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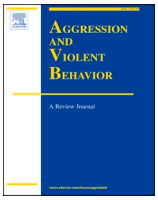

Effectiveness of Virtual Reality interventions for aggression, anger and impulsiveness: A multilevel meta-analysis

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ABSTRACT

Interventions based on Virtual Reality (VR) appear to be a promising option for the treatment of aggression, enabling the creation of immersive simulations for individuals to learn and practice strategies in a controlled and supervised environment.

The aim of this study is to determine the effectiveness of VR interventions in reducing anger, aggression and impulsiveness. A systematic search produced eleven valid articles for a meta-analysis consisting of a total sample of 479 participants aged 26.37 ± 18.5, of whom 88.1 % were men.

The study found a statistically significant reduction in observer reported aggression ($g = -0.27$; $p = 0.029$), self-reported aggression ($g = -0.47$; $p < 0.001$), anger ($g = -0.74$; $p = 0.005$) and impulsiveness ($g = -0.47$; $p < 0.001$). Regarding the possible improvement over conventional therapies or waiting list control groups, the weighted mean difference analysis revealed a significant overall effect favouring VR intervention over the control groups ($g = -1.05$; $p = 0.003$), although specific analysis for the different outcomes could not be conducted due to the limited number of studies reporting control group data.

These results suggest that the use of VR can be effective in reducing aggression, anger and impulsiveness. Differences in effectiveness may be partially explained by the heterogeneity of the interventions and study samples. The possible biases of the selected studies and the limitations of the meta-analysis itself are considered. Future research may use these findings to optimise the effectiveness of therapeutic interventions using VR.

1. Introduction

Aggression is defined as an intentional action aimed at causing physical or psychological harm to a person who is motivated to avoid it (Anderson & Bushman, 2002). This multidimensional behaviour encompasses a wide range of actions that can be categorised based on their phenomenological or functional expressions. Phenomenological classifications include categories such as direct and indirect, overt and covert, or physical and verbal aggression. From a functional perspective, aggression can be distinguished as reactive or proactive (Krahé, 2013). Reactive aggression is characterised by the primary intention of harming another, typically in response to provocation, whereas proactive aggression is considered instrumental behaviour employed to achieve a goal or benefit (Penado et al., 2014).

Although aggression, violence, and anger often co-occur, they represent distinct concepts and are not interchangeable. While aggression involves a specific action intended to cause harm, anger is a negatively valenced emotion arising from a perceived wrongdoing, accompanied by a motivational tendency to counteract the wrongdoing (Fernandez, 2013; Smedslund, 1993). Thus, it is possible to experience anger without expressing aggression, and vice versa (Fernandez, 2013). Conversely, violence represents a maladaptive function of aggression and is distinguished by its extreme, destructive, and disproportionate nature relative to the triggering stimulus (Allen & Anderson, 2017).

To address the complexity of aggression, several theoretical models have been developed to understand its genesis and persistence. One such model is the Social Information Processing Theory (SIP), proposed by Crick and Dodge (1994), highlights deficiencies in the cognitive processing of social situations as a critical variable influencing the adoption of aggressive strategies in resolving everyday conflicts (Dodge et al., 2015). This model explores the role of the so-called hostile attribution bias, characterised by a tendency to attribute hostile intentions to others' behaviour in ambiguous situations. This bias emerges from the interaction between individual predispositions, such as an impulsive temperament, and adverse life experiences, including physical abuse, failure in key life tasks, exposure to hostile models, and a lack of secure

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attachments with protective adults (Dodge, 2006).

In parallel, the Anger-Hostility-Aggression (AHA) Syndrome proposed by Spielberger and Reheiser (2009) emphasises the close relationship between these three constructs and the importance of differentiating them for precise and effective clinical assessment. In this model, aggression constitutes the behavioural component, hostility refers to the cognitive component encompassing negative attitudes that motivate or justify aggression, and anger, the affective component, is conceptualised as an emotional state varying in intensity from mild irritation to intense rage.

Finally, the General Aggression Model (GAM) by Anderson and Bushman (2002) underscores that the determinants of aggression comprise a complex interactive network of factors, including personal attributes such as personality traits, negative moods, biases, and attitudes, alongside situational variables such as provocation, frustration, or incentives. These factors influence cognitions, feelings, and arousal, impacting appraisal and decision-making processes that lead to aggressive behaviour (Allen et al., 2018). According to Anderson and Bushman (2002), anger may play various roles in aggression. Firstly, it reduces inhibitions against aggression by justifying retaliation and impeding processes such as moral reasoning. Additionally, it sustains aggressive intent by increasing attention to and recall of provoking events. It also serves as an internal informational source for identifying causes of others' behaviour, fostering hostile interpretations of ambiguous situations. Lastly, it energises behaviour by increasing physiological arousal, thereby facilitating aggressive responses.

Thus, anger and its cognitive correlate (hostility) are considered fundamental elements in explaining reactive aggression, which is often motivated by a perceived wrongdoing. In contrast, these elements are less central to proactive aggression, a form of aggression that does not necessarily require affective mediation but represents a dysfunctional strategy learned and employed to achieve objectives beyond merely causing harm (Crick & Dodge, 1996; Moore et al., 2019; Penado et al., 2014).

However, impulsiveness is also an important factor, associated not only with reactive aggression, which is intrinsically impulsive (Andreu et al., 2006), but also with proactive aggression. In the SIP Model, impulsiveness is understood as a low acceptability threshold for chosen response. The first possible response may be executed immediately without consideration of its consequences or characteristics. This low acceptability threshold inhibits the ruling out or reconsideration of aggressive responses to social problems regardless of their possible negative consequences (Fontaine & Dodge, 2006).

Based on these explanatory models, a number of intervention programs have been developed to address aggressive behaviour in different contexts, particularly involving exercises to identify emotions, for emotional regulation and techniques to manage impulsiveness (Ciesinski et al., 2022; Cougle et al., 2017; van Teffelen et al., 2021). These interventions principally focus on cognitive behavioural strategies (Hornsveld et al., 2015; Thompson & Schmidt, 2021). Among the most common and effective techniques in treating hostility and anger uses are cognitive restructuring and cognitive bias modification (Ciesinski et al., 2023). These therapeutic approaches have proven effective in different populations, including forensic patients and young offenders (Ciesinski et al., 2022), domestic aggressors (domestic violence) (Hammett et al., 2023) and school aggressors (bullying) (Gaffney et al., 2021). Additionally, this type of focus has also been effective for clinical populations or those with personality disorders, especially borderline personality disorder, and in treating anxiety, depression and emotional dysfunctions (Ciesinski et al., 2022).

In the last three decades, applied psychology has been greatly enriched by the new intervention techniques made possible by Information and Communications Technologies (ICT) (Baños et al., 2022), particularly those involving Virtual Reality (VR) (Chang & Chang, 2023). VR allows the creation of realistic, three-dimensional spaces or environments, giving the illusion of being present and interacting within this space (Mohr et al., 2013). Using VR behaviour, thinking patterns and emotions can be modified through virtual experiences tailored to the specific needs of each individual (Maples-Keller et al., 2017). These technologies are valuable tools for the evaluation, diagnosis and treatment of mental disorders, as well as scientific research using controlled environments and stimuli (Valmaggia et al., 2016). VR has been primarily used in the treatment of anxiety disorders (Popa et al., 2022), different types of phobias (Lim et al., 2023; Meyerbröker et al., 2022) and addiction (Giguère et al., 2023; Thaysen-Petersen et al., 2023) and proven an effective complement to conventional treatment (Maples-Keller et al., 2017). Nevertheless, there is currently no clear consensus on the greater effectiveness of VR compared to conventional intervention techniques (Carl et al., 2019; Fodor et al., 2018).

Scientific evidence on the effectiveness of VR in treating aggression is still limited. Given the capacity of VR to induce high degrees of anger (Geraets et al., 2021; Verhoef et al., 2021), recent research has focussed on the use of VR to reduce aggression, improve emotional regulation, and impulse control among the general population as well as with offenders (Jo et al., 2022).

A number of intervention models have utilised VR for anger management by creating relaxing virtual environments (Tarrant et al., 2022). However, programs using VR have also been specifically developed to address aggressive behaviour, many of which have shown promising results. VR Aggression Prevention Therapy (VRAPT), based on the SIP Model (Crick & Dodge, 1994), involves anger management techniques through the recognition of emotions and cognitive biases with exercises in pro-social responses (Tuente et al., 2018). The Virtual Reality Game for Aggressive Impulse Management (VR-GAIME), based on the approach-avoidance bias modification paradigm (Veenstra et al., 2017) provides participants with strategies for conflict and provocation avoidance (Smeijers & Koole, 2019). YourSkills (Alsem et al., 2021; Alsem et al., 2023) is a multi-component program designed for children with aggression disorders using Cognitive Behaviour Therapy.

Despite the growing interest in this area, no studies have yet been published evaluating the effectiveness of these types of interventions. It remains unclear whether the use of VR actually offers significant therapeutic benefits compared to conventional intervention techniques.

Thus, the aim of this meta-analysis is to examine the effectiveness of therapies which employ VR in the treatment of aggression. The principal objective was to evaluate whether the use of Virtual Reality significantly reduced aggression, as well as other related variables such as anger and impulsiveness, compared to conventional treatments, alternative control conditions, and waiting list conditions. The following specific research hypotheses were formulated: 1) Treatments incorporating VR significantly reduce levels of aggression, anger, and impulsiveness; and 2) Treatments using VR are significantly more effective than standard treatments, other control conditions and waiting list conditions.

2. Materials & method

2.1. Search strategy

We carried out a meta-analysis following the guidelines for systematic reviews and meta-analyses (PRISMA; Urrutia & Bonfill, 2010) and using the online software Covidence™ (Veritas Health Innovation) enabling for the consensus of two reviewers. The search was conducted in Web of Science, Scopus, and PubMed using the terms 'VR' OR 'Virtual reality' AND violen* OR aggress* OR anger OR impulsiv*. The search included publications from 2013 to 2024.

In addition to database searches, grey literature was also included in the review strategy. Preprints from Scopus were searched using the same parameters as the main search strategy. Google Scholar was also utilised, employing the same search string and sorting the records by relevance, with the first 100 entries reviewed. Additionally, searches were conducted in Bielefeld Academic Search Engine (BASE) and ResearchGate. In these platforms, three searches were performed, combining the term

"virtual reality" with "aggression," "anger," and "impulsiveness," reviewing the first 100 records of each search.

The resulting flow diagram can be seen in Fig. 1.

2.2. Inclusion and exclusion criteria

The inclusion criteria were articles studying the impact of VR on aggression, anger or impulsiveness measured by standardized questionnaires. These articles were required to include pre-treatment and post-treatment measures and provide both the mean and standard deviation of at least the VR group, from 2013 to 2024, with data available up to 18 November 2024. Exclusion criteria were (a) books, reviews, meta-analysis, comments, editorials, master's theses, or dissertations; (b) single-case studies; and (c) systematic reviews/meta-analyses (Fig. 1).

2.3. Data extraction and analysis

The multilevel meta-analysis was conducted using the metafor package in R (Viechtbauer, 2010). First, given the absence of control groups in some of the included studies, a multilevel meta-analysis was carried out with pre-post measures of the same VR group to determine the effect the intervention on the four violence-related constructs: observed aggression, self-reported aggression, anger and impulsiveness. Thereof, the levels were (1) outcome (i.e. construct), (2) study (i.e. author and year) and (3) test (i.e. questionnaire employed). Additional to the overall effect, individual Hedges' g measures were calculated using R software and Wilson (2023) to determine the unbiased effect size in a reduced sample size (Borenstein et al., 2009) in each of the studies and constructs. Hedges' g values are considered as small effect when $g = 0.20–0.49$, medium effect $g = 0.50–0.79$, and large effect $g \geq 0.80$.

For those articles that included control group a second multilevel meta-analysis was conducted with the weighted mean difference with 95 % confidence intervals (Andrade, 2020; Hopkins & Rowlands, 2024). The focus was on the difference between pre and post measures of violence-related constructs above mentioned between the changes observed in VR vs Control group. This statistical approach enables the extent of change in the variable of interest to be discerned when compared against the usual control group, an approach similar to previous VR-related meta-analysis with similar variables, interventions and number of included studies in the analysis (Cortés-Pérez et al., 2023; Gibbons et al., 2016; He et al., 2023; Lina et al., 2020; Zhang et al., 2024). In this sense, two levels were considered for this meta-analysis: (1) outcome and (2) study, controlling the level of "test" by using equal or similar tools among the selected papers. Indeed, some studies included multiple measures to assess the constructs of aggression and anger. In order to reduce the bias, the following criteria were applied to determine which test to include in the meta-analysis. In the case of hetero-reported measures of aggression, priority was given to observations conducted by professionals over those conducted by family members, due to the specialised training of professionals and the reduced likelihood of personal biases. For self-reported measures, instruments providing a global assessment of the construct were prioritised, avoiding fragmented or partial dimensions. Additionally, preference was given to instruments widely used in the scientific literature, as this facilitates better comparability across studies and enhances the generalisability of the findings.

Potential publication bias, defined as the tendency to favour the publication of statistically significant results over non-significant ones, was evaluated through visual inspection of funnel plots and Egger's test (Egger et al., 1997; Sampedro-Piquero et al., 2023). In addition, the risk of bias was performed using RevMan 5.4 (Cochrane Collaboration Review Manager) and assessed based on 7 domains corresponding to a specific type of bias: (A) blinding of outcome assessment (detection bias); (B) incomplete outcome data (attrition bias); (C) selective reporting (reporting bias); (D) bias arising from the randomization process; (E) bias arising from non-standardized instruments. Finally, a checklist of open science principles was applied using information from each manuscript, following the framework proposed by Peelle (2016).

3. Results

The search produced a total of 631 studies after the elimination of

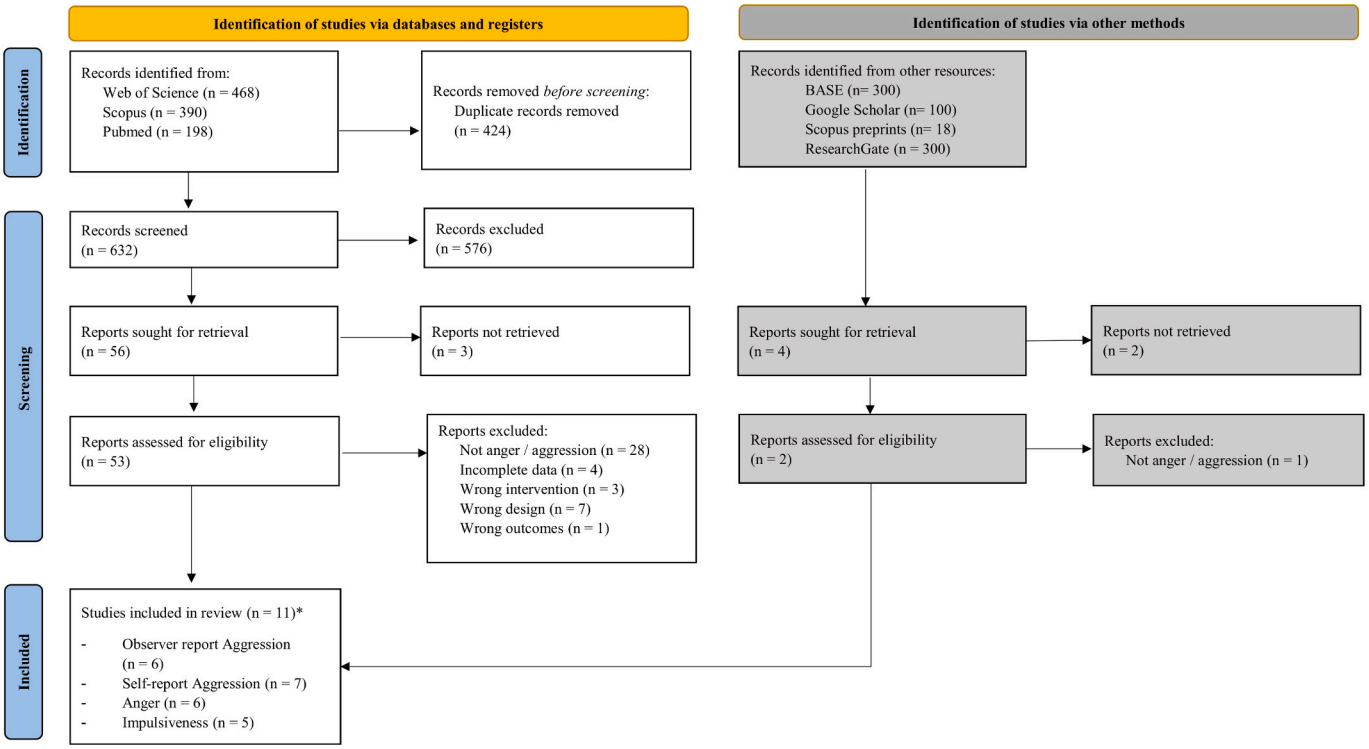

Fig. 1. Flow diagram of the study selection process. *Note: studies can be included in more than one category.

duplicates. A review of titles and abstracts led to the exclusion of 576 studies which did not meet the inclusion criteria for the review. After readings of the full texts a further 43 articles were excluded for various reasons: articles of studies whose principal objective was not the treatment of anger or aggression ($n = 28$), incomplete data ($n = 4$), wrong intervention ($n = 3$), wrong design ($n = 7$), missing articles (n = 3) and wrong outcomes ($n = 1$).

Additional records were identified through other resources, including the Bielefeld Academic Search Engine ($n = 300$), Google Scholar ($n = 100$), Scopus preprints (18), and ResearchGate (n = 300). These studies were subjected to the same selection process as those identified through databases and registers. Four reports were sought for retrieval; however, two reports could not be retrieved. The remaining two reports were assessed for eligibility. Following the assessment, one report was excluded for not being relevant to anger or aggression. Consequently, one additional study was included.

After the selection process, eleven studies were included in the meta-analysis (Alsem et al., 2023; Alsem et al., 2021; Ivarsson et al., 2023; Matsangidou et al., 2023; Mohanapriya, 2015; Palanques Alegre et al., 2022; Schena et al., 2023; Smeijers et al., 2021; Tuente et al., 2020; Woicik et al., 2023; Zinzow et al., 2018). The specific features of each research are presented in Table 1.

The total sample of the meta-analysis consisted of 479 participants (456 males and 86 females; 287 in the VR group vs 192 in the control group) with a mean age 26.37 years ± 18.5 Std. Dev. The samples of four studies consisted of minors, all part of clinical populations: children with aggressive behaviour (Alsem et al., 2021, 2023), children with Attention Deficit Hyperactivity Disorder (Schena et al., 2023) and minors in judicial proceedings (Palanques Alegre et al., 2022). Of the studies involving adults, four included forensic psychiatric patients (Ivarsson et al., 2023; Smeijers et al., 2021; Tuente et al., 2020; Woicik et al., 2023), one included patients with dementia (Matsangidou et al., 2023), one adult alcoholic clients (Mohanapriya, 2015) and one involved veterans (Zinzow et al., 2018).

Out of the eleven studies analysed for the meta-analysis, six used measures of observer-report aggression (Alsem et al., 2021, 2023; Schena et al., 2023; Smeijers et al., 2021;Tuente et al., 2020; Woicik et al., 2023), seven used self-report measures of aggression (Alsem et al., 2021, 2023; Ivarsson et al., 2023; Smeijers et al., 2021; Tuente et al., 2020; Woicik et al., 2023; Zinzow et al., 2018), six used measures of

Table 1
Manuscripts selected for meta-analysis.

#	Author and year	Country	Sample	Age mean (SD)	% Men	Number of participants			Outcome questionnaire (Aggression/Anger/ Impulsiveness)
						All (Design)	Experimental group (VR)	Control group (condition)	
1	Alsem et al., 2023	Netherlands	Boys with aggressive behaviour aged 8–13 years old	10.58 (1.44)	100	74 (RCT)	40 (Your SkillsVR)	34 (Care as usual)	Aggression: CBCL, TRF[a], IRPA[a]
2	Alsem et al., 2021	Netherlands	Boys with aggressive behaviour aged 8–12 years old	n.a.	100	6 (Pre-experimental)	6 (Your SkillsVR)	0	Aggression: Likert scale, frequency past month
3	Ivarsson et al., 2023	Sweden	Incarcerated male violent offenders	29 (8.1)	100	14 (Pre-experimental)	14 (VRAPT)	0	Aggression: AQ/Anger: STAXI-AX, STAXI-S, STAXI-T
4	Matsangidou et al., 2023	Cyprus	Patients with dementia	73.15 (16.17)	35	20 (Pre-experimental)	20 (Exposure to virtual environments)	0	Aggression: OAS-MNR/ Anger: subscale OERS[a]
5	Mohanapriya, 2015	India	Adult alcoholic clients	32.9 (n. a.)	100	30 (Pre-experimental)	30 (Kinect Adventures)	0	Anger: Clinical Anger Scale
6	Palanques Alegre et al., 2022	Spain	Minors who served a judicial measure	16.91 (1.45)	81.72	93 (Quasi-experimental)	45 (PSIOUS VR)	48 (CBT)	Impulsiveness: MACI, subscale Impulsive Propensity (DD)[a]
7	Schena et al., 2023	Italy	Children with ADHD aged 5–12 years old	8	55	60 (RCT)	30 (IamHero)	30 (Care as usual)	Aggression: Conners-3 scale[a]/Impulsiveness: Conners-3 scale[a]
8	Smeijers et al., 2021	Netherlands	Forensic psychiatric outpatients	36.13 (12.88)	100	31 (RCT)	15 (ART + VR-GAIME)	16 (ART + placebo game)	Aggression: AQ[a], RPQ, SDAS[a]/Anger: STAS[a]/ Impulsiveness: Subscale BIS/BAS[a]
9	Tuente et al., 2020	Netherlands	Forensic inpatients	39.4 (10.6)	100	128 (RCT)	64 (VRAPT)	64 (Waiting)	Aggression: AVL[a]; BDHI; RPQ, SDAS[a]/Anger: STAXI-2 NAS-PI[a]/Impulsiveness: BIS-11[a]
10	Woicik et al., 2023	Netherlands	Incarcerated male offenders	32 (8.4)	100	17 (Pre-experimental)	17 (VRAPT)	0	Aggression: AQ, RPQ, SDAS-9/Anger: NAS-PI/ Impulsiveness: BIS-11
11	Zinzow et al., 2018	USA	Veterans aged ≥18 years old	38.67 (9.31)	100	6 (Pre-experimental)	6 (VRET + CBT)	0	Aggression: Subscale DBS
			Total sample:	26.37 (18.5)	88.1	479	287	192	

Abbreviations: ADHD, Attention Deficit Hyperactivity Disorder; AQ, Aggression Questionnaire; ART, Aggression Replacement Training; AVL, Aggression Questionnaire; BIS-11, Barratt Impulsiveness Scale; BDHI, Buss-Durkee Hostility Inventory; BIS/BAS, Behavioural Inhibition System/Behavioural Activation System; CBCL, Child Behaviour Checklist; CBT, Cognitive Behavioural Therapy; DBS, Driving Behaviour Survey; IRPA, Instrument for Reactive and Proactive Aggression; MACI, Millon Adolescent Clinical Inventory; NAS-PI, Novaco Anger Scale and Provocation Inventory; OAS-MNR, Overt Aggression Scale-Modified for Neurorehabilitation; OERS, Observed Emotion Rating Scale; RCT, Randomized Controlled Trial; RPQ, Reactive Proactive Questionnaire; SDAS, Social Dysfunction and Aggression Scale; STAS, State Trait Anger Scale; STAXI-2, State-Trait Anger Expression Inventory-2; STAXI-AX, State Trait Anger Scale – Anger Expression; STAXI-S, State Trait Anger Scale – State; STAXI-T, State Trait Anger Scale – Trait; TRF, Teachers Report Form; VR, Virtual Reality; VR-GAIME, Virtual Reality Game for Aggressive Impulse Management; VRAPT, Virtual Reality Aggression Prevention Therapy.

[a] Measures selected for the comparison between VR and Control Group.

anger (Ivarsson et al., 2023; Matsangidou et al., 2023; Mohanapriya, 2015; Smeijers et al., 2021; Tuente et al., 2020; Woicik et al., 2023), and five used measures of impulsiveness (Palanques Alegre et al., 2022; Schena et al., 2023; Smeijers et al., 2021; Tuente et al., 2020; Woicik et al., 2023).

In the eleven studies examined, four were Randomized Controlled Trials (Alsem et al., 2023; Schena et al., 2023; Smeijers et al., 2021; Tuente et al., 2020). However, the study by Schena et al. (2023) did not provide data on the control group. Another study followed a quasi-experimental design with pre- and post-test analyses and a quasi-control group (Palanques Alegre et al., 2022). Additionally, six studies utilised pre-experimental designs that did not include a control group (Alsem et al., 2021; Ivarsson et al., 2023; Matsangidou et al., 2023; Mohanapriya, 2015; Woicik et al., 2023; Zinzow et al., 2018).

Of the five studies included in the control group, four used an active control group (Alsem et al., 2023; Palanques Alegre et al., 2022; Schena et al., 2023; Smeijers et al., 2021) while the remaining study (Tuente et al., 2020) used a group of patients on a waiting list as the control group.

The risk of bias of the meta-analysis, together with the specific risk for each article, is displayed in Fig. 2. Furthermore, open science principles of each manuscript were considered in Supplementary Table S1 according to the checklist proposed by Peelle (2016).

3.1. Virtual Reality interventions

Table 2 outlines the main characteristics of the interventions included in the meta-analysis. These interventions vary widely in terms of duration, frequency, format, and the professional profiles of those delivering them. The number of sessions ranges from a single intervention (Matsangidou et al., 2023) to a maximum of 16 sessions (Ivarsson et al., 2023; Tuente et al., 2020; Woicik et al., 2023), while session duration varies from 5 to 7 min (Mohanapriya, 2015) to 90 min (Palanques Alegre et al., 2022; Zinzow et al., 2018). The frequency of sessions is predominantly weekly (e.g., Alsem et al., 2023; Palanques Alegre et al., 2022), although some interventions are delivered daily (Mohanapriya, 2015) or twice weekly (Tuente et al., 2020; Woicik et al., 2023). The total duration of the programs ranges from a single intervention (Matsangidou et al., 2023) to six months (Schena et al., 2023), with a common duration of approximately 8–10 weeks (e.g., Alsem et al., 2023; Palanques Alegre et al., 2022).

Regarding the professionals delivering the interventions, the majority are licensed therapists or clinical psychologists (e.g., Alsem et al., 2023; Palanques Alegre et al., 2022; Zinzow et al., 2018). However, some studies mention trained facilitators (Ivarsson et al., 2023), while others do not specify the professionals involved (Smeijers et al., 2021). With regard to follow-up, the majority of interventions did not include this phase. Four studies, however, conducted follow-up assessments (Ivarsson et al., 2023; Tuente et al., 2020; Woicik et al., 2023; Zinzow et al., 2018). Among them, only one included a control group in the follow-up assessment (Tuente et al., 2020). When follow-up was conducted, it occurred between 1 and 12 weeks after the intervention had concluded.

In the eleven articles reviewed in the study, interventions incorporated Virtual Reality in different ways to treat anger and aggression, either to address specific aspects or to adapt to specific clinical scenarios. These interventions can be classified into three categories, from greater to lesser degree of virtual interaction: a) Structured programs that involve a range of interactive situations using virtual avatars; b) Serious games; and c) Relaxing virtual environments.

In the first category, structured programs that involve a range of interactive situations using virtual avatars, two specific interventions were identified. The first, "YourSkills virtual reality" (Alsem et al., 2021, 2023) consisted of a virtual adaptation of a structured treatment program based on Cognitive Behaviour Therapy (CBT) designed specifically for children with problems of aggression. The principal objective of this program was to reduce the prevalence of aggressive behaviour, improve emotional regulation and information processing skills. In this program, participants face situations provoking anger, often involving frustration in previously assigned tasks.

VRAPT, or "Virtual Reality Aggression Prevention Therapy" (Ivarsson et al., 2023; Tuente et al., 2020; Woicik et al., 2023) is a treatment program based on the SIP Model (Crick & Dodge, 1994) and consists of three principal components: a) exercises to improve the recognition of emotions; b) exercises to regulate physiological activation; and c) role play exercises using virtual avatars controlled by the therapist.

The second category, Virtual Reality in the context of serious games, was used in a number of ways. In "VR-GAIME – Virtual Reality Game for Aggressive impulse Management" (Smeijers et al., 2021), participants adopt the role of a messenger encountering different avatars on their route. These avatars may be friendly or aggressive. The task of the participant involves making approach movements towards friendly avatars and avoidance movements in response to hostile characters. The "IamHero" program (Schena et al., 2023) presents a number of activities designed to improve the cognitive-behavioural skills of children with Attention Deficit Hyperactivity Disorder (ADHD). These activities include giving geographical directions, avoiding obstacles and collecting rewards as well as tasks related with spatial codification. In the study by Mohanapriya (2015), the game "Kinect Adventures" was utilised, specifically the "River Rush" module. In this game, participants are placed in a virtual raft and must physically move to control de direction of the raft and avoid obstacles. This activity aimed to enhance concentration and coordination, thereby assisting participants in improving their anger control. Finally, Zinzow et al. (2018) used a driving simulator program to reduce aggressive driving.

Other studies have used virtual environments with minimal or null interactions to reinforce relaxation techniques or mindfulness. Palanques Alegre et al. (2022) used the PSIOUS® platform to practice progressive relaxation, diaphragmatic breathing and mindfulness.

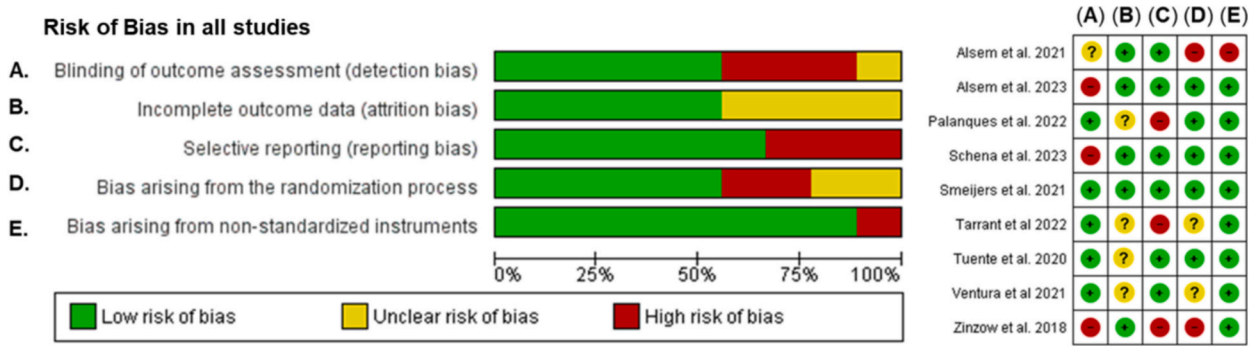

Fig. 2. Overall risk of bias of the meta-analysis and for each included study.

Table 2
Description of Virtual Reality interventions.

#	Author and year	Number of sessions	Session duration	Frequency	Total duration	Delivered by	Follow-up
1	Alsem et al., 2023	10	45 min	Weekly	10 weeks	Licensed therapists	None
2	Alsem et al., 2021	10	45 min	Weekly	10 weeks	Licensed therapist	None
3	Ivarsson et al., 2023	16	45–60 min	Variable	7–48 weeks (M = 17.5, S.D. = 11.6)	Trained program facilitators	12 weeks
4	Matsangidou et al., 2023	1	Up to 20 min	Not applicable	Not applicable	Not reported	None
5	Mohanapriya, 2015	5	5–7 min	Daily	5 days	Researcher	None
6	Palanques Alegre et al., 2022	10	90 min	Weekly	10 weeks	Licensed psychologists at therapeutic centres	None
7	Schena et al., 2023	Not reported	50 min	Weekly	6 months	Referring therapists (speech therapists, neuropsychomotricists, physiotherapists)	None
8	Smeijers et al., 2021	5	Up to 30 min	Weekly	5 weeks	Not reported	None
9	Tuente et al., 2020	16	60 min	Twice weekly	8 weeks	Trained Licensed psychologists and non-verbal therapists	3 months
10	Woicik et al., 2023	16	60 min	Twice weekly	8–26 weeks (M = 13)	Trained psychologists	12 weeks
11	Zinzow et al., 2018	8	90 min	Not reported	Not reported	Licensed clinical psychologist	1 month

Matsangidou et al. (2023) utilised a VR system that included a variety of virtual environments featuring nature scenes, travel destinations, and artistic experiences.

3.2. Virtual Reality intervention's effectiveness

To analyse the VR intervention's effectiveness, we examined the shift in mean values before and after its implementation for each measured outcome, as depicted in Fig. 3. These forest plots showed a statistically significant reduction of different values of violence-related outcomes, such as observer-reported aggression ($g = -0.27$; $p = 0.029$) self-reported aggression ($g = -0.47$; $p < 0.0001$), anger ($g = -0.74$; $p = 0.0054$) and impulsiveness ($g = -0.47$; $p = 0.0004$).

Regarding the weighted mean difference, which takes into account the mean difference between pre- and post- analyses of each group, we observed that the global multilevel meta-analysis of the most common standardized instruments resulted in significant effect size favouring VR intervention over the control group ($g = -1.05$; $p = 0.0025$; Fig. 4). However, here neither the specific analysis of the four different outcomes nor the test study level were carried out due to low number of studies reporting control group data. Complete information of means and standard deviations of each group and study, together with effect size, can be found in Supplementary Table S2.

The Egger test for funnel plot asymmetry did not detect statistically significant asymmetry in Meta-analysis 1 "pre-post VR" ($t(40) = -1.40$; $p = 0.17$) nor Meta-analysis 2 "pre-post differences VR vs. Control" ($t(9) = 0.39$; $p = 0.71$), suggesting low risk of publication bias and lack of asymmetry (Fig. 5).

Last, four studies with different outcomes included follow-up measures of the VR group (Ivarsson et al., 2023; Tuente et al., 2020; Woicik et al., 2023; Zinzow et al., 2018), and only one of them with control group (Tuente et al., 2020). Table 3 displays the effect size of the tests of those manuscripts with follow-up measures after VR intervention. One of the significant effect sizes regarding anger reduced over time (i.e. STAXI-AX, Ivarsson et al., 2023), but others seem to increase, such as anger measured by NAS-PI in Tuente et al. (2020) and self-reported aggression in both Tuente et al. (2020) and Zinzow et al. (2018). However, the majority of the Hedges' g calculations turn out not to be statistically significant, probably due to small sample size, as in Woicik et al. (2023) with a sample of 16 that reduced to 8 in the follow-up and, thus, Wilcoxon effect size was used in their study.

4. Discussion

The purpose of the present study was to evaluate the effectiveness of the use of Virtual Reality in the treatment of aggression and variables associated with anger and impulsiveness. The results of the meta-analysis support the initial research hypotheses.

First, treatments incorporating Virtual Reality proved effective in reducing impulsiveness, anger and both observer-reported and self-reported aggression. Second, the effectiveness of treatments using VR was significantly greater in comparison with different control conditions, although specific analysis for the different outcomes could not be conducted due to the limited number of studies reporting control group data.

These results coincide with findings from previous studies, although scientific evidence in this area is currently very limited. A systematic review conducted by Dellazizzo et al. (2019) found that VR-based treatments not only demonstrated significant improvements in aggression but also in impulsiveness and anger. However, it is important to note that this review only included one study specifically evaluating aggression (Zinzow et al., 2018), indicating a clear limitation in the available evidence. The present review included studies in which anger management was a specific therapeutic objective using VR. In contrast, the review by Dellazizzo et al. (2019) included articles on interventions treating other psychological pathologies, such as Post-traumatic Stress Disorder through Virtual Reality Exposure Therapy (VRET) (Beidel et al., 2019). Consequently, the reduction in anger reported by Dellazizzo et al. (2019) appears to be associated with an overall improvement in the psychopathological condition of the participants.

It is important to note that VR interventions have been shown to be effective in reducing aggression according to both self-reported and observer-reported evaluations. However, the differences observed between these two types of assessments highlight the inherent difficulty in the conceptualisation and measurement of aggression and are in line with the findings of previous research, which also identified discrepancies between self-report evaluations and those by external observers (Hornsveld & Kraaimaat, 2022). It is, therefore, recommended to use a multicomponent evaluation system with different methods and sources in analysing aggression (Carrasco, 2006).

Additionally, although the results indicate significant reductions in both anger and aggression, it is important to consider the distinction between reactive and proactive aggression (Dodge, 1991). Only certain types of aggressive behaviour are influenced by an emotional response while others are determined by the decision-making process, that is, the selection of the most appropriate response in a given situation. Thus,

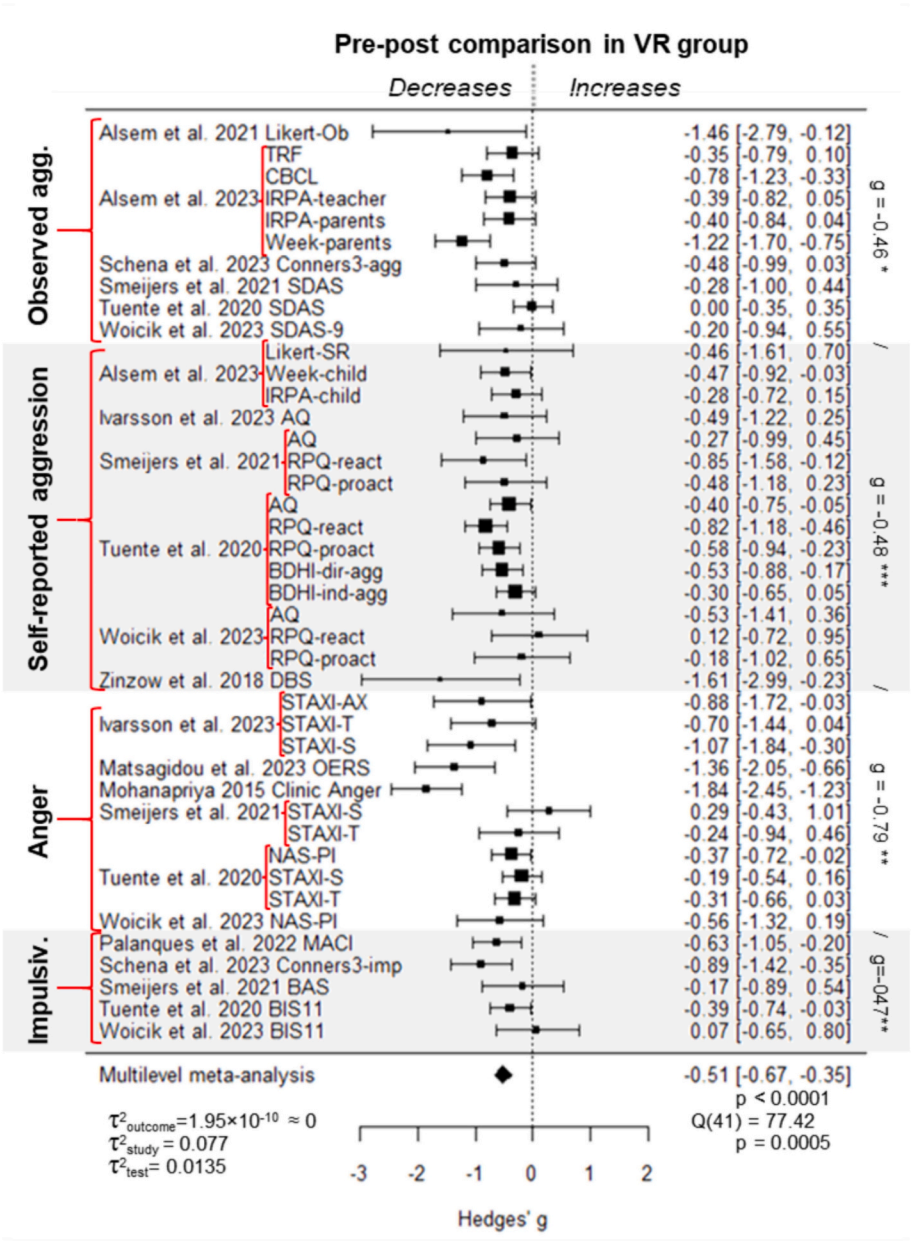

Fig. 3. Forest plots of each outcome assessed in the multilevel meta-analysis using pre-post measures of the VR group. Abbreviations: agg, aggression; AQ, Aggression Questionnaire; BAS, Behavioural Activation System - drive; BDHI, Buss-Durkee Hostility Inventory direct and indirect aggression, BIS-11, Barratt Impulsiveness Scale; DBS, Driving Behaviour Survey-aggressive behaviour; IRPA, Instrument for Reactive and Proactive Aggression; MACI, Millon Adolescent Clinical Inventory; NAS-PI, Novaco Anger Scale and Provocation Inventory; RPQ, The Reactive–Proactive Aggression Questionnaire; SDAS, Social Dysfunction and Aggression Scale; STAXI-AX, State Trait Anger Scale – Anger Expression; STAXI-S, State Trait Anger Scale – State; STAXI-T, State Trait Anger Scale – Trait; TRF, Teachers Report Form. *$p < 0.05$; **$p < 0.01$; ***$p < 0.005$.

while reactive and proactive aggression may be conceived as two complementary expressions of aggressive behaviour (Romero-Martínez et al., 2022), it is essential to differentiate between the two when evaluating the effectiveness of interventions given the different underlying cognitive processes and functions.

The limited research on the specific topic of violence can be compared to well-established therapeutical interventions or other VR treatments in order to address the relative magnitude of the effectiveness found in this meta-analysis. In this sense, other studies from depression, anxiety and phobias can shed light on the expected effect size when using VR for therapeutical purposes. On the one hand, in the meta-analytic literature, the effect size for the common psychological treatments is rather medium for depression (CBT, d = 0.22 in Cuijpers et al., 2010; g = 0.45 in Hofmann & Smits, 2008), large for PTSD (exposure therapy, g = 0.86 posttreatment and 0.528 at follow-up; McLean et al., 2022) and, interestingly, mixed results in anger and aggression treatments (effect sizes ranging from 0.27 to 1.52 in different meta-analyses reviewed in Lee & DiGiuseppe, 2018). On the other hand, VR-based interventions for anxiety are one of the most reported in the literature and seem to favour the conventional psychological treatment in acrophobia (g = 1.89), astraphobia (g = 0.95), odontophobia (g = 2.58) but favour the control group in panic disorder (g = −0.47; Schröder et al., 2023). In general, medium to large effect sizes have been found in VR-based therapies for anxiety (g = 0.79) and depressive (g = 0.73) symptoms (Fodor et al., 2018), which are similar values to those of these meta-analyses ranging from 0.51 to 1.05.

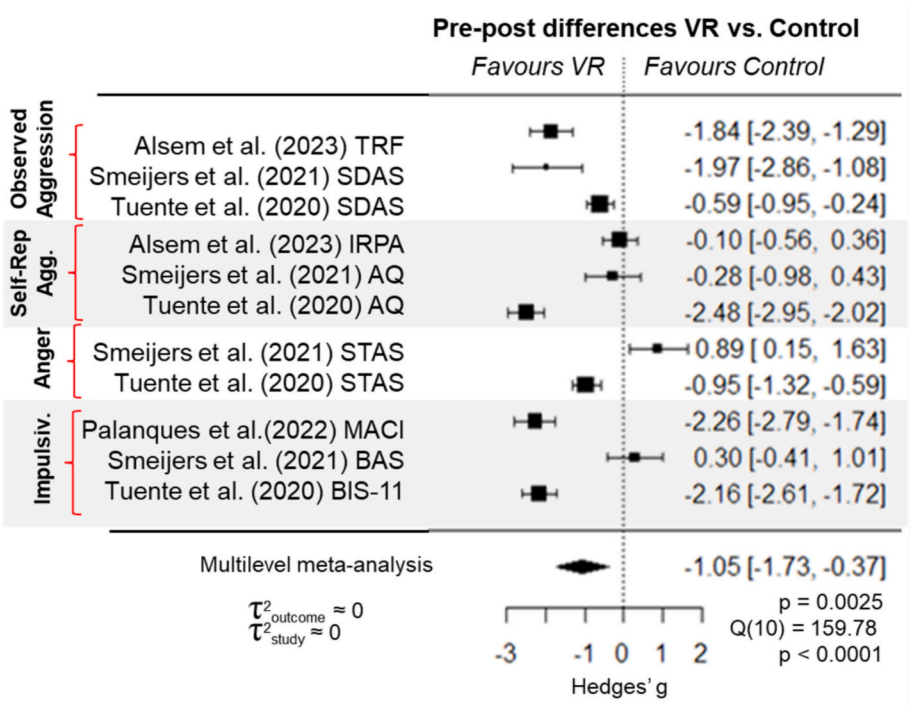

Fig. 4. Forest plot of the multilevel meta-analysis model of pre-post weighted mean differences of control and VR groups. Abbreviations: AQ, aggression Questionnaire; BAS, Behavioural Activation System; BIS-11, Barratt Impulsiveness Scale; IRPA, Instrument for Reactive and Proactive Aggression; MACI, Millon Adolescent Clinical Inventory; SDAS, Social Dysfunction and Aggression Scale; STAS, State-Trait Anger Scale; TRF, Teachers Report Form.

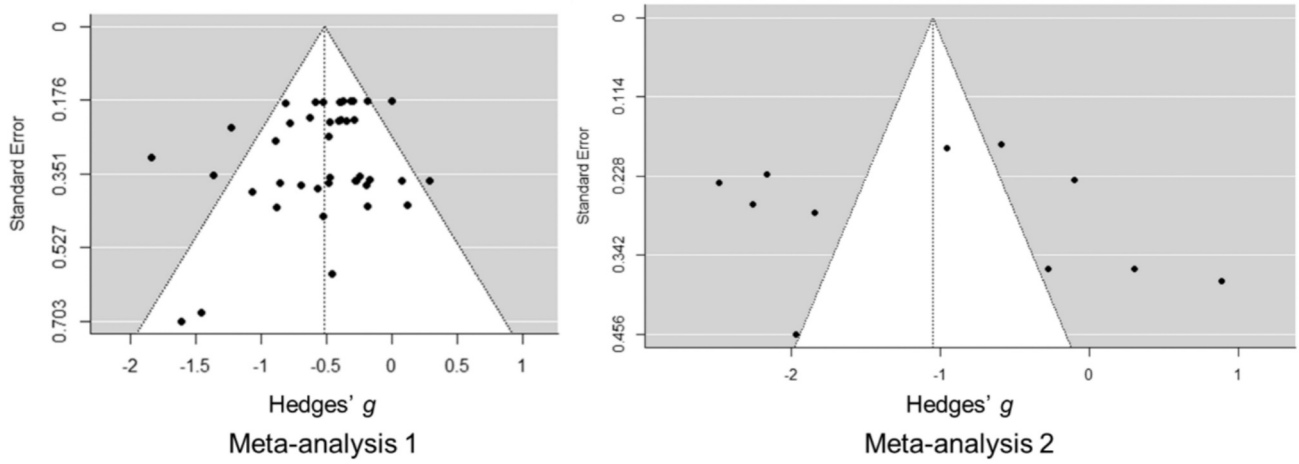

Fig. 5. Funnel plots of meta-analysis for publication bias detection. Meta-analysis 1 is represented in Fig. 3, and Meta-analysis 2 in Fig. 4.

It is worth noting that only a limited number of studies in the meta-analysis included follow-up measures (four in total), and among these, only one incorporated a control group. The findings exhibit some inconsistencies: while one study reported a sustained reduction in anger over time (STAXI-AX; Ivarsson et al., 2023), others showed increases, such as anger assessed with the NAS-PI (Tuente et al., 2020) and self-reported aggression (Tuente et al., 2020; Zinzow et al., 2018). Importantly, the studies reporting increases in follow-up outcomes employed shorter follow-up intervals (1 and 3 months). These inconsistencies are similar to those found in other VR interventions for different pathologies, as seen in Fodor et al. (2018), where results were also inconclusive regarding the long-term effects. This highlights the need for further research to determine the long-term effectiveness of VR interventions, particularly with extended follow-up periods and designs incorporating control groups.

The present study has several limitations, primarily the heterogeneity of the selected articles in terms of age, sample, and VR used, as well as the nature of the control groups. Additionally, the number of studies included in the meta-analysis is relatively small, which may be attributed to the novelty of VR techniques in aggression treatment and the limited empirical research available in this area. Moreover, very few studies included follow-up assessments, and only one employed a control group in conjunction with follow-up (Tuente et al., 2020). The lack of follow-up assessments limits the ability to evaluate the long-term effectiveness and sustainability of VR interventions in the treatment of aggression, as it is unclear whether the observed improvements persist beyond the immediate post-intervention period. Another limitation is the non-inclusion of the construct 'hostility' in the meta-analysis.

Nevertheless, meta-analyses such as this one can contribute to standardizing criteria and identifying the most advantageous aspects of

Table 3
Effect sizes of follow-up measures after VR intervention.

Author and year	Variable	Test	*g* PRE-POST	*g* PRE-Follow-up
Ivarsson et al. (2023)	Self-reported aggression	AQ	−0.49	−0.39
	Anger	STAXI-AX	−1.02*	−0.69
		STAXI-T	−0.70	−0.37
		STAXI-S	−0.99*	−0.94*
Tuente et al. (2020)	Observer reported aggression	SDAS	0.00	0.00
	Self-reported aggression	AQ	−0.40*	−0.56**
		RPQ – r	−0.83***	−0.96***
		RPQ – p	−0.58***	−0.67***
	Anger	NAS-PI	−0.37	−0.40*
		STAXI-S	−0.18	0.01
		STAXI-T	−0.31	−0.27
	Impulsiveness	BIS-11	−0.38	−0.31
Woicik et al. (2023)	Observer reported aggression	SDAS-9	−0.20	−0.58
	Self-reported aggression	AQ	−0.53	−0.50
		RPQ – r	0.12	0.02
		RPQ – p	−0.18	−0.05
	Anger	NAS-PI	−0.56	−0.47
	Impulsiveness	BIS-11	0.07	0.09
Zinzow et al. (2018)	Self-reported aggression	DBS	−1.61*	−2.03***

Abbreviations: AQ, Aggression Questionnaire; BIS-11, Barratt Impulsiveness Scale; DBS, Driving Behaviour Survey; NAS-PI, Novaco Anger Scale and Provocation Inventory; RPQ-r, Reactive Proactive Questionnaire – Reactive subscale; RPQ-p, Reactive Proactive Questionnaire – Proactive subscale; SDAS, Social Dysfunction and Aggression Scale; STAXI-AX, State Trait Anger Scale – Anger Expression; STAXI-S, State Trait Anger Scale – State; STAXI-T, State Trait Anger Scale – Trait.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.005$.

VR for mitigating aggression across different sample populations, serving as a value adjunct to conventional treatments. Although VR appears to improve the effectiveness of conventional aggression treatments, the limitations presented in this study make the conclusions still insufficient. Given the promising potential of VR in aggression treatment, further research is needed to expand the empirical evidence and refine intervention protocols, enabling more precise conclusions regarding its effectiveness.

5. Conclusions

The complex nature of aggression necessarily requires multidimensional interventions which address the various cognitive emotional and behavioural processes involved in aggression. It is important to underscore that VR cannot in itself be considered therapeutic but rather can serve as a tool that complements, supports and enriches other intervention models. Thus, the effectiveness of these interventions necessarily depends on the effectiveness of the underlying therapeutic model. In the treatment of aggression, VR can be a useful tool in standardizing interventions, to improve adherence to treatment and enhance its validity, providing greater experiential immersion and simulating situations which are difficult to reproduce in a real-life scenario (González Moraga et al., 2022). Nevertheless, the effectiveness of VR will largely depend on the empirical validity of the intervention models and programs in which it is embedded. Controlled randomized testing, where VR is the only variable for groups of patients receiving empirically validated treatment, is the most effective manner to determine if the use of VR can be significantly effective in helping to reduce aggressive behaviour.

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CRediT authorship contribution statement

David Roncero: Writing – original draft, Investigation, Conceptualization. **Román D. Moreno-Fernández:** Writing – review & editing, Visualization, Methodology, Formal analysis. **Álvaro Fernández-Moreno:** Writing – original draft, Validation.

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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

Data will be made available on request.

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[1] Asterisks (*) are used to mark the articles included in the meta-analysis.

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