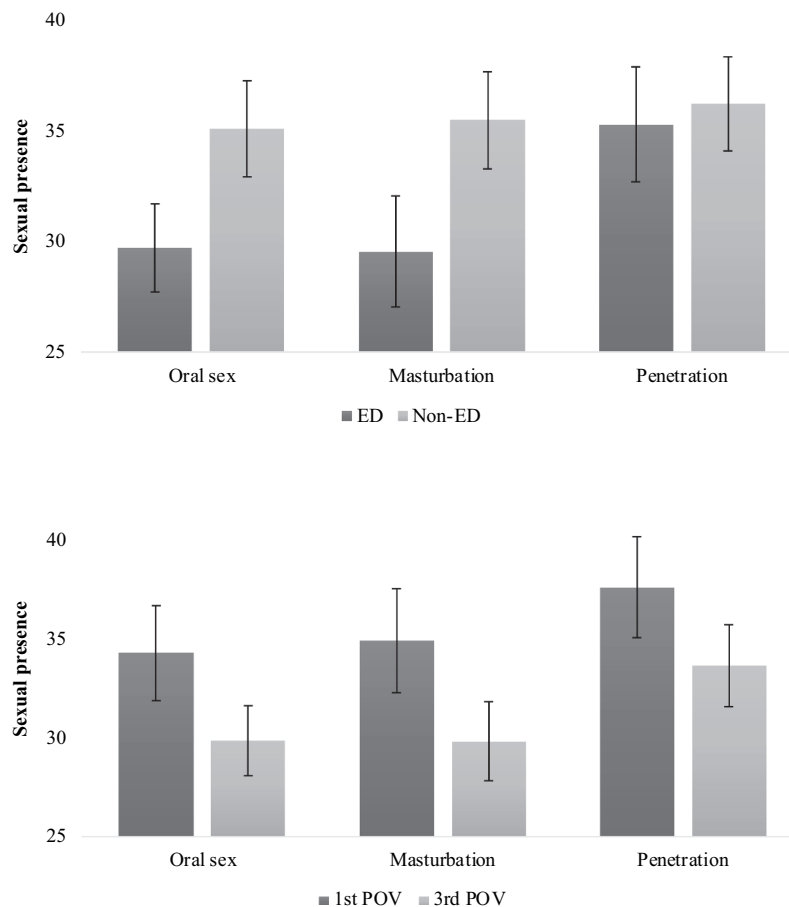


Figure 4. Sexual presence ratings for each scenario for both groups (ED vs. Non-ED) and conditions (first-person POV vs. third-person POV). Error bars represent standard error of the mean. $*p < .05$.

films compared to healthy controls. In the present study, the lower sexual arousal scores in the ED group during the oral sex and masturbation scenarios, compared to the penetration scenario (where ED and non-ED groups did not differ), could be partly explained by the Dual Control Model (Bancroft et al., 2009; Quinta-Gomes et al., 2022). According to this model, sexual arousal is regulated by an excitatory and inhibitory system, in which a certain level of stimulus salience is necessary to surpass the threshold of inhibition and trigger an arousal response. In other words, it is plausible that the intensity, explicitness, and involvement of characters in the penetration scenario outweighed the inhibitory components related to ED compared to the two other scenarios which could be perceived as less engaging. Studies have found that penetrative intercourse was perceived as more arousing than other sexual practices, such as oral sex and masturbation (Husain & Qureshi, 2016; Purnine et al., 1994; Rupp & Wallen, 2009). However, as our participants' arousal scores ranged from low to moderate even among the non-ED group, the conclusion regarding the capacity of these virtual sexual scenarios to elicit sexual arousal should be interpreted with caution. Finally, the elevated negative anticipation of sexual pain in the ED group during the masturbation scenario may reflect a heightened perception of vulnerability to pain when passively receiving direct, partner-initiated stimulation without reciprocal interaction. In contrast, the modest group differences observed in

the oral sex and penetration scenarios might suggest that being active in these contexts may provide a sense of control and reduce both pain anticipation and self-focused concerns, thereby mitigating anticipatory fears.

Previous research has demonstrated VR's potential to induce fear responses in individuals with vaginismus and sexual aversion (Brown & Brotto, 2023; Lafortune et al., 2022; Lafortune, Dubé, et al., 2023), although the similar and relatively low levels of fear in ED and non-ED groups suggest that the VR scenarios did not trigger the fear component associated with performance anxiety in ED. This may be because the sexual scenarios did not emphasize the consequences of low erectile or arousal responses on sexual interaction with a real-life partner – with a VR simulation featuring fictional characters who do not react negatively to participants' erectile responses (e.g., judgment, rejection, disappointment) – thereby tempering the activation of performance anxiety or rendering such fear responses unwarranted (Bancroft et al., 2005, 2009; Quinta-Gomes et al., 2018, 2022). This could have contributed to the low anxiety levels observed, especially considering the use of subjective instead of physiological measures and feedback of sexual arousal (e.g., thermography, plethysmography).

The absence of group differences in the degree of conviction regarding negative beliefs may suggest a similar pattern to that observed for anxiety (low activation of performance anxiety in ED group). However, the higher prevalence of

catastrophic beliefs about low erectile functioning in the ED group compared to the non-ED group might indicate that both groups did not differ in terms of certainty, but rather in the content of feared sexual scenarios (cf. Table 3). This observation may reflect the nature of the catastrophizing measure, which did not explicitly focus on anticipated negative scenarios related to erectile response.

Interestingly, some observed trends for sexual presence scores mirrored that of sexual arousal. Specifically, sexual presence was notably lower in the masturbation and oral sex scenarios compared to penetration for the ED group. To our knowledge, no studies have specifically examined sexual presence in individuals with ED. The similarities in trends between sexual presence and sexual arousal are consistent with existing literature, which reveals a moderate to strong association between these constructs in response to erotic stimuli presented in VR (Milani et al., 2022; Simon & Greitemeyer, 2019).

Contrary to Elsey et al.'s findings (2019), but consistent with Milani et al.'s study (2022), POV had no discernible impact on sexual arousal in the scenarios examined in the present experiment. However, our results align with Elsey et al. (2019) regarding sexual presence, as they found no significant effect of POV modality on reported sexual presence levels. These findings contribute to the conflicting evidence in this area and provide novel data suggesting that POV modality has no effect on ED manifestations. Nevertheless, it remains to be determined whether optimal activation of performance anxiety, as outlined above, would have produced similar results.

Strengths and Limitations of the Study

The generalizability of this study is limited by a relatively small sample, predominantly composed of middle-aged Caucasian male adults. The sample size and statistical power also hindered our ability to examine the effects of the sets of sexual scenarios (i.e., male-female and male-male) on the outcomes. Additionally, the sample size affected our ability to detect significant small-to-medium effects. Also, participants were not screened for the use of phosphodiesterase type 5 inhibitors. Moreover, the fictional nature of the three-dimensional scenarios and the inability to customize avatars and characters to match participants' characteristics and preferred partners' physical attributes (e.g., age, genitals, body mass/hair, skin color) may have influenced responses compared to real-world sexual situations. Along the same line, the relatively limited scope of the stimuli used (i.e., audiovisual) and the lack of interactivity (i.e., watching passively the VR sexual scenarios without character responsiveness to participants' reactions) could not capture the complexity of real-life sexual interactions. Moreover, since an empty space was chosen to minimize animation artifacts and to focus the user's attention on sexual behaviors and physical attributes, it only partially replicates sexual encounters where environmental elements (e.g., objects, settings) play a significant role in shaping the sexual experience and response. Additionally, the choice of sexual position for each targeted behavior (i.e., oral sex, masturbation, penetration) might have also influenced the results; for example, the more "passive" position of the user underneath the partner in our study (cowgirl) compared to a more

"active" position (missionary). Finally, the use of single-item questions limits the depth and scope for capturing complex, multidimensional constructs (e.g., fear, sexual arousal), while subjective self-report measures are prone to social desirability biases and the Hawthorne effect, potentially leading to differences between responses in the laboratory and in naturalistic settings.

Still, this is the first study to use immersive, three-dimensional virtual environments to examine the cognitive, emotional, and sexual responses associated with ED, while also investigating the effect of VR POV in both clinical and non-clinical samples. The strengths of the study also lie in its sexually diverse sample, the use of photorealistic virtual simulations tailored to participants' sexual orientation and depicting various sexual behaviors, as well as its experimental design, with the empirical literature on ED primarily consists of observational studies.

Conclusion

This study primarily examined the relevance of using state-of-the-art VR paradigms to investigate the manifestations and mechanisms in ED. Virtual sexual scenarios show potential in studying impaired sexual response in ED, but future research should explore whether simulations depicting increasingly realistic and interactive sexual behaviors can elicit performance anxiety, either in a laboratory or at-home setting. Such research should include various types of real-time sexual interactions with characters displaying different reactions to participants' sexual responses (either negative or positive) and multi-sensory interactive stimuli (e.g., haptic sensations with connected sex toys). These efforts are essential to bridge the gap between virtual environments and real-life sexuality, maximizing the potential of this technology for research on individuals experiencing ED or other sexual difficulties related to performance concerns or fears (e.g., sexual interest or orgasmic disorders, premature ejaculation). If future advancements in realistic, multi-sensory, and interactive virtual environments prove more effective than current sexual scenarios at eliciting sexual performance anxiety, subsequent clinical trials should assess the efficacy of integrating these enhanced virtual scenarios into exposure-based interventions and home-based exercises to reduce ED-related fears, maladaptive anticipatory thoughts, and avoidance behaviors. Future experimental studies should also compare the effects of different types of erotic materials (e.g., audio, 2D videos, pictures, VR) on cognitive, emotional, and sexual response of individuals with ED, to further support the benefits of VR over other mediums. The ability of VR to alleviate the ethical tensions in experimental sex research could breathe new life into the study of ED, a field traditionally dominated by case studies, conceptual literature, and cross-sectional studies without direct observation of lived sexual experiences. This opens promising new avenues of research and underscores the relevance of using VR in sexual health studies.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author, D.L., upon reasonable request.

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