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Active imagery rescripting in virtual reality as a promising tool to address psychological conditions

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ABSTRACT

Imagery rescripting (IR) is a cognitive-experiential technique used for the treatment of various mental conditions through the re-working of aversive memories. It has been widely applied in psychotherapy to address Post-Traumatic Stress Disorder (PTSD) and personality, anxiety, and eating disorders. Despite usually being effective, IR's underlying mechanism has not been clarified yet. Consistently, different assumptions may correspond to different IR versions and outcomes. Among these versions, active IR (AIR) – meaning a rescripting where the patient is the active '*rescriptor*' – seems to have particularly positive effects. So far, IR use has been almost exclusively limited to in vivo settings. But the increasing availability of Virtual Reality (VR) in the last few years has favored the *in virtuo* implementation of safe and effective psychological treatments. On these grounds – and given that virtual scenarios can offer the possibility to perform any necessary actions and even more than real ones – we hypothesize that implementing AIR in VR can be effective in treating psychological conditions. As a preliminary evaluation of this assumption, we systematically searched the literature and reviewed the studies concerning VR realizations of AIR addressing mental issues. Our literature analysis provides the first evidence supporting this hypothesis, yet urging further research and testing.

1. Introduction

A growing body of research identifies Imagery Rescripting (IR) as a promising therapeutic technique addressing aversive memories (Arntz, 2012). In their meta-analysis, Morina et al. (2017) considered 19 trials – concerning post-traumatic stress disorder, social anxiety disorder, body dysmorphic disorder, depression, bulimia, and obsessive-compulsive disorder – and found that it significantly reduced symptoms from pre-to post-treatment. IR is also a consolidated tool for treating personality disorders (Arntz, 2011; Dadomo et al., 2017), and interestingly, it was recently suggested to be effective against the subclinical consequences of experiencing injustice (Twardawski et al., 2021), implying the technique can be effective for aversive memories in general, not only those related to recognized disorders.

Although therapeutic techniques have traditionally been developed and employed in *vivo* (i.e., face-to-face) clinical settings, continuous technological progress is rapidly leading to a more open approach. Indeed, extending therapy to technologically-mediated contexts can allow us to benefit from the significant advantages they offer. For instance, the delivery of psychological treatments to adults suffering from mental disorders via telehealth proved to be no less effective than in-person (Thomas et al., 2021), with the plus of eliminating possible location barriers. In line with this, IR also showed to be effective when delivered via telehealth (Paulik et al., 2021). In this regard, Virtual Reality (VR) – given the possibility of recreating any necessary physical and social environments while also safely acting inside them – is becoming increasingly appealing for psychological applications (Riva, 2022). Furthermore, VR allows for personalization, as virtual scenarios can be created and customized through optional features. While attending a virtual session, additional technology (e.g., biometrical devices, eye tracking) can further capture physical responses to the treatment. Finally, digital technology allows recording sessions for personal reviewing and reflection on the therapy journey or therapist training, given ethical and data security requirements are met. From these premises, (1) **we hypothesize** that implementing active IR (AIR, as defined below) in VR can be effective in treating psychological conditions characterized by aversive memories, and (2) **we perform a preliminary evaluation** of this assumption by systematically searching the literature and reviewing the studies concerning VR realizations of AIR addressing mental issues. We want to emphasize that this work does not aim to test

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the proposed hypothesis but only to theoretically evaluate – by examining the literature – whether it should be considered for testing.

In the following sections, we specify our hypothesis (cf. 1.1), describe our search process (cf. 2), and present the results (cf. 3). As we finally discuss (cf. 4), these results support our proposition that AIR in VR can be a promising tool for treating psychological conditions. In our discussion, we consider key aspects of our evaluation, possible uses/opportunities of the technique, as well as limitations of our work and recommendations for further research.

1.1. AIR as an effective treatment for psychological conditions and its VR implementation

In the context of psychological treatment, IR consists in evoking an aversive memory connected to the targeted condition and re-experiencing it in a positive, empowering way (Arntz, 2012; Brockman & Calvert, 2016; Hayes & van der Wijngaart, 2020; Mancini & Mancini, 2018; Smucker, 2005; Young et al., 2003). In its standard application, it is performed in the therapy room, where the patient closes their eyes and, under the therapist's supervision, gradually relives in their mind a distressing memory, changing the course of crucial events to write a new healing script for that memory. Since IR's underlying mechanism has not been clarified yet, precise implementation guidelines are still missing. As a result, researchers and clinicians may realize the technique differently, with outcomes that can depend on implementation details. Therefore, to specify our hypothesis, we will start by identifying three main features of IR – (F1) Degree of control, (F2) Memory time-location, and (F3) Memory implicitness – which will also guide our literature search.

(F1) Degree of control. Although Pierre Janet pioneered IR as a therapeutic technique in the late 1800s, his work was largely ignored for a long time and, only recently, became an established clinical tool in Cognitive Behavioral Therapy (CBT) (Beck, 2020; Edwards, 2007), and Schema Therapy (ST) in particular (Arntz, 2012; Young et al., 2003). Nonetheless, different rationales and corresponding protocols are used to implement the technique. Brockman and Calvert (2016) identified two main conceptions of IR, referring to its application to negative childhood memories characterizing Post-Traumatic Stress Disorder (PTSD) and Personality Disorders (PDs), respectively. PTSD treatment consisted of a three-stage self-driven protocol emphasizing acquiring mastery/control over the traumatic memories (Smucker, 2005; Smucker & Dancu, 1999). In contrast, treating PDs entailed a two-phase ST-protocol where the patient rescripted the event after the therapist had acted as a model (Hayes & van der Wijngaart, 2020; Young et al., 2003). In both cases, the patient performs rescripting. However, in the PTSD case, the clinician only supports the patient's imagery actions through Socratic, non-directive questions, not being involved in the scene, giving the patient a maximum sense of control. In the PD case, the therapist first plays a modeling role to empower the inner child of the patient and then assists "*with the least amount of instruction possible, allowing the patient to lead the process*" (Hayes & van der Wijngaart, 2020, p. 122).

The central role played by mastering a traumatic memory is consistent with Sensorimotor and Cognitive-Evolutionary Therapies, which suggest successful action driven by one's defense motivational system to be crucial in overcoming trauma (Liotti, 2011; Ogden et al., 2006). Interestingly, explicit self-representation (definable as self-consciousness), autobiographical memory, and social emotions – such as shame and guilt – all emerge by the second year of age (Howe, 2013; Lewis, 2011; Rochat, 2018), indicating a deep connection between the explicit sense of agency, imagery ability, and the negative emotions that characterize most psychopathologies. Moreover, the acquisition of attachment dimensions in the early years supports the Schema Therapy idea that being supported by a caring/protecting figure helps develop the sense of controlling event outcomes essential in rescripting aversive memories (Gagliardi, 2021, 2022). Finally, the enhanced effect of being protagonists in the rescripting was confirmed by recent experiments, where participants were asked to rescript an aversive movie (Siegesleitner et al., 2020) or an imagined situation in which they were victims of injustice (Twardawski et al., 2021). In both cases, those who imagined changing the story themselves had more benefits than those who imagined asking someone else to do that.

On these grounds, we focus on **Active Imagery Rescripting** (AIR), which we define as the IR where the patient experiences a (higher) **sense of control** over the rescripted events. It is noteworthy that, in the standard therapy-room application, there is no contextual change compared to the non-active IR – i.e., the environment is the same. However, the procedure must include some element enabling the active feature of experiencing a sense of control. According to our definition, this feeling can be generated by both *direct or indirect action* – such as doing something, asking the therapist to do something, or simply expressing one's will for something to happen and seeing its realization in the scene – where direct action should reasonably provide the highest empowerment. Therefore, we hypothesize that the possibility to act with a sense of control in rescripting is a fundamental aspect of its success.

(F2) Memory time-location. Another relevant aspect of IR is the point in time of the rescripted event in the patient's life history. The literature suggests that the technique can be effective for early memories (childhood) but also for later ones (adolescence and adulthood). In particular, IR was shown to work with relatively recent episodes – e.g., nightmares (Albanese et al., 2022) or refugee traumas (Steel et al., 2023). This evidence is consistent with the Schema Therapy assumption that IR addresses the emotional problem underlying all the events connected by the same '*affect bridge*' – i.e., events experienced as analogous by virtue of the same affective content characterizing them (Hayes & van der Wijngaart, 2020). Moreover, it is in line with the documented efficacy of IR in treating the subclinical consequences of experimentally induced aversive memories (Siegesleitner et al., 2020; Twardawski et al., 2021). Hence, we consider the rescripting of events located at any time point in the patient's life history.

(F3) Memory implicitness. Finally, some studies may not be primarily aimed at rescripting memories but may be doing so implicitly. In other words, the object of the study may imply a memory to rescript even though the patient is not asked to evoke such a memory explicitly. This could be the case of a specific phobia or trauma – such as public speaking or a road accident, where a treatment consisting of being exposed to a scene and acting in it may imply rescripting without any specific memory being evoked explicitly.

Following these considerations, we focus on (1) AIR, where (2) any memory can be addressed (regardless of its location in the patient's life history), and (3) the rescripted memory is explicit or implicit. Given that virtual scenarios can offer the possibility to perform any necessary actions and even more than real ones, we hypothesize that implementing AIR in VR can be effective in treating psychological conditions.

2. Methods

To evaluate our hypothesis, we carried out a systematic literature search driven by the implicit question '*What studies do concern implementing AIR in VR for treating a psychological condition?*' – and extracted the pertinent data, providing an overview of the current evidence. We also performed a critical appraisal of the selected studies.

2.1. Systematic literature search

Our systematic search of the literature relied on the integrative review method, following the steps of identifying the review purpose (as

for our hypothesis), literature search, data evaluation, data analysis, and presentation (Whittemore & Knafl, 2005). This method allows for the inclusion of qualitative, quantitative, and mixed-methods studies.

2.1.1. Eligibility criteria

Our search for articles and their retrieval were guided by the inclusion criteria specified in Table 1. The table also indicates a few corresponding relevant exclusions.

The table shows the inclusion criteria and instances of relevant exclusions.

2.1.2. Search strategy and process

We started by exploring the literature through scoping searches, including any possible sources (grey and scientific literature). To ensure the inclusion of all relevant articles, we started the database search as wide as possible, narrowing it down gradually – by using available limiters and performing automatic and manual screening. Overall, our search process consisted of the following four steps: (1) Database search. (2) Automated removal. (3) Eligibility screening. (4) Eligibility assessment (using the above inclusion criteria). The process is illustrated in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram below, built in compliance with the guidelines and template provided by the PRISMA website, www.prisma-statement.org (Page et al., 2021) (Fig. 1). We finally checked our results through a few Google Scholar searches, which confirmed no relevant papers had been excluded. Next, we detail each step of the search process.

(1) Database search. On date 20 May 2023, we carried out our search using the following databases: Scopus (DB1), MEDLINE (DB2), Academic Search Premier (DB3), APA PsycInfo (DB4), CINAHL Plus (DB5), Psychology and Behavioral Sciences Collection (DB6), AMED (DB7), and APA PsycArticles (DB8). (DB2-DB8 were accessed through EBSCO, www.ebsco.com).

We employed the following search query: "virtual reality" AND ("image*" OR "rescript*" OR "public speaking" OR "game*") AND ("treatment" OR "therapy"), addressing "title, abstract, and keywords" for DB1 and all record fields for DB2-DB8 (EBSCO). The choice of a highly inclusive search query (not limited to 'virtual reality', 'imagery rescripting', and 'treatment' or 'therapy') was driven by the necessity to include possible AIR realizations labeled in different ways. In particular, for public speaking anxiety interventions and treatments through serious-games. These database searches resulted in 7840 records (3787 from Scopus and 4053 from EBSCO).

(2) Record removal and screening. The first results of 7840 records were automatically refined by excluding 4908 of them. Specifically, those:

(1) whose title included the terms "review" OR "meta-analysis" OR "survey";
(2) whose title and keywords included the terms "medic*" OR "stroke" OR "alzheimer" OR "parkinson" OR "pain" OR "cardiac" OR "vascular" OR "aneurysm" OR "artery" OR "coronary" OR "motor" OR "*scopic" OR "surgery" OR "surgical" OR "emdr" OR "rehab*" OR "educat*";
(3) which corresponded to papers (A) not in English or (B) reviews or book chapters (C) or classified as belonging to the field of Neuroscience, Biochemistry, Genetics and Molecular Biology, or Physics and Astronomy in Scopus (in this case, limiters were used);
(4) which corresponded to papers not in English or non-peer-reviewed in EBSCO (again, in this case, limiters were used).

The results were 783 records in Scopus and 1266 records in EBSCO, which automatically identified 251 duplicates (leaving 1015 EBSCO records and 1798 total records). From here, 336 additional duplicates were identified by EndNote X9 and removed. The process yielded 1462 records for manual screening. We manually and independently screened these remaining papers' titles and abstracts using the web-based application Rayyan (www.rayyan.ai). We went through all records, one by one, and excluded the papers that were undoubtedly unrelated to IR in VR applied to a psychological condition.[1] The result was the selection of

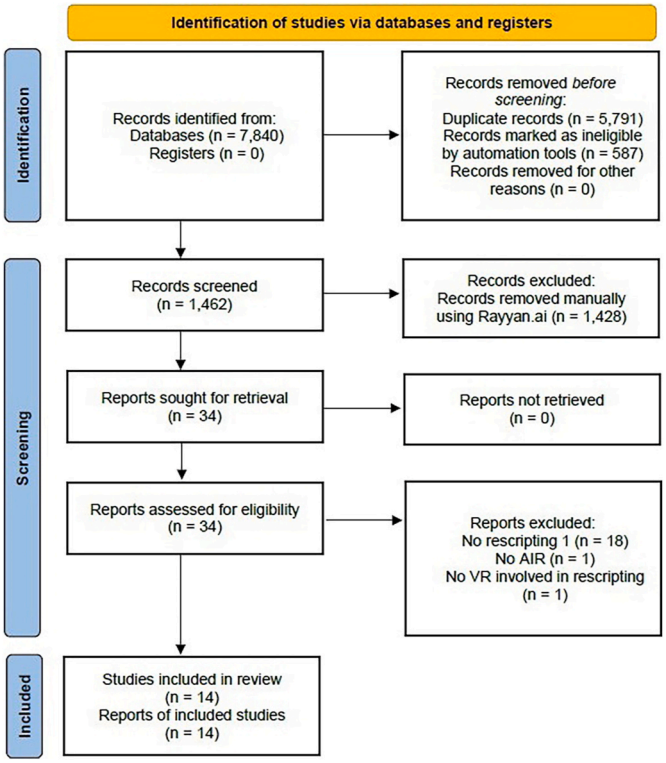

Fig. 1. PRISMA diagram for in virtuo AIR implementations.
From the initial 7840 documents, 14 articles were selected.

Table 1
Inclusion criteria.

	Inclusion Criteria	Relevant exclusions
1	Empirical study	Reviews, meta-analyses, theoretical proposals, commentaries, opinion pieces
2	Peer reviewed	Books, book chapters, theses, etc.
3	In English language	
4	Dated 1990–2023 (Search Performed May 20, 2023)	
5	IR is implemented in VR	No IR or VR not involved in IR
6	IR is used as a treatment of a psychological, non-organic disorder	Treatment of an organic disorder (e.g., autism, psychosis)
7	Exposure or other technique also implements rescripting	
8	IR is active (as define above)	IR where the participant has no sense of control in rescripting
9	IR can concern a memory located at any time	
10	IR can concern an implicit/explicit memory	

[1] At this point, we relied on human processing by reading the titles and abstracts rather than an algorithmic/filtering procedure for two main reasons: (1) Papers could omit to express explicitly a rescripting was performed, and we wanted to ensure all relevant works were included. (2) An algorithm could exclude cases we might not have considered relevant in advance. We used Rayyan to help with the organization of the records.

34 papers for further assessment.

(3) Eligibility assessment. As a final step, we assessed the content of the remaining 34 papers against the eligibility criteria. 14 articles met them and were included in the review. Among the 20 excluded, the one from van Kuik et al. (2023) deserved particular attention since it met all criteria except for the implementation of active rescripting, as we defined it. This case will be further discussed below (cf. 4).

2.2. Critical appraisal

Both authors independently reviewed the included studies using the Mixed Methods Appraisal Tool (MMAT), version 2018 (Hong et al., 2018). The MMAT first requires a study to pass a two-question screening – (1) *Are there clear research questions?* (2) *Do the collected data allow us to address the research questions?* – and then considers 5 study categories: (1) Qualitative Studies, (2) Randomized Controlled Trials, (3) Non-Randomized Studies, (4) Quantitative Descriptive Studies, and (5) Mixed Methods Studies. For each category, a set of 5 appraisal questions – with the possible answers 'Yes', 'No', 'Can't Tell' – allows a study quality to be scored (see the Appendix for the appraisal categories and questions that apply to our case).

2.3. Data extraction

Both authors independently extracted data from the included studies in the following categories: (1) Country where the study took place. (2) Condition treated. (3) Type of study. (4) Sample Composition. (5) Diagnosis criteria. (6) Treatment performed. (7) Variables taken into account. (8) Instruments used to measure variables. (9) Main Outcomes. The extracted information was summarized in the following extraction table (Table 2), built using the PICO (Problem, Intervention, Comparison, Outcomes) (Miller & Forrest, 2001; Richardson et al., 1995) review framework as a basis.

The table illustrates the data extracted from the selected articles. Studies S1-12 are divided into four categories (highlighted in different colors) depending on their focus: (1) S1-7, Public Speaking Anxiety (PSA) (light yellow). (2) S8, Nightmare Distress (light grey). (3) S9-10, Post-Traumatic Stress Disorder (PTSD) (light green). (4) S11-12, Obesity with Binge Eating Disorder (BED) (light red). The following acronyms are used: VRET (Virtual Reality Exposure Therapy), CBT (Cognitive-Behavior Therapy), CT (Cognitive Therapy), IGE (Imaginal Gradual Exposure), EGT (Exposure Group Therapy), ACET (Action-Cue Exposure Therapy), WL (Waitlist), BMI (Body-Mass Index), DSM (Diagnostic and Statistical Manual of Mental Disorders). The following abbreviations are used: Pre-T (pre-treatment), Post-T (post-treatment), m (months), y (years), F-up (follow-up).

3. Results

As to producing the results, we (1) categorized the studies into groups by psychological condition treated, (2) critically appraised them for their strengths and weaknesses., and (3) reviewed them considering AIR features F1-3, following the textual narrative synthesis approach (Lucas et al., 2007). Due to the heterogeneity across studies, a meta-analysis of quantitative data was not possible.

3.1. Categorization by psychological condition

Our search resulted in the selection of 14 articles implementing AIR for a psychological condition, targeting a memory that can be remote or recent, explicit or implicit. These papers were first divided into four groups according to the issue they address:

1. Public Speaking Anxiety (PSA): (S1) Anderson et al. (2003). (S2) Anderson et al. (2005). (S3a) Wallach et al. (2009). (S3b) Safir et al. (2011) (this study is an S3a follow-up). (S4) Wallach et al. (2011). (S5a) Anderson et al. (2013). (S5b) Anderson et al. (2016) (this study is an S5a follow-up). (S6) Nazligul et al. (2017). (S7) Premkumar et al. (2021).
2. Nightmare Distress: (S8) McNamara et al. (2018).
3. Post-Traumatic Stress Disorder (PTSD): (S9) Menelas et al. (2018). (S10) Kengne et al. (2018).
4. Obesity with Binge Eating Disorder (BED): (S11) Cesa et al. (2013). (S12) Manzoni et al. (2016).

Given that two papers (S3b and S5b) covered a long-term follow-up of a previous study (S3a and S5a, respectively), the actual number of studies was 12. Among them, there were 5 randomized control trials (RCTs), 4 feasibility studies (i.e., studies considering only a treatment group with no control), and 3 studies on single clinical cases. Different countries were represented, with four studies from the USA, two from Canada, Israel, and Italy, and one from Turkey and the UK. A total of 489 participants were involved. The publishing dates spanned from 2003 to 2021, which implied a significant range of technological performance for the employed devices (e.g., computational power, image resolution), although, in all cases, head-mounted displays were used.

3.2. Critical appraisal

To apply the Mixed Methods Appraisal Tool (MMAT), we divided the selected studies into the MMAT categories, identifying three of the five available categories: (1) Qualitative: S1, S9-10; (2) Non-Randomized: S2, S6-8; (3) RCT: S3-5, S11-12. We then rated the studies independently by answering the corresponding questions. Finally, we discussed and agreed on the appraisal values (see Table 3 for our final answers and the Appendix for the appraisal categories and questions that apply to our case).

The table shows the answers given to the MMAT appraisal questions. Studies S1–S12 are divided into three groups (highlighted in different colors) depending on the research design: (1) Qualitative: S1, S9-10 (brown). (2) Non-Randomized: S2, S6-8 (blue). (3) Randomized Control Trial (RCT): S3-5, S11-12 (yellow).

Most selected studies had high quality, with a 'yes' to every question. Most issues were found in the case studies. Overall, we could give a positive answer to 90% of the questions. It is worth noting that an essential point of our evaluation focused on how studies assessed pre- and post-treatment conditions to reach reliable results. As reported in Table 2 (instruments column), the selected studies used heterogeneous methods to assess each condition before and after the treatment. We considered each study with respect to this aspect, reaching an overall positive evaluation. In order to substantiate their conclusions, almost all studies relied on standard questionnaires. Some also offered coherent clinical explanations of the treatment effects, reinforcing the reliability of the outcomes. Five studies referred directly to the DSM (Diagnostic and Statistical Manual of Mental Disorders), the manual – published by the American Psychiatric Society (APA) – containing classification and diagnostic criteria of all mental disorders, widely considered the official reference in psychiatry and clinical psychology. In this case, instruments specifically created to assess symptoms related to the DSM criteria were used – such as the SCID (Structured Clinical Interview for the DSM) and PCL (PTSD Checklist). After examining all studies and their assessment procedures, we could reach substantial confidence in the reliability of their outcomes.

3.3. Textual narrative synthesis and grouping by sense of control

We synthesized our results and created two further groups according to the sense of control participants (presumably) felt during rescripting, which links directly to the AIR's first feature (F1). Since being able to express voluntary bodily movements is the most effective empowering element (Liotti, 2011; Ogden et al., 2006), we discriminated between these groups according to the possibility of performing physical action.

Table 2
Extraction table.

	Selected Studies									
	Study	Country	Condition Treated	Type of Study	Sample Composition	Diagnosis	Treatment	Variables	Instruments	Main Outcomes
S1	Anderson et al. (2003)	USA	Public Speaking Anxiety (PSA)	2 Case Studies	Two PSA-patients (N = 2) in private practice treated with VRET (8-month F-up, N = 1)	Social Phobia in which public speaking is the most feared stimulus according to Structured Clinical Interview for the DSM-IV (SCID)	Case Study 1: 5 Anxiety Management Sessions. 1 Speech Session. 4 VRET Sessions Case Study 2: 2 Speech Sessions. 5 VRET Sessions. 1 Review Session	- Anxiety -Performance	(1) Personal Report of Confidence as a Speaker (PRCS). (2) Self-Statements During Public Speaking (SSPS). (3) State-Trait Anxiety Inventory (STAY). (4) Beck Depression Inventory (BDI). (5) Clinical Global Improvement Scale (CGI) Patient Report. (6) Presence Questionnaire (PQ). (7) Immersion Questionnaire (IQ). (8) Subjective Units of Distress Scale (SUDS). (9) Behavioral Avoidance Test (BAT) (self and audience speech-scoring of level of anxiety and performance)	Reduction of Anxiety (PRCS, SSPS, SUDS) (STAY relatively stable)
S2	Anderson et al. (2005)	USA	Public Speaking Anxiety (PSA)	Feasibility Study	A single group of PSA-participants (N = 10) treated with VRET (3-month F-up, N = 8)	Social Phobia or Panic Disorder with Agoraphobia in which public speaking is the most feared stimulus according to Structured Clinical Interview for the DSM-IV (SCID)	4 Anxiety Management Sessions 4 VRET Sessions	-Anxiety -Performance	(1) Personal Report of Confidence as a Speaker (PRCS). (2) Personal Report of Communication Apprehension. (3) Self-Statements During Public Speaking (SSPS). (4) Clinical Global Improvement–Patient Rating scale. (5) Behavioral Avoidance Test (BAT) (audience speech-scoring of level of anxiety and performance)	- Reduction of Anxiety (all instruments) - Improvement of Performance [Post-T & 3m-F-up]
S3	(a) Wallach et al. (2009) (b) Safir et al. (2011)	Israel	Public Speaking Anxiety (PSA)	Randomized Controlled Trial (RCT)	PSA-participants divided into: - CBT + VRET (C1) (N = 28) - CBT + IGE (C2) (N = 30) - Control (WL) (N = 30) (12-month F-up, C1 N = 25, C2 N = 24)	Social Phobia with Specific PSA (self-reported, no diagnosis)	C1: 12 sessions (4 CBT 1h Sessions + 8 VRET 1h Sessions) C2: 12 Sessions (4 CBT 1h Sessions + 8 IGE 1h Sessions)	-Anxiety -Performance	(1) Liebowitz Social Anxiety scale (LSAS). (2) Self-statements during public speaking (SSPS). (3) Fear of negative evaluation (FNE). (4) Behavioral task (BT) (scores from audience and participants on 10 anxiety indicators)	CBT-VRET & CBT + IGE are (equally) effective in reducing anxiety: CBT-VRET Post-T: Reduction of Anxiety (LSAS fear, LSAS avoidance, SSPS positive, SSPS negative, BT self-rating) – Remission on LSAS avoidance, SSPS positive, SSPS negative Post-T-to-F-up: No Difference (LSAS fear, LSAS avoidance, SSPS positive, SSPS negative) (CBT + IGE improved in LSAS fear)
S4	Wallach et al. (2011)	Israel	Public Speaking Anxiety (PSA)	Randomized Controlled Trial (RCT)	PSA-participants divided into: - VRET (C1) (N = 10) - CT (C2) (N = 10) Considering: - CBT + IGE (C3) (N = 30) - Control (WL) (N = 30) from S3	Social Phobia with Specific PSA (self-reported, no diagnosis)	C1: 12 Sessions (VRET only) C2: 12 Sessions C3: 12 Sessions	-Anxiety	(1) Liebowitz Social Anxiety scale (LSAS). (2) Self-statements during public speaking (SSPS). (3) Fear of negative evaluation (FNE). (4) Behavioral task (BT) (scores from audience and participants on 10 anxiety indicators)	VRET & CT are (equally) effective in reducing anxiety (and equally effective to CBT + IGE (S3) Post-T: CT not superior to VRET on cognitive measures

(*continued on next page*)

Table 2 (*continued*)

	Selected Studies									
	Study	Country	Condition Treated	Type of Study	Sample Composition	Diagnosis	Treatment	Variables	Instruments	Main Outcomes
S5	(a) Anderson et al. (2013) (b) Anderson et al. (2016)	USA	Public Speaking Anxiety (PSA)	Randomized Controlled Trial (RCT)	PSA-participants divided into: - VRET (C1) (N = 32) - In Vivo EGT (C2) (N = 33) - Control (WL) (N = 25) (3-month F-up, C1 N = 29, C2 N = 27) (12-month F-up, C1 N = 26, C2 N = 24) (6-year F-up, C1 N = 13, C2 N = 15)	Social Phobia in which public speaking is the most feared stimulus according to Structured Clinical Interview for the DSM-IV (SCID)	C1: 8 Sessions (4 Anxiety Management Sessions + 4 30-min VRET Sessions) EGT: 8 Sessions (Anxiety Management Sessions + 6 20-min exposure trials)	-Anxiety -Performance	(1) SCID for Anxiety. (2) Personal Report of Confidence as a Speaker (PRCS). (3) Fear of Negative valuation—Brief Form (FNE-B). (4) Behavioral Avoidance Test (BAT) (audience speech-scoring of level of anxiety and performance). (5) Clinician Global Impressions of Improvement (CGI). (6) Expectancy for treatment outcome. (7) Working Alliance Inventory—Short Form (WAI-SF). (8) Homework compliance. (9) Client Satisfaction Questionnaire (CSQ-8). (10) Patient Global Improvement (PGI) (at 6y-follow-up)	VRET is effective in reducing PSA in Social Phobia (self-report on PSA, speech at Post-T, 3m-1y-6y-F-up): 3m F-up: VRET: 63% Social Phobia partial or full remission Post-T & 3m-1y-F-up: no significant difference VRET-EGT (PRCS, FNE-B)
S6	Nazligul et al. (2017)	Turkey	Public Speaking Anxiety (PSA)	Feasibility Study	A single group of PSA-participants (N = 6) treated with VRET	Social Phobia according to Liebowitz Social Anxiety Scale (LSAS)	1 Psychoeducation Session (in vivo) 1 VR Session	-Anxiety	(1) Liebowitz Social Anxiety Scale (LSAS). (2) Subjective Units of Distress Scale (SUDS). (3) Interaction Anxiousness Scale (IAS)	- Reduction of Anxiety [Post-T]
S7	Premkumar et al. (2021)	UK	Public Speaking Anxiety (PSA)	Feasibility Study	A single group of PSA-participants (N = 27) treated with VRET (1-month F-up, N = 21)	Self-reported sub-clinical high PSA	2 VRET Sessions	-Anxiety -Fear of negative evaluation	(1) Speech Anxiety Thoughts Inventory (SATI). (2) Public Speaking Anxiety Scale (PSAS). (3) Personal Report of Confidence as a Speaker—Short Form (PRCS-SF). (4) Liebowitz Social Anxiety Scale (LSAS). (5) Brief Fear of Negative Evaluation Revised Scale (BFNE-RS). (6) Subjective Units of Distress Scale (SUDS)	- Reduction of Anxiety - Reduction of Fear of Negative Evaluation [Post-T & 1m F-up]
S8	McNamara et al. (2018)	USA	Nightmare Distress	Feasibility Study	A single group of participants (N = 19) suffering from *nightmare distress* treated in VR (*ReScript*)	Self-reported Nightmare Distress	8 VR *ReScript* Sessions	-Anxiety -Nightmare Distress -Daytime Nightmare Effects -Nightmare Frequency	(1) Nightmare Distress Questionnaire (NDQ).(2) Nightmare Frequency Questionnaire (NFQ). (3) Nightmare Effects Questionnaire (NEQ). (4) Suicide Risk Scale (SRS). (5) Suicidal Behavior Questionnaire (SBQ). (6) Depression, Anxiety and Stress Scale (DASS). (7) PTSD Checklist (PCL-C) - Civilian Version. (8) Cambridge Depersonalization Disorder Questionnaire (CDDQ). (9) Nightmare Daytime Effects Survey (NDES). (10) Kennedy Simulator Sickness Questionnaire (SSQ)	Reduction of: - Anxiety (DASS) - Nightmare Distress - Daytime Nightmare Effects - Nightmare Frequency
S9	Menelas et al. (2018)	Canada	Post-Traumatic Stress Disorder (PTSD)	2 Case Studies	Two truck drivers (N = 2) suffering from PTSD treated with a serious game therapy (ACET)	PTSD due to road accident assessed through PTSD Checklist for DSM-5 (PCL-5)	8 VR ACET Sessions	-PTSD symptoms -Patient reactions during therapy and reports of his life	(1) PTSD Checklist for DSM-5 (PCL-5). (2) Qualitative measure of patient's reactions during therapy and reports of their life	Desensitization and verbalization of fears associated with trauma (Pre-Post-T PCL-5 scores are not reported)

(*continued on next page*)

Table 2 (*continued*)

	Selected Studies									
	Study	Country	Condition Treated	Type of Study	Sample Composition	Diagnosis	Treatment	Variables	Instruments	Main Outcomes
S10	Kengne et al. (2018)	Canada	Post-Traumatic Stress Disorder (PTSD)	1 Case Study	One truck driver (N = 1) suffering from PTSD treated with a serious game therapy (ACET)	PTSD due to road accident	8 VR ACET Session	-PTSD symptoms -Patient reactions during therapy and reports of his life	Qualitative measure of patient's reactions during therapy and reports of their life	The patient became present and active in the virtual scene and his life (he could move on and take control of his life again)
S11	Cesa et al. (2013)	Italy	Obesity with Binge Eating Disorder (BED)	Randomized Controlled Trial (RCT)	Obese patient suffering from BED divided into: - Inpatient Treatment (IP) (N = 19) - IP + CBT (C1) (N = 20) - IP + ECT (C2) (N = 27) (12-month F-up, IP N = 12, C1 N = 14, C2 N = 18)	Obesity with Binge Eating Disorder (BED) according to DSM-IV-TR (BMI>40)	C1: 15 sessions (5 weekly group sessions + 10 biweekly individual sessions) C2: 15 Sessions (5 weekly group sessions + 10 biweekly individual VR sessions)	-Weight -Number of Binge Eating Episodes (in previous month) -Body Satisfaction	(1) Weight. (2) Number of Binge Eating Episodes. (3) Body Satisfaction Scale (BSS) (*). (4) Body Image Avoidance Questionnaire (BIAQ) (*). (5) Contour Drawing Rating Scale (CDRS) (*) (*) Not measured at F-up	ECT is effective in: Reducing Weight; Reducing Binge Eating Episodes; Improving Body Satisfaction (at Post-T & F-up) Comparison ECT-BCT-IP at Post-T: All groups improved on Weight, Binge Eating Episodes, Body Satisfaction Weight: no significant differences between groups at Pre-T, but only ECT and CBT maintained improvement at F-up
S12	Manzoni et al. (2016)	Italy	Obesity with Binge Eating Disorder (BED)	Randomized Controlled Trial (RCT)	Obese patient suffering from BED divided into: - Inpatient Treatment (IP) (N = 50) - IP + CBT (C1) (N = 52) - IP + ECT (C2) (N = 56) (12-month F-up, IP N = 29, C1 N = 38, C2 N = 46)	Obesity with Binge Eating Disorder (BED) (BMI>40)	C1: 15 sessions (5 weekly group sessions + 10 biweekly individual sessions) C2: 15 Sessions (5 weekly group sessions + 10 biweekly individual VR sessions)	Weight	(1) Weight. (2) Body Satisfaction Scale (BSS) (*). (3) Body Image Avoidance Questionnaire (BIAQ) (*). (4) Contour Drawing Rating Scale (CDRS) (*) (*) Measures not reported	ECT is effective in: Reducing Weight (at Post-T & F-up) Comparison ECT-BCT-IP: Weight: (1) All groups improved at Post-T (with no significant differences) (2) ECT maintained improvement at F-up

Table 3
Selected studies: MMAT Table.

	Selected Studies – MMAT Table					
Study	Category	Q1	Q2	Q3	Q4	Q5
S1	Qualitative	Yes	Yes	Yes	Yes	Yes
S2	Non-Randomized	Yes	Yes	Yes	Yes	Yes
S3	RCT	Yes	Yes	Yes	Yes	Yes
S4	RCT	Yes	Yes	No	Yes	Yes
S5	RCT	Yes	Yes	Yes	Yes	Yes
S6	Non-Randomized	Yes	Yes	No	Yes	Yes
S7	Non-Randomized	Yes	Yes	Yes	Yes	Yes
S8	Non-Randomized	Yes	Yes	Yes	Yes	Yes
S9	Qualitative	Yes	Yes	No	No	Yes
S10	Qualitative	Yes	Yes	Yes	No	Yes
S11	RCT	Yes	Yes	Yes	Yes	Yes
S12	RCT	Yes	Yes	No	Yes	Yes

We only grouped results by this feature, as by the other ones (F2, F3), they were not separable.[2]

3.3.1. Group 1 – direct sense of control

The studies in this first group (S7-10) allowed patients to act in the rescripting and self-manage the level of exposure to the aversive stimuli, thereby allowing for a higher degree of control (see Table 2). The salient features of these studies can be summarized as follows:

S7. Premkumar et al. (2021) treated a single group of PSA-participants (N = 27) with VRET. They self-reported sub-clinical high PSA. They only had 2 VRET sessions to give a 20-min speech in a virtual classroom. But they could autonomously manipulate both audience features and own salience at 4-min intervals. A follow-up was realized after 1 month (N = 21). Data analysis showed reduction of anxiety and fear of negative evaluation at both post-treatment and follow-up.

S8. McNamara et al. (2018) used VR to treat participants suffering from self-reported 'nightmare distress' (N = 19). They had 8 VR *ReScript* sessions (2 sessions per week for 4 weeks), each consecutively presenting three nightmare images embedded in the VR application. They used manual controls to manipulate the pictures and then described in writing the result, finally rehearsing what they wrote. Self-report results showed a reduction in anxiety, nightmare distress, daytime nightmare effects, and nightmare frequency.

S9. Menelas et al. (2018) presented two case studies of truck drivers suffering from PTSD following a road accident. The disorder was assessed through the PTSD Checklist for DSM-5 (PCL-5) (Blevins et al., 2015). The authors developed a specific VR truck-driving simulator – a serious game reproducing driving a truck (using a wheel, gears, and pedals) in realistic conditions – and applied what they termed Action-Centered Exposure Therapy (ACET). ACET consisted of 8 VR sessions of gradual, active, indirect exposure to the patient's accident scene through the truck-driving simulator, allowing patients to gradually learn how to face their traumatic memories and overcome trauma.

S10. Kengne et al. (2018) presented a single case study of a truck driver suffering from PTSD. Treatment was carried out using the same VR truck-driving simulator as in S9 and applying the same ACET. The authors reported that the patient became present and active in the virtual scene and his life. He could move on and take control of his life again.

Whilst the first two studies (S7, S8) had a stronger study design, the others (S9, S10) can only be seen as indicative of our argument as they presented a small number of clinical cases.

3.3.2. Group 2 – indirect sense of control

In the second group of studies (S1-6, S11-12), the therapist was more involved in the rescripting process, empowering the patient by acting in accordance with them – which corresponds to a lower degree of control (see Table 2). These studies' relevant characteristics can be summarized as follows:

S1. Anderson et al. (2003) reported about two patients (P1, P2) with PSA who were treated with VRET in private practice. Patients were diagnosed with Social Phobia (in which public speaking was the most feared stimulus) using the DSM-IV SCID (First et al., 1996). P1 underwent 5 anxiety management sessions, 1 speech session, and 4 VRET sessions. On the other hand, P2 only had 2 speech sessions, 5 VRET sessions, and a final review session. VRET consisted of giving a speech from a podium in a virtual classroom with an audience of 5 individuals. The therapist manipulated the audience according to the gradual exposure decided with the patient, encouraged exposure, and directed and assisted the patient. After treatment, anxiety was overall reduced.

S2. Anderson et al. (2005) treated with VRET a single group of PSA-participants (N = 10) diagnosed with Social Phobia or Panic Disorder with Agoraphobia (in which public speaking was the most feared stimulus) using the DSM-IV SCID (First et al., 1996). They had 4 anxiety management sessions and 4 VRET sessions. Treatment in VR consisted of giving a speech at a virtual conference table or in an auditorium. Again, the therapist manipulated the audience according to the gradual exposure decided with the patient and encouraged exposure. Treatment resulted in a reduction of anxiety and improvement of performance at both post-treatment and 3-month follow-up.

S3. Wallach et al. (2009) treated participants with PSA for 12 sessions, dividing them into two groups/conditions – CBT + VRET (C1, N = 28) and CBT + IGE (Imaginal Gradual Exposure) (C2, N = 30) – and a waitlist control (WL, N = 30). They self-reported Social Phobia with specific PSA (without receiving a formal diagnosis). The VR treatment comprised 8 1-h VRET sessions, in which the patient could give a speech/lecture from a podium in front of a large, virtual audience. The therapist manipulated the audience according to the gradual exposure decided with the patient and discussed the outcomes with the patient. CBT + VRET and CBT + IGE resulted to be (equally) effective in reducing anxiety.

S4. As in S3, Wallach et al. (2011) divided participants with PSA into two groups/conditions – CBT + VRET (C1, N = 10) and CT (Cognitive Therapy) (C2, N = 10) – and treated them for 12 sessions. They self-reported Social Phobia with specific PSA (without receiving a formal diagnosis). These groups were additionally compared to the CBT + IGE group (C3, N = 30) and waitlist control (WL, N = 30) from S3. Patients in C1 had 12 1h VRET sessions to give a speech/lecture from a podium in front of a large, virtual audience. Again, the therapist manipulated the audience according to the gradual exposure decided with the patient and discussed the outcomes with the patient. VRET and CT were (equally) effective in reducing anxiety – and as effective as CBT + IGE from S3.

S5. Anderson et al. (2013) divided PSA-participants into two groups/conditions – VRET (C1, N = 32) and in vivo EGT (Exposure Group Therapy) (C2, N = 33) – and a waitlist control (WL, N = 25) and treated them for 8 sessions. Patients were diagnosed with Social Phobia (in which public speaking was the most feared stimulus) using the DSM-IV SCID (First et al., 1996). VRET was in 4 sessions, with the task to give an up to 30-min speech in a virtual conference room, classroom, or auditorium (120 min overall). As with previous studies, the therapist manipulated the audience according to the gradual exposure decided with the patient and encouraged exposure. VRET was effective in reducing PSA, producing 63% Social Phobia partial or full remission at 3-month follow-up. No differences were found between VRET and EGT at post-treatment and follow-ups in confidence as a speaker and fear of negative evaluation.

[2] The following acronyms are used: VRET (Virtual Reality Exposure Therapy), CBT (Cognitive-Behavior Therapy), CT (Cognitive Therapy), IGE (Imaginal Gradual Exposure), EGT (Exposure Group Therapy), ACET (Action-Cue Exposure Therapy), WL (Waitlist), DSM (Diagnostic and Statistical Manual of Mental Disorders), SCID (Structured Clinical Interview for the DSM), PCL (PTSD Checklist).

S6. Nazligul et al. (2017) treated a single group of PSA-participants (junior software engineers) (N = 6) with VRET. They were diagnosed with Social Phobia according to the Liebowitz Social Anxiety Scale (LSAS) (Liebowitz, 1987). They had 1 psychoeducation session and 1 VR session in which they gave a 35-40-min speech on one or more of 3 controversial topics in a virtual classroom. Again, the therapist manipulated audience features according to the gradual exposure decided with the patient. Anxiety was reported to be reduced at post-treatment.

S11. Cesa et al. (2013) treated three groups of patients with obesity and BED, all undergoing a 6-week Inpatient Treatment (baseline: IP, N = 19). Diagnoses were given according to the DSM-IV-TR. To test the efficacy of their VR-Enhanced CBT (ECT), during the IP period, two of the three groups received an additional 5-week treatment in 15 sessions, instantiating the two conditions: (C1) IP + CBT (N = 20) and (C2) IP + ECT (N = 27). Additional treatment consisted of 5 weekly group and 10 biweekly individual sessions. In the C2 individual sessions, patients had a 1-h VR treatment using triggering virtual scenarios from a set of 14 available. In these scenarios, patients practiced skills to manage an experienced critical situation related to their body image and rescripted it guided by the therapist. ECT resulted effective in reducing weight, binge eating episodes, and improving body satisfaction (at post-treatment and follow-up). At post-treatment, all groups improved on all variables. In terms of weight, there were no significant differences between groups, but only ECT and CBT maintained their improvements at follow-up.

S12. Manzoni et al. (2016) threated patients with obesity with BED, following the same lines as in S11. VR-Enhanced CBT (ECT) was tested considering a baseline Inpatient Treatment (IP, N = 50), IP + CBT (C1, N = 52) and IP + ECT (C2, N = 56) (with additional 15 sessions in 5 weeks). Patients were immersed in VR scenarios representing experienced critical situations related to their body image and rescripted them guided by the therapist. Results showed that all groups improved weight at post-treatment (with no significant differences). But only IP + CBT and IP + ECT kept their positive change, with IP + ECT being more effective than IP + CBT in maintaining it.

Most of these studies (S3-5, S11-12) were RCTs with comparatively large sample sizes. S2 and S6 were not randomized with small sample sizes, limiting their generalizability.

3.4. Environmental features and interaction

Finally, we consider in more detail the VR experience offered in each study, as expressed by the features of the scenario and how users can interact with it. In the case of a treatment, these elements – especially the visual ones – can determine clinical success or failure, making it crucial to maximize the quality of the experience given the resources available. In all our studies, patients were endowed with VR headsets, which allowed indirect control of the environment through audio communication with the therapist. To examine the specific scenario configurations adopted and interaction options offered, we can refer to the four groups we identified regarding the issue addressed: (1) PSA (S1-7), (2) Nightmare Distress (S8), (3) PTSD (S9-10), and (4) BED (S11-12) (cf. 3.1).

3.4.1. VR set-ups for treatment of public speaking anxiety (PSA)

(1) Treatment of anxiety for speaking in public always included a virtual space where the patient could give a talk in front of an audience from a virtual podium, which could display speech notes. Since the objective was to let the patient speak, no further interaction with the environment was usually implemented. In the early studies by Anderson et al. (2003; 2005) (S1-2), the virtual space was a conference room or a small auditorium (5 and 22 audience members, respectively), and the audience was reproduced by a video of real people embedded in the virtual scenario (the first study only used the conference room). The later work by Anderson et al. (2013) (S5) included more possible scenarios – a virtual conference room, a virtual classroom, and a virtual auditorium (5, 35, and 100 audience members, respectively). The patient could interact with the scene through a manual control for scrolling their speech notes. While these authors focused more on clinical aspects, Wallach et al. (2009; 2011) (S3-4) described their technical setup in detail, specifying patients used a VFX3D headset. The scenes were purchased from a specialized company, which ensured the required quality and functionality, but no details were given about their specific features, except for including a large audience. The only interaction allowed seemed to be through the headset. In Nazligul et al.'s study (2017) (S6), participants were university students. They wore an Oculus RIFT headset, and the scenario was a university classroom modeled on what participants were used to. Audience members could be up to 32, were randomly located, and could vary in terms of sex (male, female), clothing (formal, informal), and activity (e.g., using their phone, talking, asking a question). Similarly, Premkumar et al. (2021) (S7) recruited university students and adopted a classroom scenario. This time, participants were given a Samsung Gear VR headset housing a Samsung Galaxy S7 smartphone for visualization. However, contrary to all other PSA studies, this one implemented self-guided exposure. In a speech session, participants had a few 1-min breaks during which a menu appeared, allowing them to change five features of the environment: (a) Number of audience members (6, 12, or 20). (b) Type of audience reaction. (c) Distance from the audience. (d) Number of prompts shown in a slide (which the participant could also scroll using the headset controls). (e) Salience of self (letting a room wall display their picture, a silhouette, or no image).

3.4.2. VR set-ups for treatment of nightmare distress

The study by McNamara et al. (2018) on nightmare distress (S8) had a minimal design. Patients wore an Oculus headset and manual controls, which immersed them into a room where a threatening image was reproduced three-dimensionally. They could turn their head to exclude the image from their view or manipulate it using the controls.

3.4.3. VR set-ups for treatment of post-traumatic stress disorder (PTSD) (truck-driving)

On the contrary, Menelas et al.'s (2018) and Kengne et al.'s (2018) studies on PTSD (S9-10) had a more complex gaming design consisting of a realistic truck-driving simulator controllable through a wheel, gears, and pedals. The environment – developed using the professional software Unreal Engine 4 – was randomly populated by typical road elements – such as signs, vehicles, buildings, etc.) – and animated by random events – such as cars passing by or having an accident. Weather and time could also be controlled, producing a highly immersive experience.

3.4.4. VR set-ups for treatment of Binge Eating Disorder (BED)

Finally, the studies on BED by Cesa et al. (2013) and Manzoni et al. (2016) (S11-12) relied on the NeuroVR 2 open-source software, which provided a set of 14 customizable scenarios related to the eating disorder (e.g., a restaurant, a pub, and a gym). The patients could re-experience a problematic social situation by adopting either the first (themselves) or a third-person perspective (observing themselves). No details were given about any other possible interaction.

This overview clarifies the wide range of implementation options characterizing the examined studies. The authors did not measure participants' attitudes towards or familiarity with VR use. They also did not carry out a formal evaluation of the VR experience offered to the patients, but the positive therapeutic outcomes confirmed its adequacy. Finally, it is worth noting that none of the studies compared real memories with virtually reproduced ones – which is consistent with most of them not being designed to implement a form of memory rescripting in VR.

4. Discussion

In this work, we hypothesize that implementing AIR in VR can be effective in treating psychological conditions and provide a preliminary evaluation of this hypothesis supported by the available literature. Through a systematic search, we selected 14 articles – corresponding to 12 different studies – which we then divided into four groups according to the targeted disorder: (1) Public Speaking Anxiety (PSA). (2) Nightmare Distress. (3) Post-Traumatic Stress Disorder (PTSD). (4) Obesity with Binge Eating Disorder (BED). Furthermore, we synthesized the studies by the degree of control exerted by the patient during rescripting – either direct or indirect sense of control. The quality of the studies was sufficient to provide reliable data. This evaluation process confirmed our hypothesis, suggesting that future research should address its testing.

As our results show (cf. 3.3, Table 2), the reviewed studies relied on the well-established Cognitive Behavioral Therapy (CBT) (Beck, 2020; Beck & Fleming, 2021) as a general reference framework – implementing some form of Virtual Reality Exposure Therapy (VRET) (Lindner, 2021) – and many compared their VR treatment to a specific in-person CBT instantiation – such as individual Cognitive Therapy (CT) or Group CBT (GCBT). All studies reported the successful therapeutic application of VR-AIR to the psychological condition addressed, and those which made a comparison demonstrated that the in virtuo implementation was as effective – and sometimes even more – than the in vivo CBT reference.

Nonetheless, we had to verify the selected works' implemented treatments met our definition of AIR. Overall, they propose four different rescripting scenarios: (1) A public speaking room. (2) A space where to manipulate an image. (3) A truck driving simulator. And (4) a life situation to re-experience one's body image from different perspectives. In most cases, treatments did not explicitly aim to rescript a memory – as referring to *Exposure Therapy* often suggested. Therefore, our primary concern was to ensure a memory was actually rescripted (we set no requirements on the memory time location and explicitness). To guarantee that, we excluded treatments for disorders not implying a specific situation (generic anxiety, for example) or where that situation was not rescripted (as in the case of facing a related but possibly new task). Moreover, we wanted the participant to be the active *rescriptor*. All studies met these two essential requirements – (a) re-experiencing a memory (b) in an active way – depending on the issue they addressed and the treatment design they adopted:

(1) Since verbal communication in a social context is a primary human activity, public speaking (S1-7) was the only anxiety-related case reasonably meeting the requirement of rescripting a memory of a similar situation (Thunnissen et al., 2022). Giving a speech in front of a virtual audience ensured the participant acted and had a sense of control, which was enhanced by agreeing with the therapist on the anxiogenic level of the stimulus to be progressively exposed to. In one case, the authors implemented a completely self-guided exposure, considering it a particularly effective healing factor (S7) (*direct sense of control*).
(2) The only study on nightmare distress (S8) was purposely about rescripting threatening images, with a strong, active component both manual – when the participant modified an image – and verbal – when they reprocessed their changes linguistically (*direct sense of control*). In this case, the connection with a memory relied on the emotional content shared by one's nightmare and the modified image (Demblon & D'Argembeau, 2016). In fact, the dimension of power-powerlessness can also work as a memory trigger (Liotti, 2011; Ogden et al., 2006). The study did not clarify if – and to what extent – the participants could select images matching the visual contents of their nightmares.
(3) The two studies about PTSD (S9-10) specifically addressed trauma resulting from a road accident while driving a truck, thereby ensuring referring to a memory. Using the wheel, gears, and pedals reasonably contributed to a higher bodily immersion into the scene. Overall, the truck driving simulator made action and a sense of control an inherent part of rescripting, which was – again – regarded as an essential component of the healing process by the authors (*direct sense of control*).
(4) Finally, the studies concerning obesity and binge eating (S11-12) used VR to let the participant look at themselves from different viewpoints (one's body location and an external position) to re-experience and rescript critical situations related to their body image.

In all these studies, the participant's sense of control was an essential therapeutic component. Some authors explicitly emphasized the importance of being active protagonists in the treatment (S7-10). We agree with them and believe the positive results reported by the reviewed studies corroborate this position. We also argue that, with more research in the area and advances in technology, the VR implementation can enhance the sense of direct control for the patient – allowing for increased involvement of the body – which we expect to be even more beneficial in empowering them (Liotti, 2011; Ogden et al., 2006). In this regard, emerging VR devices, such as motion- and biometry-capturing and haptic suits and gloves, may play a major role.

Interestingly, the study from van Kuik et al. (2023) – explicitly aimed to implement IR in VR to treat PTSD from childhood sexual abuse – was excluded from our selection for not meeting the requirement of active rescripting. Despite the quality of this work, we believe at least two implementation constraints prevented participants from experiencing a sufficient sense of control. The first was their physical impairment: "*Patients were unable to move around the world by themselves, instead their avatars were directed through the virtual world by the therapist or research assistant scene by scene*" (van Kuik et al., 2023, p. 75). The second was that scenarios had to be prepared in advance, making it impossible for the patient to perform a rescripting incompatible with the predefined contexts, additionally limiting their sense of control. In line with our hypothesis, we suggest these implementation constraints may have significantly undermined the efficacy of the treatment.

A significant advantage of the VR-implemented AIR is the possibility of delivering treatments remotely via telehealth. The constant technological improvements and increasing affordability of VR headsets lead us to expect that – in the near future – VR therapies will be delivered online. On the other hand, although most therapists value telehealth (AlRasheed et al., 2022; Thomas et al., 2021), some do not consider it a valid alternative to in-person treatment, often for the lack of direct and comprehensive human interaction, limiting non-verbal communication. Moreover, using digital technology requires the therapist to acquire adequate skills. This additional requisite may also discourage the use of VR. Nonetheless, we can expect technological advancement will make the remote experience more and more immersive and these issues progressively less significant.

Using VR in mental health also implies possible adverse effects – such as cybersickness (i.e., unpleasant physical effects like nausea or dizziness) or symptom deterioration. As Lundin et al. (2023) found in their systematic review, these effects are usually not reported (of the 73 studies examined, 45 did not mention them at all). Our study confirms this finding, given that only one study out of 12 (S8) used a self-report (the Kennedy Simulator Sickness Questionnaire, SSQ) to measure VR adverse effects. To our knowledge, no negative consequences of in vivo AIR have been reported. However, since VR treatments are still relatively new, it is noteworthy that the *in virtuo* implementation of AIR might have unintended effects. In particular: (1) VR can stimulate uncomfortable bodily and psychological reactions (e.g., cybersickness), which may affect the memory to be rescripted, exacerbating the related distress. Only patients who feel entirely comfortable with VR technology should access this treatment. Yet, recent technological developments have considerably improved the headset experience, minimizing some physical side effects. (2) The VR scenario used for the rescripting may

not correspond enough to the memory to be rescripted, possibly generating an additional negative memory similar to the original one. The degree of closeness between the memory and its VR representation should be carefully discussed with the patient before starting the process. (3) The interaction and communication between the therapist and the patient may appear unnatural in the virtual world and create difficulties that in an imagined scene would not be present. In particular, the VR equipment (e.g., headsets and manual controls) may be a barrier between the two. Such possible misattunement and its effects should be considered when implementing the scenario, and more research is needed to explore these issues. (4) Finally, the VR application – as any technology – could malfunction, forcing the treatment to be interrupted before completion, possibly leaving the patient with a feeling of uncertainty or arousal. The therapist needs to make the patient aware of this possibility and be prepared to work with the patient from where the rescripting had stopped to ensure the patient's sense of safety and control.

We also want to emphasize that VR therapy involves ethical issues analogous to those concerning its in vivo counterpart (Yellowlees et al., 2012). In particular, the technological infrastructure supporting treatment delivery must ensure confidentiality and safety – e.g., when relying on a cloud service to provide therapy or to keep clinical records. Moreover, virtual scenarios and their functionalities require careful evaluation before being employed for therapy, and clinicians must be trained for their use. When treating public speaking anxiety, for example, some features of a large audience – such as the possibility of expressing negative emotions – may cause reactions in a patient difficult to manage for the therapist. In each case, it also needs to be established if the VR treatment has to be preferred over the in vivo one and to clarify the possible ethical implications of this decision. Technology is evolving and, with it, opportunities and risks, as well as related social norms and ethical judgment.

In conclusion, the selected studies corroborate our proposition that implementing active rescripting in virtual reality can be an additional effective tool to treat mental conditions. But – given its limitations – our analysis should be regarded only as a preliminary evaluation. In the following section, we discuss these limits and suggest a few lines for further research.

4.1. Limitations and future work

Although the extant literature supports our hypothesis, our analysis was limited by at least three relevant factors: (1) The selected studies are modest in number and almost all from Western Countries. (2) They often include small samples and mostly have higher socioeconomic status white participants. (3) They are heterogeneous and usually not aimed to rescript a memory actively.

(1) Although its performance and affordability have rapidly increased in the last decade, VR is a relatively new technology. As a result, not many studies have been dedicated to IR until now. Moreover, the studies we selected were almost all realized in Western countries. More studies, including a broader range of cultures, are required to address psychological conditions through VR-AIR. We can expect their number will significantly increase in the years to come, allowing for the ultimate testing of our hypothesis.

(2) Several studies had small sample sizes, and most had higher socioeconomic status white participants – which may imply a particular attitude towards VR technology and treatment. Future studies should be more comprehensive to ensure the generalizability of results to the entire population.

(3) Finally, given the scarcity of studies explicitly aimed at implementing IR – and especially AIR – in VR, we had to search for those implicitly fulfilling these requirements. The result was 12 studies (14 articles) divided into four categories, with significant differences in research background, focus (PSA, nightmare distress, truck driving PTSD, obesity with BED), and implementation techniques (*direct/indirect sense of control*), reducing the possibility of comparing results and drawing conclusions. A more homogeneous study set will allow for systematic reviews and meta-analyses. Future studies should address a specific problem, allowing for building scenarios close enough to one's experience to make them an evocation of the past (as in S11-12, for example). Moreover, the active part of rescripting should be explicitly included in the design and carefully implemented. With our current research program, we are pursuing these objectives by targeting eating disorders and implementing a set of customizable scenes related to these issues.

5. Conclusions

In the last two decades, imaginary rescripting has been consistently successfully applied to the treatment of a variety of mental disorders in face-to-face therapeutic settings. In particular, the (more) active form of this technique seems to be especially beneficial for the patient. On the other hand, virtual reality has significantly improved in performance and affordability, making its use in clinical psychology more and more appealing. In this work, we (1) hypothesized that implementing active imagery rescripting in virtual reality can be effective in treating psychological conditions and (2) provided a preliminary evaluation of this hypothesis through a systematic search and discussion. The set of studies we identified supported our proposition, but their heterogeneity and features only allow us to encourage further testing.

Conflict of interest

None.

CRediT authorship contribution statement

Marcantonio Gagliardi: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Marianne Markowski:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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Appendix

Mixed Methods Appraisal Tool (MMAT) appraisal questions for qualitative studies, randomized controlled trials, and non-randomized studies:

MMAT Questions					
Category	Q1	Q2	Q3	Q4	Q5
Qualitative	Is the qualitative approach appropriate to answer the research question?	Are the qualitative data collection methods adequate to address the research question?	Are the findings adequately derived from the data?	Is the interpretation of results sufficiently substantiated by data?	Is there coherence between qualitative data sources, collection, analysis and interpretation?
RCT	Is randomization appropriately performed?	Are the groups comparable at baseline?	Are there complete outcome data?	Are outcome assessors blinded to the intervention provided?	Did the participants adhere to the assigned intervention?
Non-Randomized	Are the participants representative of the target population?	Are measurements appropriate regarding both the outcome and intervention (or exposure)?	Are there complete outcome data?	Are the confounders accounted for in the design and analysis?	During the study period, is the intervention administered (or exposure occurred) as intended?

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