



Systematic Review

Application of Extended Reality in the Treatment of Contamination Fear: A Systematic Review

Zahra Attarilar^{1*}, Niloofar Beigzadeh¹¹Student Research Committee, Tabriz University of Medical Sciences, Tabriz, Iran*Corresponding author: Zahra Attarilar, Email: zahra99attarilar@gmail.com**Abstract**

Introduction: Fear of contamination is a major dimension of disabling symptoms in obsessive-compulsive disorder (OCD), and there appears to be a direct link between fear, anxiety, and the resulting washing compulsions. Exposure and response prevention (ERP) has long been the treatment of choice, although in-vivo exposure has encountered several barriers to this process. Augmented reality (AR), including virtual reality (VR), AR, and mixed reality (MR), provides a controlled, safe, and repeatable setting in which exposure becomes a direct process. This review provides insight into the use of extended reality (XR) in inducing target emotions and reducing symptoms in OCD.

Methods: A systematic search was conducted using the PRISMA statement guidelines for PubMed, Scopus, and Web of Science databases, with a focus on studies utilizing VR, AR, or MR for evaluating and treating contamination fear or OCD symptoms. Fourteen studies fitted the inclusion criteria. Quality was assessed using the Cochrane Handbook RoB2 tool when assessing randomized controlled trials, and the Joanna Briggs Institute quality assessment instrument was applied to non-randomized studies.

Results: Overall, ten studies demonstrated positive results, including reductions in OCD symptoms, positive changes in contamination-related cognitive themes, and successful induction of anxiety and disgust. Nonetheless, the remaining four studies provided conflicting results, mainly due to less presence, less than expected improvements in symptoms, and limitations of the technology. No studies showed negative clinical outcomes. The evidence for the use of VR was strongest, particularly when combined with ERP. Moreover, AR was consistently successful in inducing contamination-related anxiety in real-life situations, and MR had some preliminary and inconclusive findings.

Conclusion: In general, XR has great potential as an adjunct or alternative treatment to standard ERP due to its ability to induce anxiety and disgust responses, patient engagement, and exposure. However, the mentioned limitations, including the use of small samples, variability in protocols, and short duration of follow-ups, highlight the need for larger studies.

Keywords: Extended reality, Contamination fear, Obsessive-compulsive disorder

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Introduction

Obsessive-compulsive disorder (OCD) has long been recognized as a pervasive mental health issue that is characterized by intrusive thoughts and compulsive behaviors. In the revised diagnostic and statistical manual of mental disorders (the 5th edition), OCD was moved from the category of anxiety disorders to a distinct disorder (American Psychiatric Association, 2013).^{1,2} Among the many types of OCD, fear of contamination is the most prevalent, affecting approximately 30–50% of individuals with OCD and causing compulsive washing in this group.^{3,4} In addition to fear, the emotional experience of disgust elicited by perceived contamination is considered an important accompanying feature that may exacerbate the disorder.^{5,6} Compared with fear responses, disgust responses have been shown to be particularly resistant to reduction through exposure-based therapies.^{7,8}

The primary initial treatment for fear of contamination is rule-based exposure and response prevention (ERP), which is a type of cognitive-behavioral therapy (CBT)

that involves systematically exposing patients to feared stimuli with the instruction not to perform the intrusive behaviors.^{9,10} Although in vivo exposure is effective, it is accompanied by certain logistical issues, such as issues of safety, costs, variability of conditions, and moderate rates of dropouts.¹¹ Imaginal exposure, while safer, often turns out to be difficult and is frequently accompanied by higher levels of anxiety and disgust.^{12,13}

Virtual reality (VR), augmented reality (AR), and mixed reality (MR) form the extended reality (XR) system, which has proven to be a viable treatment for anxiety disorders during the last ten years.¹⁴⁻¹⁶ XR technologies deliver interactive three-dimensional environments that enable users to experience simulated environments through safe and managed exposure to their specific fears. According to some studies, VR exposure therapy (VRET) can reduce anxiety as effectively and meaningfully as real-world (in vivo) exposure, with the added benefit of greater patient acceptance.¹⁷⁻¹⁹

Beyond anxiety reduction, recent studies have examined



the capacity of VR to elicit and modulate disgust-related responses (13, 20). However, most of them have focused on fear or anxiety, with relatively few studies examining the potential of VR to reduce disgust.⁸ Given that disgust in contamination-based fears typically subsides more slowly than fear, assessing whether XR can effectively target both emotions may have essential clinical implications.^{16,21} In addition to VR, AR is increasingly being investigated for use in exposure-based interventions. By overlaying virtual elements onto the real-world environment, AR enables patients to confront threatening stimuli in authentic and ecologically valid contexts without direct physical risk.^{19,22} Emerging evidence suggests that AR may enhance presence and interactivity while also offering advantages in terms of cost-effectiveness and time efficiency relative to VR.^{18,19,23}

Coleman et al have recently found that the existing literature has largely focused on VR-based assessment and treatment of OCD and provided limited information on long-term treatment outcomes.²⁴ This review emphasizes contamination fear (CF) as the most disabling symptom of contamination-related OCD and highlights the role of XR technologies in inducing anxiety or disgust responses for symptom relief. It further provides a specific overview of VR, AR, and MR technologies for this disorder and offers more focused information on the role of AR-assisted ERP therapy. However, given the predominant focus of existing research on symptom induction and the lack of evidence regarding sustained treatment outcomes, it is essential to conduct a new study specifically investigating the mechanisms of fear and the long-term efficacy of XR-based interventions.

Methods

Search Strategy

PubMed, Scopus, and Web of Science databases were searched for studies that evaluated the application of XR technology in treating contamination-related fear. Additionally, Google Scholar search results were consulted to make the search more inclusive through applying the following terms:

((“extended reality” OR “virtual reality” OR “augmented reality” OR “mixed reality” OR “XR” OR “immersive technology”) AND ((“contamination” OR “contamination fear” OR “fear of contamination” OR “contamination-related anxiety” OR “obsessive-compulsive disorder” OR “OCD” OR “contamination phobia”))).

Equivalent search strings were adapted for each database according to its indexing syntax. No temporal restrictions were applied, and only publications in English were included in the investigation.

Eligibility Criteria

The inclusion criteria required that studies examining the use of XR technologies, including VR, AR, MR, or other immersive technologies. Moreover, eligible studies needed to assess fear of contamination or contamination-related symptoms, including any symptoms associated with OCD.

In addition, the studies had to be published in a peer-reviewed journal or conference proceeding and report empirical findings, whether qualitative, quantitative, or mixed-methods.

On the other hand, the exclusion criteria included publications that were in any language other than English. Furthermore, review articles, editorials, or opinions and publications that involved non-human subjects were excluded from the review.

Study Selection and Data Extraction

All retrieved records were imported into EndNote (version X9) to remove duplicates. Two reviewers independently screened titles and abstracts against the inclusion criteria, followed by full-text screening. Disagreements were resolved by discussion or consultation with a third reviewer. Moreover, a standard form was used to extract data, including study design, sample characteristics, XR method, outcome measures, and key findings.

Quality Assessment

The quality of the randomized controlled trials (RCTs) was evaluated using the Cochrane Risk of Bias 2 (RoB2) tool, whereas that of the non-randomized and quasi-experimental studies was assessed by the Joanna Briggs Institute (JBI) critical appraisal checklist.

Results

A detailed overview of the study identification, screening, and inclusion process is presented in [Figure 1](#). This systematic review presented data from fourteen research studies that evaluated the use of XR technology, including VR, AR, and MR, to treat fear of contamination related to OCD. These studies had been conducted in Turkey, Spain, China, Canada, USA, Iran, Germany, Czech Republic, Dominican Republic, and Australia using a range of study designs, such as pre-post designs and between-group comparisons.

Based on the extracted study characteristics ([Table 1](#)), sample sizes widely varied, ranging from 3 to 66 participants. Most studies focused on adults with contamination-focused OCD. In addition, the interventions generally consisted of 3–12 sessions of XR-based ERP. However, there were considerable variations across studies in terms of treatment protocols and outcome measures.

This systematic review synthesized evidence from fourteen experimental and clinical trials assessing the efficacy of XR technologies, including VR, AR, and MR, for the treatment of CF.

Virtual Reality Interventions

Ten studies examined VR interventions for contamination-related OCD. Five randomized or controlled trials consistently reported significant symptom reductions. Specifically, VR-based VR-ERP yielded clinically meaningful decreases in OCD severity (8, 30, 32), as measured by the Yale-Brown Obsessive-Compulsive Scale (Y-BOCS), and facilitated cognitive changes related

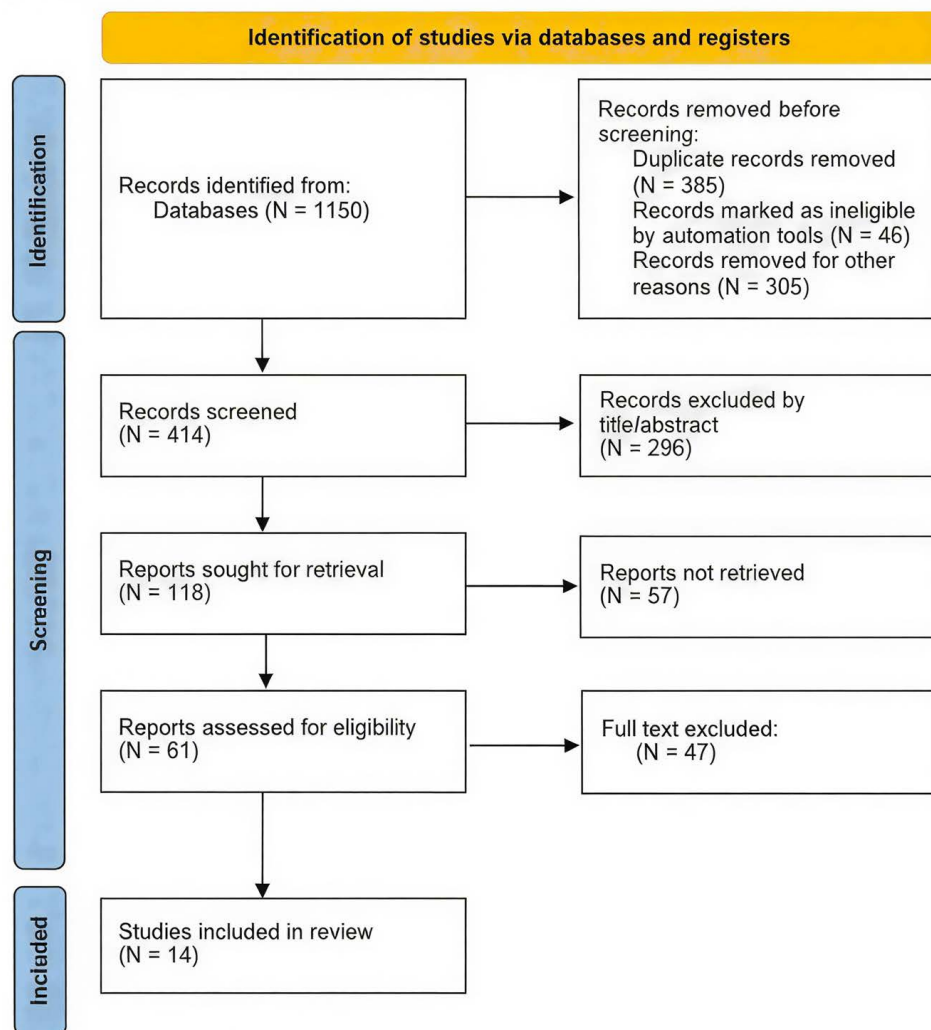


Figure 1. PRISMA Flow Diagram of the Study Selection Process

Note. PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

to contamination.^{29-32,34} It should be noted that these outcomes were largely comparable to those achieved through in vivo or imaginal exposure, supporting VR as a viable alternative for delivering ERP.

Three additional validation and experimental studies demonstrated that VR environments produce consistent key reactions, including anxiety and disgust and washing urges, in both clinical and non-clinical participants. Participants showed increased emotional distress when they detected higher levels of contamination in the VR scenarios. Moreover, disgust functioned as the connecting factor that linked anxiety to the washing urge, thereby showing its fundamental position in these reactions.^{8,13}

One case-series study reported only modest reductions in OCD symptoms.³² The VR treatment caused specific disgust-related symptoms and bodily reactions. However, only two participants met treatment success standards, and two participants planned to stop therapy because it failed to meet their needs. The research studies identified minimal negative effects that included cybersickness and gentle uneasiness.^{9,33,34} The majority of VR research studies produced positive results, with seven out of ten studies confirming beneficial outcomes^{13,20,28-30,32,34}, while three studies reported either mixed or weak results.^{8,9,33}

Augmented Reality Interventions

Three studies investigated AR interventions. Two validation studies demonstrated that AR stimuli (e.g., garbage bags, moldy bread, dirty shoes, and rotten meat) effectively elicited contamination-related anxiety, with effect sizes ranging from small to large depending on the stimulus type.^{25,26} These effects were consistent across clinical and non-clinical samples. A third study using the “CleanScape” AR system found that patients with contamination-based OCD reported significantly higher state anxiety compared to healthy controls, highlighting the potential of AR as a safe and resource-efficient adjunct to ERP.²⁷

All three AR studies revealed positive outcomes, supporting the feasibility of AR for eliciting anxiety in real-world contexts while requiring relatively low resource investment.

Mixed Reality Interventions

Evidence for MR interventions remains limited, with only one identified study.³¹ A pilot RCT comparing MR-ERP to care-as-usual demonstrated comparable reductions in Y-BOCS scores across groups, indicating non-inferiority but not superiority. The participants gave mixed feedback

Table 1. Summary of Included Studies Evaluating Extended Reality Interventions for Contamination Fear

Author/ Year	Study Design	Sample Characteristics	XR Modality	Outcome Measures	Key Findings
Mujgan Inozu (2020) Turkey ⁸	Experimental; between-groups (experimental vs. control). Pre-post measurement after virtual reality-exposure and response prevention (VR-ERP) sessions.	(Non-clinical participants (n=21) with high contamination fear (CF). Experimental group: n=9. Control group: n=12. Mean age: 20.62	VR exposure (VRE)-ERP. Virtual environments with varying degrees of dirtiness. Minimum of 3 VR-ERP sessions per participant.	Self-reported anxiety, disgust, and urge to wash.	Contamination-related ratings increased with higher dirtiness levels in VR. After VR-ERP sessions, the experimental group showed significant decreases in anxiety, disgust, and urge to wash compared to the control group. VR-ERP can be an effective alternative to in vivo exposure for contamination-related OCD symptoms.
Alison J. Cullen (2021) Australia ⁹	Experimental validation study (within-subject comparison VR vs. in vivo ERP)	Sample size: 22 patients with contamination obsessive-compulsive disorder (OCD). Adults diagnosed with contamination-based OCD; no further demographic details were reported.	VR using HTC Vive hardware	- Subjective anxiety ratings - Psychophysiological measures (heart rate and respiration) - Engagement and adherence metrics	- VR and in vivo ERP provoked comparable anxiety profiles - VR allowed flexible, interactive exposure - VR improved engagement and adherence - Therapeutic alliance maintained during VR sessions
Mujgan Inozu (2021) Turkey ¹³	Experimental; between-groups design (high CF vs. low CF). Tested VR scenarios with varying degrees of dirtiness	High CF group: n=33. Low CF group: n=33. Total n=66.	VR contamination scenarios. Multiple environments differing in "overall dirtiness."	Self-reported anxiety, disgust, and urge to wash after each VR task. Mediation analysis of disgust in the relationship between contamination anxiety and urge to wash.	High CF group reported significantly higher anxiety, disgust, and urge to wash than low CF group. Increased dirtiness in VR scenarios led to higher anxiety and disgust in both groups. Disgust mediated the link between contamination anxiety and urge to wash. VR is as a feasible exposure tool for contamination-based OCD therapy.
Mylène Laforest (2016) Canada ²⁰	Single-case study design with multiple baselines across participants	Sample size: 3 adults Adults with OCD, dominant contamination subtype	VR for in vitro exposure therapy	Daily assessment of obsessions and compulsions, clinical information, self-reports, ARMA time-series analysis, and visual inspection of graphs	Statistically significant improvements in all participants; overall positive improvements in 2 out of 3 participants. VR-based CBT showed preliminary support for treating OCD with contamination features.
Didem et al (2014) Turkey ²⁵	Experimental; pre-post design with EEG measurements during augmented reality (AR)-based exposure therapy.	Participants: Patients with anxiety disorders, including those with contamination obsession. Exact sample size, age, and gender: not specified in excerpt — would need full text to complete.	AR systems designed for exposure therapy. Used for contamination obsession, symmetry obsession, and insect phobia.	EEG signals (beta and theta activity in temporal regions) before and after AR treatment. Induction of anxiety and changes in brainwave patterns during exposure.	AR could effectively induce anxiety responses in patients with phobias and obsessions. EEG analysis displayed measurable changes in beta and theta waves, suggesting neural activity shifts associated with treatment. Offers advantages over traditional exposure methods in terms of controllability and monitoring.
Zoilo et al (2021) Spain ²⁶	Experimental validation study; between-groups comparison (OCD vs. controls).	Clinical group: 17 patients with cleaning OCD. Control group: 11 participants without OCD.	AR stimuli shown via an AR system. Stimuli developed: Plastic bag full of garbage, Moldy bread, Dirty sports shoe, Rotten meat	Perceived anxiety in response to each AR stimulus (scale not specified in excerpt). Between-group comparisons (OCD vs. control). Effect size calculations.	Significant statistical differences in anxiety ratings between groups for the rotten meat stimulus. All stimuli demonstrated measurable effect sizes: Plastic bag: Small effect Bread: Small-to-medium effect Shoe: Small-to-medium effect Meat: Large effect Results support the potential clinical use of these AR stimuli for treating cleaning OCD.
Yuhan Ji (2025) China ²⁷	Experimental; between-groups comparison (contamination-based OCD vs. Control) using AR-based ERP.	Clinical group: 22 patients with contamination-based OCD. Control group: 22 participants without OCD.	AR scenarios with five contamination-related environments of varying severity.	Subjective distress (state anxiety ratings). Objective distress measures (type not specified; likely physiological or behavioral).	AR exposure induced elevated state anxiety in both groups. The contamination-based OCD group showed significantly higher anxiety levels than controls. Developed AR scenarios effectively elicited emotional responses. Thus, can be applied as a complementary tool in ERP for contamination-based OCD.

Table 1. Continued.

Author/ Year	Study Design	Sample Characteristics	XR Modality	Outcome Measures	Key Findings
Mylène Laforest (2016) Canada ²⁸	Experimental; mixed within-between subject protocol. Compared responses to clean vs. contaminated VR environments in OCD and control participants.	OCD group: 12 adults with contamination-subtype OCD. Control group: 20 adults without OCD. Total n = 32.	Virtual reality; 6-wall cave-like immersive projection system. Scenarios: Clean control room Contaminated filthy public restroom	Subjective: Self-reported anxiety questionnaires Objective: Heart rate Presence rating (sense of “being there”) Side effects questionnaire	Filthy public restroom environment induced significantly higher anxiety in the OCD group (both subjective and objective measures). Presence correlated with anxiety in the OCD group; no group difference in presence scores. OCD participants reported more unwanted side effects than controls. Supports VR as a therapeutic tool for inducing contamination-related anxiety for exposure purposes.
Mujgan Inozu (2025) USA ²⁹	Randomized controlled trial (RCT); between-groups (VRE vs. in vivo exposure vs. imaginal exposure vs. wait-list control). Pre-post measurement after ~10 exposure sessions.	Total n = 44 adults with DSM-5 OCD (contamination obsessions and cleaning compulsions). The VRE group: n = 7. In vivo exposure group: n = 8. Imaginal exposure group: n = 8. Wait-list control group: n = 10.	VRE. Contamination-related scenarios designed to provoke anxiety and compulsive urges. Average of 10 exposure sessions, two per week.	Yale–brown obsessive–compulsive scale (Y-BOCS) Contamination-related cognition measures Psychological well-being	VRE significantly reduced OCD symptom severity and contamination-related cognitions while improving psychological well-being. Effects comparable to in vivo and imaginal exposure in reducing contamination-related anxiety and compulsive behaviors. VRE is suggested as a viable alternative to traditional exposure techniques for contamination-related OCD.
Razieh Javaherrenani (2022) Iran ³⁰	RCT; between-groups (VRERP vs. standard CBT). Pre-post and 3-month follow-up measurements after 12 weekly sessions.	Total n = 36 adults with DSM-5 OCD (contamination subtype). The intervention group (VRERP in CBT): n not specified (out of 29 completers). Control group (standard CBT): n not specified (out of 29 completers). 29 participants completed treatment.	VRE and response prevention (VRERP). “contaminated” virtual environment integrated into CBT sessions. 60-minute CBT sessions and 12 weekly sessions.	(Y-BOCS; obsession and compulsion subscales). Beck Depression Inventory-II (BDI-II). Beck Anxiety Inventory (BAI). Obsessive Beliefs Questionnaire-44 (OBQ-44). World Health Organization Disability Assessment Scale-2 (WHODAS-2). Key findings:	Significant reductions in Y-BOCS obsession and compulsion scores in the VRERP group (large effect sizes). Obq-44 and WHODAS-2 scores improved significantly more in the VRERP group compared to the control. BDI-II and BAI scores decreased in both groups, but no significant between-group differences were observed. VRERP was found to be an effective alternative exposure tool within CBT for contamination-type OCD.
Franziska Miegel (2023) Germany ³¹	Pilot RCT; between-groups (MERP vs. care-as-usual). Pre-post and 3-month follow-up measurements after intervention.	Total n = 20 inpatients with contamination-related OCD. The MERP group: n not specified. Care-as-usual group: n not specified.	Mixed reality exposure and response prevention (MERP). Six sessions over 3 weeks.	Y-BOCS Qualitative feedback on safety, feasibility, and acceptance Sense of presence ratings.	Both MERP and care-as-usual groups showed similar Y-BOCS reductions from baseline to post. No clinically significant deterioration was detected in the MERP group. Mixed patient evaluations, some acceptance, and some reservations Sense of presence was below the midpoint of the scale. Qualitative feedback suggested the need for software improvements.
Franziska Miegel (2022) Germany ³²	Case series (no control group). Pre-post measurement after 6 weeks of VERP.	Total n = 8 female patients with contamination-related OCD (C-OCD). Primary emotion targeted: Disgust.	VERP Four consecutive VR exposure sessions within a 6-week treatment period Measurements included subjective units of distress (SUD), heart rate, skin conductivity, presence, and simulator sickness.	Y-BOCS) SUD Physiological arousal (heart rate and skin conductivity) Sense of presence Simulator sickness	VERP successfully induced distress and physiological arousal linked to disgust. Sense of presence was moderate. Qualitative feedback was mixed. OCD symptoms reduced with medium-large effect sizes, but only 2/8 patients were responders. Two patients discontinued due to a lack of treatment success. The results suggested feasibility for evoking disgust-related distress but limited overall symptom improvement.
Iveta Fajnerová (2023) Czech Republic ³³	Validation study (experimental, single-session exposure with OCD patients and healthy controls)	Sample size: 44 OCD patients, 31 healthy controls, adults diagnosed with OCD, and the healthy control group	The VR house environment	-Self-reported distress/ anxiety (0–5 scale) per stimulus -Compulsive tendencies (0–5 scale) - Questionnaires on subjective anxiety before/after VR - Sense of presence in VR - Simulator sickness	- OCD group reported higher distress and compulsive behavior than controls when exposed to VR stimuli - No overall increase in anxiety after VR exposure - Subjective distress and compulsive ratings not correlated with symptom severity or sense of presence - Weak association with cybersickness symptoms

Table 1. Continued.

Author/ Year	Study Design	Sample Characteristics	XR Modality	Outcome Measures	Key Findings
García-Batista (2022) Dominican Republic ³⁴	Experimental validation study (development and testing of VR scenarios)	Sample size: 40 participants (20 C-OCD, 20 healthy controls) C-OCD group: Aged 18–48, Y-BOCS score > 13, confirmed C-OCD via SCID-I; Control group: Aged 18–56; all residents of the Dominican Republic	VR—two scenarios: Dirty public bathroom and unhygienic kitchen	- State and subjective anxiety levels - Emotional response to VR scenarios	- VR exposure elicited high levels of anxiety in both groups, significantly higher in the C-OCD group - VR scenarios are suitable for eliciting emotional responses relevant to contamination OCD treatment - VR can complement existing OCD treatments

Note. DSM-5: Diagnostic and statistical manual of mental disorders (the 5th edition); ARMA: Autoregressive moving average model; CBT: Cognitive-behavioral therapy; EEG: Electro-encephalogram.

because some of them experienced only weak presence while recommending software enhancements. Similarly, a small-scale pilot study noted moderate presence levels and partial symptom improvement. The research results confirm that although MR functions effectively, it requires additional development to reach clinical intervention standards.

Overall Patterns

Across XR modalities, interventions consistently elicited anxiety and disgust, which are emotions that are critical for inhibitory learning during ERP. Among the fourteen studies included in this review:

- Ten reported positive outcomes, including significant symptom reduction or robust induction of target emotional responses.
- Four demonstrated mixed or modest results, characterized by limited presence, modest symptom change, or minor tolerability issues.
- None indicated negative or harmful effects beyond minor side effects (e.g., cybersickness).

The most compelling evidence was observed for VR-ERP delivered within structured CBT protocols, yielding reliable reductions in OCD symptom severity. Moreover, AR interventions demonstrated feasibility and high ecological validity, particularly in resource-limited settings. Although MR is conceptually promising, it remains at an early stage, with current technological constraints limiting therapeutic impact.

Quality Assessment

The methodological quality of the included studies was assessed using the Cochrane RoB2 tool for RCTs and the JBI critical appraisal checklists for non-randomized designs. Based on the research results, the evidence quality ranged from low to moderate because of multiple methodological faults that appeared throughout the studies.

Sample Size: Most studies involved small samples, ranging from 3 participants in single-case designs²⁰ to 66 participants in experimental validation studies.¹³ RCTs included between 20 and 44 participants,^{29–31} limiting the generalizability of findings.

Intervention variability: Protocols differed in number and length of sessions (3–12 sessions; 20–60 minutes) and XR stimuli types. In addition, VR environments included public restrooms and kitchens.^{28,34} Further, AR studies

focused on contamination-relevant objects^{26,27}, and MR interventions were tested in small six-session pilot trials.³¹ These differences complicate cross-study comparisons.

Outcome Measurement: The Y-BOCS was the most frequently used standardized measure.^{29,30,32} Anxiety was assessed via self-reports and physiological measures, such as heart rate.²⁸ Additionally, disgust, a core emotion in CF, was inconsistently measured, sometimes via ad hoc assessments¹³ or not at all. Few studies examined disgust as a mediator of treatment response.

Follow-up: A limited number of studies conducted follow-up assessments after the treatment. Only one of the RCTs³⁰ was reported to measure outcomes at 3 months. Most studies did not investigate outcome measures after the immediate post-intervention period.

Risk of Bias and Reporting Transparency: Several RCTs raised randomization and allocation concealment concerns during Cochrane RoB2 assessments.^{29,31} Due to the nature of XR intervention designs, blinding of participants and outcome assessors was typically not feasible. Moreover, many non-randomized and validation studies assessed with the JBI checklist lacked a control group^{28,32}, thereby increasing the potential risk of bias.

Tolerability and Feasibility Aspects: Instances of cybersickness, simulator sickness, and diminished sense of presence were documented during VR and MR studies.^{31,33} The qualitative feedback from MR interventions also expressed technology-related limitations, such as insufficient immersion and software instability.³¹

Table 2 provides a structured summary of study designs, participant characteristics, XR modalities, and main findings.

The overall quality of the evidence indicates that XR-based ERP is a promising intervention for CF, with VR demonstrating the most robust empirical support. Nevertheless, several limitations, including small sample sizes, heterogeneity of protocols, inconsistent assessment of disgust, short follow-up periods, and potential risk of bias, temper the strength of these conclusions. Consequently, there is an urgent need for high-quality, large-sample RCTs that implement standardized protocols and incorporate long-term outcome assessments in order to establish XR as a reliable and effective clinical tool.

Discussion

This systematic review summarized the findings of

Table 2. Quality Assessment of the Included Studies

Author (Year)	Country	Design	Sample Size	XR Modality	RoB2/JBI Rating	Key Quality Notes
Inozu (2020) ⁸	Turkey	Experimental (pre-post)	n = 21	VR	Moderate-low	Small, non-clinical sample; promising symptom reductions
Cullen (2021) ⁹	Australia	Experimental validation	n = 22	VR	Moderate-low	No long-term follow-up; cybersickness noted
Inozu (2021) ¹³	Turkey	Experimental (between-groups)	n = 66	VR	Moderate	Adequate sample size; robust induction of disgust; non-clinical population
Laforest (2016) ²⁰	Canada	Experimental	n = 32	VR	Moderate	Clear design; anxiety/presence measured; side effects noted
Didem (2014) ²⁵	Turkey	Experimental (pre-post EEG)	n not clear	AR	Low-moderate	Promising EEG results; insufficient sample reporting
Zoilo (2021) ²⁶	Spain	Validation study	n = 28	AR	Moderate	Anxiety induction robust; small sample
Ji (2025) ²⁷	China	Experimental (between-groups)	n = 44	AR	Moderate	CleanScape AR system validated; no follow-up
Laforest (2016) ²⁸	Canada	Single-case	n = 32	VR	Low	Very limited sample; preliminary findings
Inozu (2025) ²⁹	USA	RCT	n = 44	VR	Moderate	Adequate randomization; small sample; short follow-up; limited blinding
Javaherrenani (2022) ³⁰	Iran	RCT	n = 36	VR	Moderate	Good protocol integration; attrition accounted for; short follow-ups
Miegel (2023) ³¹	Germany	RCT pilot	n = 20	MR	Moderate-low	Small pilot; limited presence; qualitative feedback mixed
Miegel (2022) ³²	Germany	Case series	n = 8	VR	Low-moderate	Symptom improvements in subset; high dropout
Fajnerová (2023) ³³	Czech Republic	Validation study	n = 75	VR	Moderate-low	Cybersickness observed; limited clinical applicability
García-Batista (2022) ³⁴	Dominican Republic	Validation study	n = 40	VR	Moderate	Strong induction of anxiety; no follow-up

Note. JBI: Joanna Briggs Institute critical appraisal checklist; EEG: Electro-encephalogram; RCT: Randomized controlled trial; VR: Virtual reality; AR: Augmented reality; XR: Extended reality.

fourteen experimental and clinical studies that explored the use of XR technologies, including VR, AR, and MR, for addressing (CF), a common and debilitating aspect of OCD. Across these different XR approaches, interventions consistently triggered the two main emotional responses linked to CF (i.e., anxiety and disgust) and often led to noticeable reductions in OCD symptom severity. Differences in the strength of evidence were observed across XR modalities, study designs, and methodological quality.

Extended Reality as a Tool for Targeting Anxiety and Disgust in Contamination Fear

In traditional ERP, eliciting sufficient emotional activation during exposure is critical for inhibitory learning and the eventual reduction of compulsive behaviors.⁷ While in vivo exposure is considered the gold standard, it is frequently associated with practical and emotional barriers, including safety concerns, unpredictable stimuli, high costs, and patient reluctance.⁹⁻¹¹ XR technologies address many of these limitations by creating controlled, repeatable, and gradable exposure environments.^{14,15}

A key advantage revealed in this review is the ability of XR to reliably provoke both anxiety and disgust responses. This is particularly relevant because disgust has been shown to decline more slowly than fear in CF (5, 6) and is strongly associated with persistent washing compulsions.¹⁷ Several VR studies^{8,13,32} demonstrated that increasing

the “dirtiness” of virtual environments proportionally heightened both anxiety and disgust, with disgust often mediating the relationship between contamination anxiety and the urge to wash. These findings support the inclusion of disgust-targeted interventions in XR protocols, potentially enhancing treatment durability.

Comparative Efficacy of Extended Reality Modalities

VR emerged as the most extensively studied modality, with nine studies included. Seven studies (78% of the total research) demonstrated positive results regarding decreased OCD symptoms and better contamination-related thoughts and successful anxiety and disgust induction. Nonetheless, two studies (22%) produced conflicting results because they discovered short-term benefits together with issues of cybersickness and discomfort and discomfort. VR technology generates feelings of disgust and anxiety in users, which proves essential because disgust tends to resist exposure therapy more than fear does.

Furthermore, VR represents the primary method for research studies, achieving the highest operational success rates. The combination of VR-ERP with CBT through RCTs^{8,29,30} revealed that this treatment method produces substantial decreases in OCD symptoms and contamination-related thoughts while achieving results similar to those of traditional exposure methods. The participants gave positive responses to VR experiences,

and their emotional involvement tended to increase when they experienced higher levels of presence.²⁸ The research confirmed that VR therapy produced negative effects that included cybersickness symptoms and mild physical distress^{28,32}; thus, medical professionals should keep track of patient tolerance levels during clinical therapy sessions.^{9,33,34}

AR was evaluated in three studies, all of which (100%) reported positive results. AR stimuli could consistently elicit contamination-related anxiety in both patient and community samples. Although none of these studies assessed long-term treatment effects, AR was shown to be feasible, ecologically valid, and associated with lower resource burden than VR; this has promising implications for a potential complementary ERP tool for clinic-based applications with minimal technology access.

AR studies, though fewer in number, yielded promising results.^{26,27} AR provides acceptable ecological validity by superimposing contamination-related stimuli onto real-world environments while also ensuring safety and control. The CleanScape AR scenarios produced substantially greater anxiety in patients with contamination-related OCD than controls²⁷, demonstrating their potential clinical relevance as a complement to ERP, particularly in situations where VR resources are not an option or are prohibitively expensive.

Nevertheless, MR remains underexplored, with only two studies reporting mixed findings. While MR-based ERP achieved symptom reductions comparable to care-as-usual, qualitative feedback revealed challenges, such as limited sense of presence and insufficient software optimization. Thus, while MR shows conceptual promise in bridging ecological realism with immersive exposure, its clinical utility remains unproven at this stage.

It should be noted that MR applications are still in early experimental stages, with mixed findings. The only identified MR RCT³¹ reported symptom reductions comparable to care-as-usual, though qualitative feedback suggested that limited sense of presence and software constraints may hinder full therapeutic potential. Accordingly, future MR systems with higher immersion and interactivity may bridge the gap between the emotional efficacy of VR and the ecological realism of AR. These findings align with and extend previous reviews in the XR literature. For instance, a recent scoping review on the “extended mind and body” framework emphasized XR’s capacity to enhance human cognition across diverse domains, from education and professional training to therapeutic interventions, while also highlighting ethical and societal challenges, such as privacy, prolonged immersion effects, and unequal access.³⁵ Although its focus was broader and not limited to psychiatric populations, its conclusions regarding XR’s immersive potential and user engagement complement the findings of the present review in a clinical context. Likewise, a recent systematic review of immersive VR exposure therapy (iVRET) for fear of contamination disorders demonstrated that iVRET can effectively modulate disgust, a transdiagnostic feature

across multiple psychopathologies, in both clinical and at-risk populations.¹ Compared to that review, our synthesis included a broader range of XR modalities (VR, AR, and MR) and placed equal emphasis on anxiety and disgust outcomes, providing a more comprehensive perspective on emotional processes central to CF treatment.

Comparative Efficacy and Mechanisms

Overall, our findings indicated that XR interventions are consistently effective in eliciting target emotional responses, particularly disgust, which is critical for inhibitory learning during ERP. Out of fourteen studies included in the research, ten produced positive results, whereas four produced mixed results. No studies reported any negative effects, except for brief cybersickness symptoms and patients stopping their treatment. VR stands out as the most thoroughly supported evidence-based treatment because it functions best when integrated into established CBT protocols. The feasibility of AR stands out but scientists have yet to determine its lasting effectiveness. Moreover, MR remains in its early development stage, showing varying performance results.

Clinical Implications

The evidence suggests that XR technologies can overcome some limitations of traditional ERP, particularly in eliciting disgust, increasing patient engagement, and allowing for graduated exposure in a safe, controlled manner. These features may reduce dropout rates, a common challenge in ERP for CF.^{11,23} Furthermore, XR may be particularly beneficial in cases where in vivo exposure is logistically impractical or where patient avoidance is extreme.

The incorporation of XR into standard CBT protocols may be vital for achieving its optimal therapeutic effect. Studies in which XR was used as a stand-alone intervention^{13,32} demonstrated fairly small improvements over a long period compared to those integrating XR within a structured CBT protocol.^{8,29,30} This finding is consistent with those of meta-analytic studies on exposure therapy, suggesting cognitive restructuring and behavioral means to help establish and consolidate those gains.¹⁴

Limitations Based on Quality Assessment

The quality appraisal of the included studies revealed several important methodological weaknesses that should be considered when interpreting the findings of this review. Small sample sizes were a pervasive limitation. Most studies recruited fewer than forty participants, with some relying on as few as three to twelve individuals. Such limited sample sizes reduce statistical power and constrain the generalizability of results to broader clinical populations. This issue was particularly evident in pilot studies and case-series designs, where outcomes may be inflated by sampling bias.

In addition, there was substantial variability in intervention protocols. The number of sessions ranged from three to twelve, session durations varied, and exposure stimuli were inconsistently designed across studies. This

heterogeneity complicates direct comparisons across trials and limits the feasibility of meta-analytic synthesis. Furthermore, because studies did not report standardized XR content, the therapeutic “dose” and ecological validity of interventions were not uniform, raising concerns about potential variability in treatment outcomes.

Further, disgust, a primary emotion underlying CF, was frequently not assessed or was secondary to anxiety measures. Although XR interventions were generally effective in eliciting disgust, only a minority of studies employed validated disgust-specific instruments. This limitation reduces the precision with which conclusions can be drawn regarding XR’s unique role in targeting disgust relative to anxiety.

Moreover, few studies included follow-up assessments. Only two studies conducted follow-ups beyond three months, leaving the long-term durability of XR-based ERP largely unknown. This is particularly important given the high relapse rates observed in OCD and the necessity of sustained outcomes for evaluating clinical utility.

Additionally, risk-of-bias assessments revealed that several trials had issues with randomization, allocation concealment, and blinding. The absence of suitable control groups in non-randomized and quasi-experimental designs led to an increased risk of treatment effect overestimation. Although the available evidence shows good results, it might not represent the actual effectiveness of XR interventions.

Finally, technological and tolerability challenges were recurrent issues. The routine clinical application of MR technology faces obstacles because users report cybersickness and diminished presence and encounter software problems during their experiences. The software limitations within the system create additional barriers for patient participation and lead to inconsistent treatment administration.

Overall, these quality concerns indicate that XR interventions have the potential to reduce CF, but the research base remains limited. The research requires controlled clinical trials with standardized protocols and validated anxiety and disgust outcome measures and extended follow-up periods to achieve results that can be generalized. The clinical usefulness of these interventions and patient acceptance depends on making XR technologies easier to use while reducing negative impacts, such as cybersickness and lengthy operational times.

Future Directions

Future research needs to focus on conducting large RCTs that will examine the performance of different XR modalities through standardized testing methods and extended follow-up periods. The creation of XR material that focuses on disgust alongside anxiety treatment would result in superior therapeutic results. The combination of different methods that reduce contamination risk will lead to better ecological validity and improved emotional engagement in research studies. The assessment of cost-effectiveness stands as a crucial factor to determine how

well XR interventions can expand their reach for clinical practice applications.

Overall, XR-enabled ERP represents a promising and flexible approach for addressing CF. VR stands as the most thoroughly investigated technology because clinical practice has validated its applications. The research on AR and MR applications remains limited although these technologies bring advantages through their ability to create more realistic environments and enable wider patient access. The next-generation treatment for contamination-focused OCD emerges through the structured CBT applications of XR that concentrate specifically on anxiety and disgust^{8,16,28–30}.

Conclusion

XR technologies, including VR with AR and MR, show promise as treatment methods for people who have OCD and experience CF. VR-ERP stands as the leading evidence-based treatment that generates anxiety and disgust responses while decreasing OCD symptoms and matching the results of in vivo and imaginal exposure when combined with CBT. Although fewer in number, AR and MR interventions demonstrate feasibility and potential for complementary ERP applications, particularly in safely eliciting target emotional responses.

XR interventions provide users with advantages over traditional ERP because they let people control their exposure levels through graded and repeatable scenarios while also boosting patient involvement and focusing on disgust that serves as the main factor in contamination-related compulsions. The current body of research faces limitations because studies include small participant numbers and different experimental methods and brief periods of observation. Future research needs to duplicate these results with larger participant groups through established methods while extending observation times and creating better XR content that produces optimal emotional reactions and medical results. Collectively, these considerations indicate that XR-based ERP is a flexible and innovative approach capable of augmenting traditional CF treatments, especially for individuals who are unable to participate in in vivo exposure.

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Availability of Data and Materials

All data generated or analyzed during this study are included in this article.

Competing Interests

The authors declare that they have no conflict of interests regarding the publication of this review.

Ethical Approval

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