A Scoping Review Into Treating and Assessing Aggression and Violence Through Virtual Reality (VR)

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Master's Thesis Psychology
Positive Clinical Psychology and Technology (PCPT)
August 23, 2022

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Abstract

Introduction: Contemporary treatment methods for dealing with aggression have various limitations. However, Virtual Reality (VR) technology might have the potential to address those limitations. Therefore, the database on this research area was explored by this scoping review to establish an overview of the current state of the art regarding the treatment and assessment of aggression and violence through VR in diverse populations. **Methods:** To find relevant literature, three online databases were searched: Scopus, PsycInfo and Web of Science. In total, 15 studies were incorporated in this review after a comprehensive exploration. Those studies were analysed regarding several study characteristics, the usability/feasibility, and the effectiveness of VR in treating and assessing aggression. The extracted data were summarized and shown in tables to establish an outline of the insights. **Results:** Various research designs were applied to study the effectiveness of VR in treating and assessing aggression in a diverse set of populations. Most studies addressed exclusively male populations. VR interventions and assessment instruments were mostly administered through immersive VR technology. No clear overarching conceptualization of aggression was identified from incorporated studies and no study conceptualized violence. Various outcome measures were used to assess the effects of the VR interventions on aggression. However, studies mostly did not use the same outcome measures. Overall, participants in the various studies showed a high motivation and acceptability for VR. VR was effective in positively influencing anger, impulsivity, hostility, functional communication, moral judgement, empathy, sense of oneness and perspective taking. VR was identified to be favorable in assessing reactive aggression, aggressive social information processing, aggressive characteristics, and dysfunctional communication types. **Discussion:** Promising results were discovered regarding the treatment and assessment of aggression through VR in diverse populations. **S**tudies mostly identified VR as an effective intervention for positively influencing proximal and distal determinants of aggression and as a valid assessment instrument for aggression. Treatment results are mostly in line with a previous comprehensive review from 2019. The amount of newly discovered studies from the last three years indicates that research around aggression treatment through VR seems to have risen and that research around aggression assessment through VR seems to have started. Since research around VR aggression assessment is new, further research advancements are needed.

Keywords: Virtual reality, VR, Aggression, Treatment, Assessment

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Violence and aggression have serious consequences for the victims, for the perpetrators themselves, for the health care system and for the society (Dahlberg & Potter, 2001; National Collaborating Centre for Mental Health (UK), 1970; WHO, 2014; Wigham et al., 2022). Psychosocial treatment methods for dealing with violence exist, however their impact is modest (Fazel et al., 2016). A reason for that could be various limitations of contemporary treatment methods. For example, there are restricted possibilities to expose clients to provoking stimuli so that they can learn to regulate their anger in actual life conditions (McGuire, 2008). Virtual Reality (VR) technology could address those limitations. For example, artificial environments can be produced where stimuli can be administered which might be not administrable and manageable within a real-life environment (Rizzo et al., 2018). VR research is growing quickly and consequently the time duration between literature reviews is suggested to be shortened (Sygel & Wallinius, 2021). Therefore, the aim of the following scoping review is to explore the quality of the current evidence regarding the treatment and assessment of aggression and violence through VR in diverse populations to establish an overview of the current state of the art. At last, this scoping review investigates shortcomings of previous research and literature gaps regarding the treatment and assessment of aggression and violence through VR to inform possible future research.

Aggression and Violence

Aggression can be conceptualized as “any behavior intended to harm another person who does not want to be harmed” (DeWall et al., 2011). According to DeWall et al. (2011), aggressive behaviour served an adaptive function for human generations living in small societies a long time ago. Aggression was for example of relevance for defending the offspring and generally for ensuring the safety of one’s own group. Since humanity developed into a more socially advanced society, aggression does not serve such an adaptive function anymore. Less severe types of aggression can still be seen as having an adaptive function in for example social regulation, where however more severe types can be considered as nonadaptive, since aggression might lead to more issues than advantages (DeWall et al., 2011).

In comparison, in social psychology, violence is seen as a subtype of aggression (Allen & Anderson, 2017). According to Anderson and Bushman (2002), violence can be conceptualized as “aggression that has extreme harm as its goal (e.g., death).” Based on the given conceptualizations, any form of violence is aggression (Anderson & Bushman, 2002) in

a more severe manifestation. Therefore, in this review both constructs are of interest and are used interchangeably. Generally, conceptualizations of aggression and violence can contain the following components: unethical and offensive behaviour; having the goal to cause physical or mental suffering in another human being; having the goal to exercise control over other people; feeling and living out one's anger; verbally attacking persons; destruction of surroundings and objects; efforts to physically damage or kill somebody; forcing someone else to submit and sexual presentation and touch despite another person's refusal (National Collaborating Centre for Mental Health (UK), 1970). Based on the variety of conceptualisations, it becomes visible that aggression and violence are complex problems with various facets.

Generally, violence and aggression can be considered as serious threats for the physical and mental well-being of single human beings and the population (Wigham et al., 2022; WHO, 2014). Especially, the impact of violence on mental health can be immense. Experiencing violence can for example result in depression and anxiety disorders (WHO, 2014). Besides that, perpetrators' violence also has negative consequences for themselves since violence lead to a decrease of interpersonal relationships and social approval (National Collaborating Centre for Mental Health (UK), 1970).

The expression of aggression is composed of internal and external determinants. The internal determinants are among other things composed of personality features and issues to cope with one's anger (National Collaborating Centre for Mental Health (UK), 1970). Besides that, early forms of emotional "violence antecedents" involve difficulties with controlling and balancing one's emotions (Loeber & Hay, 1997). External determinants can incorporate the interpersonal environment in which violence takes place, a perpetrator's belief system and features of the recipients of aggression (National Collaborating Centre for Mental Health (UK), 1970). "Violence antecedents" of cognitive nature can incorporate beliefs which are supportive for aggression, and "social cognitive deficiencies" (Loeber & Hay, 1997). Furthermore, violence seems to be related to a perpetrator's deficiency to experience empathy for the person who is the recipient of violence (Dellazizzo et al., 2019). There seems to be a broad variety of antecedents and determinants which enhance violent tendencies, indicating a wide range of at-risk populations for violent tendencies.

Treatment of Aggression and Violence

Pharmacological and psychosocial interventions are available interventions for the treatment of aggression and violence (Dellazizzo et al., 2019; Wigham et al., 2022). However, pharmaceutical agents can have adverse health impacts and they are not enough on their own

(van Schalkwyk et al., 2018). With psychosocial approaches such as CBT it is tried to work on psychological and interpersonal issues which are related to the execution of violence (Wigham et al., 2022). However, the impact of these treatment approaches is modest, and it stays uncertain if established improvements through therapy remain over time (Fazel et al., 2016). Furthermore, these treatment methods are not commonly accessible, and outcomes are questionable (Rampling et al., 2016). The restricted accessibility is among other things explainable by a restricted existence of reliable and valid measurements of violence (Wigham et al., 2022). That is the case, since violence is a phenomenon difficult to assess because in contemporary investigations no overarching conceptualization is applied (Rampling et al., 2016).

There are various limitations to contemporary treatment methods which have the purpose to decrease aggression and violence. For example, there are restricted possibilities to expose clients to provoking stimuli so that they can learn to regulate their anger in actual life conditions (McGuire, 2008). That is the case in the protected forensic context. Acquiring experiences and developing the skill to regulate other peoples' and their own anger through stimulating their anger in actual interpersonal encounters is not feasible (Klein Tuente et al., 2018). Furthermore, it is problematic to get aggressive populations involved in therapy (McGuire, 2008), since therapy aimed at treating aggression is in many cases limited due to the patients' aggression itself (Klein Tuente et al., 2020). For example, clients from the forensic context are difficult to get involved in therapy since they are in many cases uncooperative and reluctant to alter their behavioural expressions. Besides that, clients are struggling to translate what they have learned in therapy into their actual life (Klein Tuente et al., 2020). One might ask if there is research on the usability and feasibility of interventions that have the purpose of treating aggression and violence, where clients are more cooperative and motivated to participate in the intervention, and where they can translate their learning insights into their actual life?

Treatment of Aggression and Violence Through Virtual Reality (VR)

Based on the aforementioned limitations of contemporary treatment approaches for decreasing aggression, there is apparently a demand for more effective interventions. VR technology could improve treatments of violence (Dellazizzo et al., 2019), by addressing some of the shortcomings. According to Sygel and Wallinius (2021), VR can be conceptualized as "a real-time computer simulated environment experienced using several sensory modalities (such as via a head-mounted display goggles and headphones) thus creating a sense of being present in the artificial environment." One benefit of VR technology

is its capability to construct treatment atmospheres and surroundings, where multisensory 3D stimuli can be produced and regulated. Therefore, artificial environments can be produced which are of pertinence for particular client groups and where thoughts, feelings and sensorimotor mechanisms can be addressed through stimuli which might be not administrable and manageable in a real-life environment (Rizzo et al., 2018). Furthermore, human beings react genuinely to computer-generated reproductions of situations from the real world (Rovira et al., 2009). Besides that, researchers or clinicians can exert control over the computer-generated events (Dellazizzo et al., 2019). For example, clients' aggression can intentionally be provoked by an instructor within an VR environment (Tuente et al., 2018). Therefore, VR technology might provide the opportunity to confront perpetrators and to simultaneously work on abilities to cope more effectively within computer-generated surroundings which are capable to trigger aggressive behavioural expressions without endangering other people (Fromberger et al., 2018).

Regarding previous reviews investigating available VR interventions for the treatment of aggression and violence, there is a comprehensive review by Dellazizzo et al. (2019). They found in total only 12 studies from 2002 to 2019, where constructs related to violence were addressed through VR interventions regardless of the population studied. Based on the discovered VR interventions, Dellazizzo et al. (2019) draw the conclusion, that VR interventions are generally effective in decreasing anger, impulsivity, aggression and effective in enhancing conflict resolution skills and empathy. The constructs that are related to violence and were addressed in previous research through VR interventions are also related to each other. As an example, dealing with anger more effectively could establish a decrease in impulsivity as well. Therefore, it is suggested for further research to involve various violence measurements (Dellazizzo et al., 2019).

However, Dellazizzo et al. (2019) only discovered two studies, where VR interventions had the aim to decrease aggressive acts directly and where aggression was addressed as a main measurement. These VR interventions may help clients to develop methods to deal with their aggression more effectively, which could potentially be translated into the context of their personal life (Dellazizzo et al., 2019). One of those two research projects was a study protocol of an ongoing RCT by Klein Tuente et al. (2018), where they created a Virtual Reality Aggression Prevention Training (VRAPT). Klein Tuente et al. (2018) expected that VR has the potential to increasingly expose forensic patients to regulated and aggressively stimulating interpersonal scenarios within a computer-generated environment. That kind of exposure could stimulate aggressive reactions and could establish

the possibility for aggressive patients to learn alternative ways of behaving. Therefore, according to Klein Tuente et al. (2018), VRAPT provides a space where behaviours can be trained instead of simply enabling a cognitive understanding. Based on the study protocol of Klein Tuente et al. (2018) and the research findings of previous investigations, summarized by Dellazizzo et al. (2019), incorporating VR interventions in treatments of violence seem to be of great value (Dellazizzo et al., 2019).

Current Study

The research insights mentioned beforehand provide a short overview of the literature that was reviewed so far regarding the treatment of violence and aggression through VR. The aim of the following scoping review is to explore the quality of the current evidence regarding the treatment of aggression and violence through VR in diverse populations to establish an overview of the current state of the art and therefore to update the findings of the previous comprehensive review by Dellazizzo et al. (2019). An update of the previous findings is already of value, since the time duration between literature reviews is suggested to be shortened regarding research topics as VR interventions since this research area is growing quickly (Sygel & Wallinius, 2021). Therefore, new findings in this research area could have already emerged in the time from the last literature review (Dellazizzo et al., 2019) until now. For example, the results of the research project by Klein Tuente et al. (2018) became available in 2020 (Klein Tuente et al., 2020). Therefore, the need for an overview of the current state of the art regarding VR interventions for treating aggression and violence becomes apparent. It is further added to this scoping review by also considering the assessment of aggression and violence through VR because of the restricted existence of valid measurements of violence (Wigham et al., 2022). Several areas of importance were detected in the literature mentioned beforehand, which inform the current systematic investigation of the current knowledge base. The following scoping review provides an overview of the quality of contemporary research regarding the treatment and assessment of aggression and violence through VR by investigating following questions:

1) For which populations is VR used to treat and assess aggression and violence and how do different populations perceive the usability and feasibility of the VR interventions and VR assessment instruments?
2) Which research designs are applied to study the effectiveness of VR in treating and assessing aggression and violence and what type of VR technology is used?
3) How are aggression and violence conceptualized by studies investigating VR for the treatment and assessment of aggression and violence?

4) How effective are VR interventions in treating aggression and violence and what are the proximal and distal outcome measures that are used to assess the effects of VR interventions on aggression and violence?
5) What is the construct validity, convergent validity, predictive validity, and measurement sensitivity of VR with regard to the assessment of aggression and violence?

Methods

Research Design

This literature review is a scoping review. Scoping reviews aim to depict the contemporary state of the art in research within a particular area of investigation regarding nature, features, and volume (van Lotringen et al., 2021). Compared to a systematic review, scoping reviews aim to present an outline of contemporary proof by taking into account numerous study designs. Therefore, the quality of the incorporated research investigations differs within a scoping review (Peters et al., 2015). The evaluation of the amount and range of existing research investigations is carried out in a systematic and transparent way to provide the possibility for easy replication (Grant & Booth, 2009). Usually, scoping reviews incorporate data into tables in order to establish a summary and a distribution of available research in the area under investigation, in order to discover gaps within available literature and in order to provide suggestions for further research investigations (Peters et al., 2015).

Search Strategy

The present scoping review was prepared and executed in accordance with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) (Moher et al., 2009). In order to find research investigations of relevance for the topic under investigation, which were published between 2019 and 2022, the online databases Scopus, PsycInfo and Web of Science were utilized. This period was chosen, since the comprehensive review by Dellazizzo et al. (2019) ended their exploration for further research articles in January 2019. The three search engines mentioned beforehand were selected since they mainly address research investigations of social, medicinal, and psychological nature. Scopus and Web of Science are online databases which incorporate a wider range of research areas whereas PsycInfo is to a greater extent aimed at psychological and mental well-being investigations (van Lotringen et al., 2021).

The introduced online databases have sophisticated exploration settings. All three online databases were explored regarding research articles and the exploration of

contemporary research within the databases was done multiple times during the course of the data collection in order to establish a comprehensive overview of the current state of the art regarding the topic under investigation. For establishing a systematic exploration of articles, terms associated with the concepts of “virtual reality” and “aggression” were generated and connected by applying the Boolean operators ‘AND’ and ‘OR’ (see Table 1).

Table 1

Search String

	Search string: Scopus
	("virtual reality" OR "virtual reality exposure" OR "virtual reality exposure therapy" OR vret OR VR OR virtual) AND (aggressi* OR violen* OR anger OR “aggressive behaviour” OR “violent behaviour” OR impulsiv* OR empath* OR "emotion regulation" OR "self-regulation" OR "conflict resolution" OR hostil* OR offender OR perpetrator OR "perspective taking" OR "role taking")
	Search string: PsycINFO
	("virtual reality" OR "virtual reality exposure" OR "virtual reality exposure therapy" OR vret OR VR OR virtual) AND (aggressi* OR violen* OR anger OR “aggressive behaviour” OR “violent behaviour” OR impulsiv* OR empath* OR "emotion regulation" OR "self-regulation" OR "conflict resolution" OR hostil* OR offender OR perpetrator OR "perspective taking" OR "role taking")
	Search string: Web of Science
	("virtual reality" OR "virtual reality exposure" OR "virtual reality exposure therapy" OR vret OR VR OR virtual) AND (aggressi* OR violen* OR anger OR “aggressive behaviour” OR “violent behaviour” OR impulsiv* OR empath* OR "emotion regulation" OR "self-

regulation" OR "conflict resolution" OR hostil* OR offender OR perpetrator OR "perspective taking" OR "role taking")

Eligibility Criteria

The following inclusion criteria were applied:

Inclusion Criteria

1) The research articles had to report original research (e.g. no literature reviews)
2) The language in which the research articles were written needed to be English or German.
3) The research articles needed to be published from 2019 onwards, since a comprehensive review by Dellazizzo et al. (2019) already reviewed the amount of VR interventions available for the treatment of violence regardless of the population studied from 2002 to January 2019.
4) Research articles were expected to investigate VR as an intervention with the purpose to positively influence aggression, violence or violence-related constructs (e.g. impulsivity, anger, empathy) (Dellazizzo et al., 2019), or as an assessment instrument for assessing aggression and violence.
5) Research articles were expected to incorporate proximal and distal outcome measures of aggression and violence that were used to assess the effectiveness of VR interventions in treating aggression and violence.

Study Selection

The systematic exploration of research articles was done with terms associated with the concepts of “virtual reality” and “aggression” in the databases PsycInfo, Web of Science and Scopus. After that, a file with the found records, incorporating titles, abstracts, authors’ names, journal name and DOI, were downloaded into a reference manager (van de Schoot et al., 2021). The reference manager EndNote was used. Duplicates within the records of all three databases were removed in EndNote. Then, a file incorporating the remaining records was uploaded into ASReview, which is an “open-source machine learning-aided pipeline with active learning for systematic reviews” (van de Schoot et al., 2021). Within ASReview, “prior knowledge” needs to be provided at first by indicating, based on the already acquired knowledge of the researcher, one relevant record and one irrelevant record for the current

review. Indicating more records establishes a more efficient “active learning process”. In this way, the “machine learning classifier” ASReview becomes capable to make a prediction about the relevancy of the uploaded records. Within the “active learning cycle”, ASReview suggests a novel record for screening and labelling (van de Schoot et al., 2021).

As a first step of the screening process, suggested studies were screened regarding their title and in the second step regarding their abstract. Following, the eligibility of the inspected studies was investigated by reading these entirely and by applying the inclusion criteria. In Figure 1, a flowchart of the inclusion and exclusion progress of scientific articles for the scoping review according to PRISMA is demonstrated (Moher et al., 2009). After a study is screened, the reviewer can select following labels within ASReview: 1 is labeled as relevant and 0 is labelled as irrelevant. Based on prior selected labels, novel records, predicted to have a higher relevancy, are suggested. The “active learning cycle” is carried on until the reviewer has arrived at a self-selected stop point (van de Schoot et al., 2021). In this review, the amount of 15 relevant studies was selected as a general stop point due to time constraints. One of the 15 incorporated studies was not suggested by ASReview but was still incorporated since this study was known to be of relevance for this review. This study was discovered while creating the search strings for the exploration within the databases. Therefore, 14 relevant studies were incorporated based on the suggestions of ASReview.

Last, since ASReview constantly reshuffles and therefore prioritizes all uploaded studies into a new list based on prior selections, study 15 to 30 on the list were screened regarding their titles after the study selection was finished. The final list of prioritized studies was downloaded as an excel file from ASReview. That was done to get some indication whether potential highly relevant studies were excluded because of the time constraints in conducting this review. The screening of the titles from study 15 to 30 revealed, that those studies give the impression of not being relevant for the aim of this review.

Data Extraction

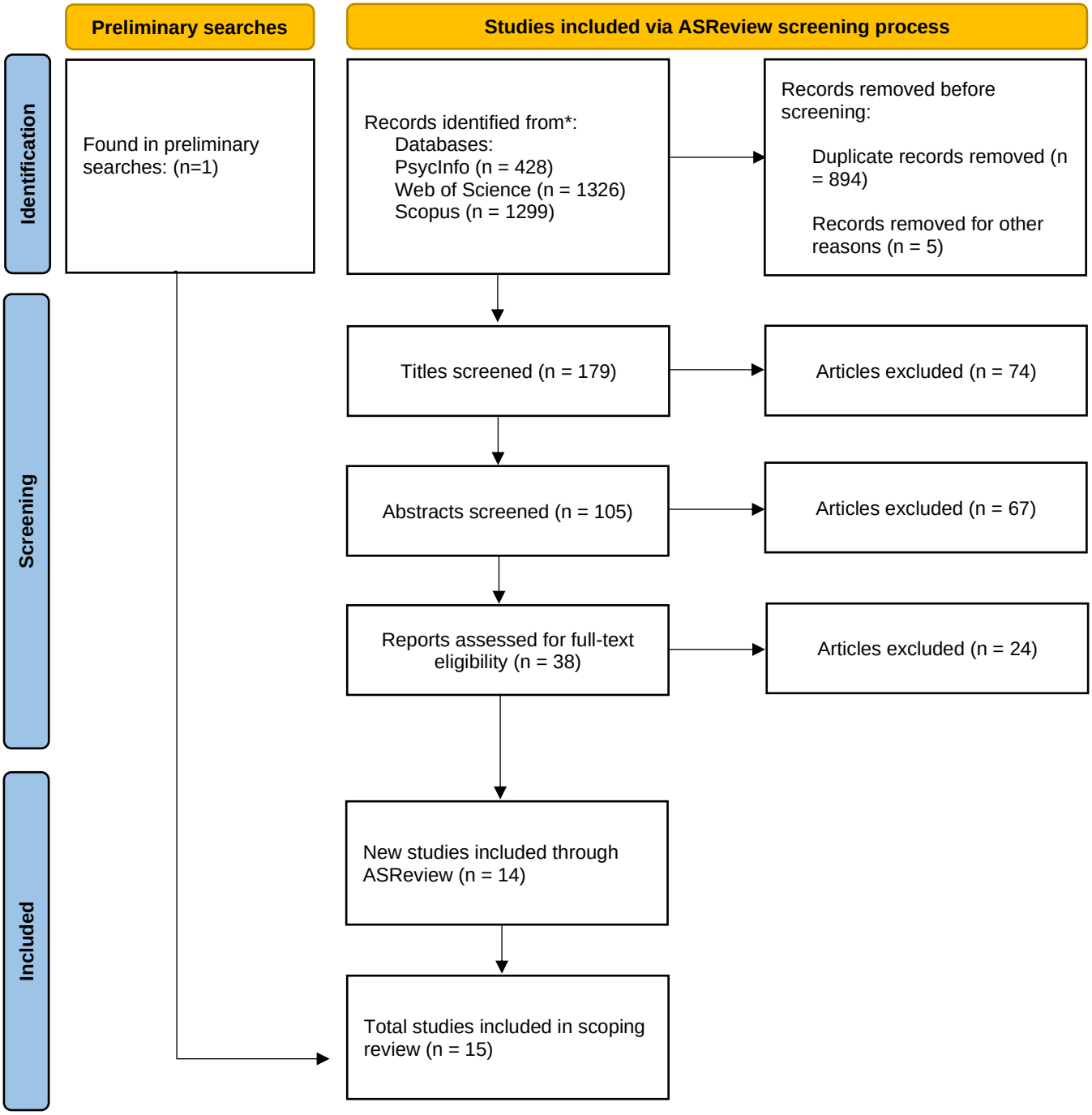
The discovered studies were entirely read and examined regarding the objective of this scoping review. The data from the incorporated studies were obtained through the efforts of one researcher. One area of interest were the populations for which VR was used to treat and assess aggression and violence. An overview of the populations and their potential aggression related issues was established within Table 2. Additionally, the size of the study samples was incorporated in Table 2 to provide a comprehension of the size dimensions of the incorporated studies. To obtain further information regarding the characteristics of the populations, characteristics such as age and gender were incorporated into Table 2 as well.

Another area of interest was the identification of the research designs (e.g. feasibility trials, RCTs) that were applied to study the effectiveness of VR in treating and assessing aggression and violence as well as the types of VR technologies that were used. That was done through the identification and description of the research designs and the VR technologies that were applied within the incorporated studies (see Table 3). Additionally, information about experimental conditions, duration and description of the VR interventions and assessments were incorporated in Table 3 to provide a better understanding of the incorporated studies. When the aforementioned information was not provided by studies, this was depicted through 'not specified'. Furthermore, it was investigated how participants in the various studies perceived the usability and feasibility of VR in treating and assessing aggression. Those data were discovered and inserted into Table 3 as well to provide a comprehensive summary. If those data of interest were not investigated or not reported by the incorporated studies, this was depicted through 'n.a.', which stands for not available.

Furthermore, it was investigated which proximal and distal outcome measures were used by the incorporated studies to assess the effects of the VR interventions on aggression. Besides that, the time points at which those outcomes measures were applied and what the outcome measures indicate regarding the effectiveness of the VR interventions in treating aggression and violence was investigated. Alternatively, regarding the incorporated studies which investigated VR as an instrument for assessing aggression and violence, the validity of VR in assessing aggression and violence was investigated. All those data were discovered and inserted into Table 4. At last, to investigate the conceptualizations of aggression and violence that were used by the incorporated studies, the used conceptualizations were extracted and inserted into Table 4 as well. Quotation marks were used to insert the original wording of the conceptualizations, so that there is not the possibility that the meaning will be lost by a reformulation. When this information of interest was not provided by the studies, this was depicted through 'not specified'.

Figure 1

Flowchart of the Inclusion and Exclusion Progress of Scientific Articles for the Scoping Review



Results

In total, 15 studies were incorporated in this scoping review. From the incorporated research articles, 10 articles examined VR interventions which had the purpose to positively influence aggression, violence, or violence-related constructs, while 6 research articles examined VR assessment instruments which had the purpose to assess aggression or violence.

Participant Characteristics

In Table 2 (see below), the characteristics of the investigated populations are summarized. From the incorporated studies, a diverse set of populations was discovered. The populations that were addressed with the VR assessment instruments were students (n = 4) and school-aged children with a diverse magnitude of problematic behaviours (n = 2). In the studies, where VR was examined as an intervention for treating aggression, the population that was addressed the most were children (n = 3). More specifically, children with aggressive behaviour issues (n = 1), children with neurodevelopmental disorders (n = 1) and children where aggression issues are not known (n = 1). Other populations, investigated by more than one study, were forensic psychiatric patients (n = 2) and adults, where a violent history is not known (n = 2). Other studies addressed “nursing home residents with dementia” (n = 1), Jewish Israeli (n = 1) and “veterans and active-duty military personnel with combat-related PTSD” (n = 1). For more details regarding the investigated populations, see Table 2.

All studies, where VR was examined as an assessment instrument, addressed exclusively male groups of participants (n = 6). In the studies investigating VR as an intervention to treat aggression, most studies targeted either exclusively male groups of participants as well (n = 4) or targeted groups of participants with both female and male participants (n = 4). Two studies not provided information regarding the gender of participants (n = 2).

Table 2

Participant Characteristics

	Authors	Treatment or Assessment	Sample, potential violence-related issues and sample size (N)	Gender	Age (years), mean (SD)
1	Kim et al. (2020)	Assessment and Treatment	"Healthy adult volunteers, recruited through on-line advertisements on a university announcement board" (37)	Male	(M = 22.20; SD = 13.20)
2	Kim et al. (2022)	Assessment	Adults from seven online communities (made use of the most by college students to obtain occupation) (58)	Male	HA group (n = 30) (M = 23.3; SD = 2.5); LA group (n = 28) (M = 23.6; SD = 2.7)
3	Lobbestael & Cima (2021) Study 1	Assessment	Single students (24)	Male	18 - 52 years old (M = 23.88; SD = 7.07)
4	Lobbestael & Cima (2021) Study 2	Assessment	Students (50)	Male	18 - 30 years old (M = 22.54; SD = 2.84)
5	Verhoef et al. (2021) a	Assessment	"School-aged boys with different levels of behaviour problems" (32)	Male	8 - 13 years old (M = 10.34; SD = 1.36)

6	Verhoef et al. (2021) b	Assessment	“Boys from special education for disruptive behavior problems (n = 118) and a random sample of boys from regular education (n = 66)” (184)	Male	7 - 13 years old (M = 10.22; SD = 1.30)
7	Alsem et al. (2021)	Treatment	“Children with aggressive behavior problems” (6)	Male	8 - 12 years old
8	Barreda-Ángeles et al. (2021)	Treatment	“Children from a public primary school in the area of Barcelona” (35)	Female (n = 18)/ Male (n = 17)	10 - 12 years old (M = 10.63; SD = 0.69)
9	Beidel et al. (2019)	Treatment	“Iraq and Afghanistan veterans and active duty military personnel with combat-related PTSD“(92)	Female (n = 6); Male (n = 86)	TMT group (n = 49) (M = 37.67; SD = 8.51); EXP group (n = 43) (M = 33.26; SD = 11.31)
10	Hasler et al. (2021)	Treatment	Jewish Israeli (100): “Majority (96%) served in the Israeli military”	Female (n = 71)/ Male (n = 29)	21 - 45 years old (M = 24.33; SD = 4.11)
11	Klein Tuente et al. (2020)	Treatment	“Forensic psychiatric inpatients” (128)	n.a	VRAPT (n = 64) (M = 39.4; SD = 10.6); Waiting List (n = 64) (M = 38.0; SD = 10.0)
12	Romero-Ayuso et al. (2020)	Treatment	“Estimated final sample size: 26 children with neurodevelopmental disorders“	n.a	6 - 11 years old

13	Smeijers et al. (2021)	Treatment	"Forensic psychiatric outpatients with aggression regulation problems" (30)	Male	(M = 36.13; SD = 12.88)
14	Sultana et al. (2021)	Treatment	"Nursing home residents with documented moderate to severe dementia" (24)	Female (n = 18)/ Male (n = 6)	≥ 65 years old (M = 85.8; SD = 8.6)
15	Ventura et al. (2021)	Treatment	Mexican men and an exclusion criterion: "a history of SH with legal consequences" (44)	Male	≥ 18 years old (M = 26.20; SD = 8.36)

Note. High aggression (HA), Low aggression (LA), Trauma Management Therapy (TMT), Exposure treatment only (EXP), Virtual reality aggression prevention training (VRAPT).

Study Characteristics and Usability/Feasibility of the Technology

In Table 3 (see below), the characteristics of the investigated studies are summarized. Regarding the 6 studies which examined VR as an assessment instrument, most studies applied a counterbalanced within-subject design (n = 3). Other studies applied a between-subject design (n = 1), executed a preliminary feasibility test (n = 1), or not specified the research design (n = 1). Regarding the 10 studies, where VR was investigated as an intervention for treating aggression, the most applied research design was a randomized controlled trial (RCT) (n = 4). Besides that, a research design that was applied more than once to study the effectiveness of VR in treating aggression was an experimental study with a counterbalanced within-subject design (n = 2) and a feasibility study (n = 2). Other research designs were a single site case series (n = 1) and a study protocol for a RCT (n = 1).

Regarding the 6 studies which examined VR as an assessment instrument, the type of VR technology that was used in all studies was a head-mounted display and controllers for the visualization and use of hands (n = 6). From those six studies, most studies made additional use of a predetermined space where participants had free movement possibilities (n = 4). Regarding the 10 studies, where VR was examined as an intervention for treating aggression, the type of VR technology that was used the most was a head-mounted display as well (n = 8). From those eight studies, most studies made additional use of headphones (n = 5) and different kind of controllers (n = 3). Besides that, some studies provided predetermined spaces, where participants had the possibility for free movements (n = 2), and other studies used a microphone with a voice transformer so that the therapists can interact with the participants through avatars with another voice (n = 2). Besides the studies which used a head-mounted display, one study used a screen (n = 1) and another study a “smart remote-controlled projector” (n = 1) to immerse participants within a virtual environment.

Regarding to how different populations perceive the usability/feasibility of the VR assessments instruments, studies reported that participants finished all tasks (n = 1), reported a low dropout rate (n = 1) and reported that participants had higher enthusiasm regarding a VR assessment compared to a non-VR based assessment (n = 1). Regarding VR as an intervention for treating aggression, most studies reported that participants showed a high motivation and acceptability for VR interventions (n = 5). This conclusion was based on a high inclusion rate, enjoyment of VR, high appreciation and active participation, completion of VR tasks, and a low attrition rate. In comparison, one study reported a high dropout rate (n = 1) and another a low adherence and recruitment rate (n = 1). Besides that, studies reported that VR established problem insight (n = 1), that participants were capable to remember their learning insights and

that VR evoked emotions and behaviours, suggesting that participants were capable of practicing and were deeply involved in VR (n = 1), that VR was moderately perceived of added value (n = 1), that participants' engagement was significantly higher in a VR intervention compared to a non-VR based intervention (n = 1) and that participants had a moderate to high confidence regarding treatment success and regarding further recommending the therapy (n = 1).

Table 3

Study Characteristics and Usability/Feasibility of the Technology

	Authors, Treatment or Assessment	Research Designs	Intervention				
			Conditions	Duration	Description	Type of VR technology	Usability and Feasibility
1	Kim et al. (2020): Assessment and Treatment	Pilot study (preliminary feasibility test)	One condition	"VR-based interactive feedback program": 45 min.	"VR training program targeted for modifying dysfunctional communication in the general population"	head-mounted display + controller	Acceptability: All participants finished all tasks; Participants showed acceptance for the program content
2	Kim et al. (2022): Assessment	Not specified	HA group; LA group Both groups: same VR intervention	"VR-based interactive feedback program": 45 min.	"Training program to modify dysfunctional communication, which used virtual reality (VR)"	head-mounted display + controller	No dropouts

3	Lobbestael & Cima (2021) Study 1: Assessment	Experimental Within-subject study (counterbalanced)	Reactive VR aggression condition; Proactive VR aggression condition	Not specified	"VR assessment tool to differently trigger and assess both reactive and proactive aggression"	"VR lab" (free movement) + head-mounted display + two "motion sensing controllers"	n.a.
4	Lobbestael & Cima (2021) Study 2: Assessment	Experimental Between-subject study	Reactive VR aggression condition; Proactive VR aggression condition	Not specified	"VR assessment tool to differently trigger and assess both reactive and proactive aggression"	Identical as in Lobbestael & Cima (2021) Study 1	n.a.
5	Verhoef et al. (2021) a: Assessment	First-phase pilot study (counterbalanced within-	One condition (One VR-based and one "vignette-based SIP assessment")	Approx. one week between VR- and "vignette-based SIP assessments"	"Interactive VR environment to assess children's aggressive SIP"	VR glasses + Free movement space + controllers	Enthusiasm after each assessment and after both assessments: Higher enthusiasm regarding VR assessment compared to "vignette-based assessment",

		subjects design)		(Each assessment: approx. 45 minutes)			$p = .001$, $d = 0.72$; $p < .001$, $d = 1.08$.
6	Verhoef et al. (2021) b: Assessment	Empirical study (counterbalanced within-subjects design)	One condition (One VR-based and one "vignette-based SIP assessment")	Approx. one week between VR- and "vignette-based SIP assessments" (Each assessment: approx. 45 minutes)	"Interactive Virtual Reality (VR) environment to assess children's aggressive SIP and responses"	VR glasses + Free movement space + controllers	n.a.
7	Alsem et al. (2021): Treatment	Small-scale feasibility study	One treatment condition	"YourSkills": 10 (45-minute) "weekly treatment sessions"	"Virtual reality–based version of the CBT treatment "YourSkills", in which children practice emotion regulation and social	Head-mounted display + headphones + controllers + Free movement space + microphone (Therapist)	**Therapists' reports:** Participants practiced more in VR than suggested; Active participation in VR **Children's appreciation:** High appreciation

					information processing”		
8	Barreda-Angeles et al. (2021): Treatment	Experimental Validation study (within-subject 2 x 2 mixed design)	One condition (Independent variables: 1) “Video content (bullying vs. neutral)”; 2) “Mode of presentation (VR vs. screen)”)	Videos: 93 - 143 seconds	“VR-based viewing of 360°-videos from the visual point-of-view (POV) of the victim in eliciting a realistic impression of the victim’s feelings in the viewer” (prevention of bullying)	“VR mode of presentation”: Head-mounted display + headphones “Screen mode of presentation”: laptop screen + mouse	n.a.
9	Beidel et al. (2019): Treatment	Randomized controlled trial	TMT vs. EXP	TMT and EXP: Both contained 29 sessions across 17 weeks (first component of TMT and EXP: 14 VRET sessions (3 times	“Virtual reality exposure therapy (VRET) realistically incorporates traumatic cues into exposure therapy”	head-mounted display + earphones	High treatment credibility: Moderate – High Confidence in treatment success; High Confidence regarding “recommending the treatment to a friend”; Overall dropout rate: 39% → Interpretation: “substantial dropout rate”

				in one week over 5 weeks))			
10	Hasler et al. (2021): Treatment	Experimental study (RCT)	VR; 2D video	"Orientation phase" of 30 seconds + "1-minute 360° video"	"VR that exposes individuals involved in intractable conflict to their opponents' point of view (POV) in an attempt to create a more critical perception and judgment of the ingroup's actions in violent confrontations with the opposing group."	"VR condition": head-mounted display + earbuds "2D video condition": screen	Significantly higher engagement in the "VR condition", $F(1, 96) = 4.15$, $p=.04$, $\eta 2=.04$, compared to the "2D video condition"
11	Klein Tuente et al. (2020): Treatment	Non-blinded multicenter RCT	"VRAPT"; Waiting list control (TAU) group	"16-biweekly sessions" (one session: approx. one hour)	VRAPT: SIP model as foundation	head-mounted display + headphones + controller + microphone (Therapist)	High motivation to participate in VRAPT (high inclusion rate); Learning insights were remembered; VRAPT evoked emotions and behaviours

12	Romero-Ayuso et al. (2020): Treatment	Protocol study for a randomized controlled trial	Experimental group (VR program: "SR-MRehab: Un colegio emocionante"); control group (basic "self-regulation program" without VR)	Interventions of both conditions: 10 sessions: 1 x 50 min. weekly sessions	"SR-MRehab: Un colegio emocionante", involving VR on emotional regulation and cognitive regulation with neurodevelopmental disorders"	Screen + "Kinect motion sensor" (body motion)	n.a.
13	Smeijers et al. (2021): Treatment	Double blind randomized controlled trial	ART (TAU) and VR-GAIME; ART and VR control game	ART: 12 weeks: 2 x 90 min. weekly sessions VR-GAIME and VR control game: First five sessions (both	"The motivational modification paradigm, serious gaming, and VR technology were combined to create a new treatment tool for the treatment of aggressive behavior: the Virtual Reality	head-mounted display + Free movement space	Participants enjoyed the VR-GAIME; VR-GAIME was moderately perceived of "added value"; VR-GAIME provided "problem insight"

				games max. 30 minutes)	Game for Aggression Impulsive Management (VR-GAIME)"		
14	Sultana et al. (2021): Treatment	A single site case series (nonrandomized and unblinded)	One condition	Intervention: Total of 2 weeks: 1 session per day (Mon - Fri); 1 session = 30 minutes	"Effect of non-head mounted VR experience reducing responsive behaviors in nursing home residents"	"Smart remote-controlled projector" + 360° videos and music	Acceptance: attrition 0 percent; "low adherence" and "recruitment rate"
15	Ventura et al. (2021): Treatment	Experimental study (counterbalanced within-subjects design)	One condition (Independent variables: "360° video (VR task)" vs. "narrative (traditional perspective-taking task)")	For each task: approximately 10 minutes; Narrative task a bit briefer	"360° video from a first-person perspective on empathy and related concepts toward a female victim of Sexual harassment (SH)"	"360°-video (VR task)": VR glasses	n.a

Note. Virtual reality aggression prevention therapy (VRAPT), Treatment as usual (TAU), Aggression Replacement Training (ART), High aggression (HA), Low aggression (LA), Trauma management therapy (TMT), Exposure treatment only (EXP), Social Information Processing (SIP).

Conceptualizations, Measurements, and Findings (Validity or Effectiveness)

Regarding the conceptualizations of aggression and violence that were used by the incorporated studies, four out of six studies which examined VR as an assessment instrument, referred to proactive and reactive aggression (*n* = 4). From those four studies, two different conceptualizations for reactive aggression as well as for proactive aggression were discovered. Besides that, three of those four VR assessment studies provided a general definition of aggression (*n* = 3) and two slightly different conceptualizations for aggression were discovered. In Table 4 (see below), the various conceptualizations of aggression, reactive aggression and proactive aggression are provided. Two out of the six studies did not provide any conceptualizations (*n* = 2). Regarding the 10 studies, where VR was examined as an intervention for treating aggression, most incorporated studies did not provide any conceptualization for aggression, violence or of a form of aggression (*n* = 6). The other studies referred to aggressive behaviour (*n* = 1), reactive aggression (*n* = 1), aggression and agitation (*n* = 1) and sexual harassment (SH) (*n* = 1). The variety of conceptualizations offered are summarized in Table 4 (see below).

Regarding the proximal and distal outcome measures that were used to assess the effects of the VR interventions on aggression, violence or violence-related constructs, a high amount of measurement instruments was discovered. Proximal outcome measures that were used by more than one study, were the Social Dysfunction and Aggression Scale (SDAS) (*n* = 2), the Reactive-Proactive Questionnaire (RPQ) (*n* = 2) and the Aggression Questionnaire (AQ) (*n* = 2). As examples for distal outcome measures, the Perspective-Taking Scale (PT-S) (*n* = 1) and the Empathy Scale (ES) (*n* = 1) can be mentioned. Some studies also made use of certain items specifically designed for their purpose (*n* = 3) and one study provided participants with a log so that they can observe their level of anger (*n* = 1). In Table 4, the whole variety of proximal and distal outcome measures that were used by the 10 incorporated studies for the assessment of the effects of VR interventions on aggression, violence or violence-related constructs are summarized.

Regarding the effectiveness of VR in treating aggression and regarding the validity of VR in assessing aggression, the following results were discovered. The six VR assessment studies discovered, that VR might be probably a favourable instrument to trigger and then to measure reactive aggression (*n* = 2), that VR is a favourable instrument regarding making an assessment of children's aggressive social information processing (SIP) and reactions (*n* = 2), that VR might correctly mirror the aggressive characteristics of a person and triggers a complementary response (*n* = 1), and that VR is able to make an assessment of the

communication type (dysfunctional) in certain interpersonal contexts (*n* = 1). Regarding the effectiveness of VR in treating aggression, the 10 treatment studies discovered that VR significantly improved anger (*n* = 2), significantly increased empathy (*n* = 2), significantly improved impulsivity and hostility (*n* = 1), significantly enhanced the sense of oneness and perspective taking (*n* = 1), significantly decreased violent attitude (*n* = 1), significantly enhanced functional communication (*n* = 1), significantly enhanced moral judgement (*n* = 1), and reduced aggression (*n* = 1). Compared to the positive results, incorporated studies reported that VR was not more effective in reducing aggressive behaviour (*n* = 2) and in reducing anger (*n* = 1) in comparison to a control group. Furthermore, VR was not more effective in reducing a violent attitude (*n* = 1) and in enhancing active perspective taking and empathetic emotions (*n* = 1) compared to another active treatment condition. At last, one study actually showed an increase in agitation (*n* = 1). For detailed findings regarding the validity of VR in assessing aggression and the effectiveness of VR in positively influencing aggression or aggression-related constructs, see Table 4.

Table 4

Conceptualizations, Measurements and Findings (Validity or Effectiveness)

	Authors	Conceptualizations of aggression and violence	Aggression-related outcome measures/ VR assessment tasks	Moment of assessment	Findings (validity or effectiveness)
1	Kim et al. (2020)	Not specified	**Assessment** "Task of exploring the communication style" (See Kim et al. (2020) for a description of the tasks) **Treatment - Violence-related outcome measures** PACI, IRI (subscales: "perspective-taking and empathetic concern"), DSI-R	**Assessment** One assessment **Treatment** "Task of practicing functional communication": "Initial, final communication scores"	**Assessment – "Task of exploring the communication style"** Able to assess the type of communication between family members; limited receptivity: cannot identify differences in social behaviours ("dysfunctional communication" with family compared to "dysfunctional communication" with friends) **Treatment – "Functional communication" and empathy** ↑ Significant increase of functional communication with another person having a dysfunctional communication

					approach/form (e.g. placating, blaming, computing)
2	Kim et al. (2022)	Not specified	**VR Assessment** "Task of exploring the communication style" and "task of expressing empathy" (See Kim et al. (2022) for a description of the tasks) **Psychological assessments:** AQ, STAXI	AQ and STAXI before the VR tasks	**Assessment** One dysfunctional communication approach (blaming) was significantly higher in "HA group" compared to the "LA group"; one dysfunctional communication approach (distracting) demonstrated a negative correlation "with two dimensions of the AQ (physical aggression: $r = -0.41$, $p < 0.05$; anger: $r = -0.40$, $p < 0.05$)"; "Emotional intensity scores" (HA group): positive correlation with (STAXI) "anger control-out scores ($r = 0.54$, $p < 0.01$)" Interpretation: tasks reveal characteristics associated with aggression and triggers a complementary reaction
3	Lobbestael & Cima (2021) Study 1	**Aggression** "behavior directed toward another with the	**Two VR assessment task** First task ("assessing proactive aggression" – "degree of	Two VR assessment tasks, assessment	**Validity** **"Reactive VR condition"**

		intention to cause harm that the other wants to avoid" **Reactive aggression** "uncontrolled or impulsive outbursts of anger that serve as a defensive reaction to provocation or frustration" **Proactive aggression** "relatively non-emotional and 'cold-blooded', often premeditated or planned, typically used to gain extrinsic benefits such as money or power"	aggression"): "number of strikes" against avatar Second task ("assessing reactive aggression" – "degree of aggression"): "number of strikes" against avatar	(RPQ; PPI-R) after both VR assessment tasks	"Degree of aggression": Significant positive correlation with RPQ (Total and reactive aggression) and PPI-R ("psychopathy total and cold-heartedness"). Interpretation: Some indication for construct validity **"Proactive VR condition"** "Degree of aggression": No significant positive correlation with RPQ and PPI-R. Interpretation: "Lack of validity"
4	Lobbestael & Cima (2021) Study 2	See Lobbestael & Cima (2021) Study 1	**Two VR assessment task:** First task ("assessing proactive aggression"): choice of action	Random assignment of participants to	**Validity** **"Reactive VR condition"** Convergent validity:

			Second task ("assessing reactive aggression"): "degree of physical aggression" ("number of hits" against avatar)	first completing measurements (PPI-R, RPQ, AQ) or VR assessment	"Degree of reactive aggression": Significant positive correlation with AQ ("total, verbal, hostility") PPI-R (total, "FD factor") Interpretation: A bit evidence for "good construct validity" **"Proactive VR condition"** "Degree of proactive aggression": No significant correlation to any study variable Interpretation: "Lack of validity"
5	Verhoef et al. (2021) a	**Aggressive behaviour** "any behavior directed towards another individual with the intent to cause harm" **Reactive aggression** "Impulsive aggressive response to perceived threat or provocation" **Proactive aggression**	**"SIP assessment" with VR:** Assessment of SIP through questions after every VR scenario	One "SIP assessment" with "six VR scenarios"	**Validity** **"SIP Assessment"** "Significant moderate" – high correlations between VR assessment and vignette assessment ("hostile intent attribution", "revenge goals", "aggressive responding") → Interpretation: "Good convergent validity"; Regarding "aggressive responding", SIP in VR showed "significantly larger variances"

		"Planned aggressive behaviour aimed at obtaining a desired outcome"			compared to vignettes $t(30) = 4.09$, $p < .001$ → Interpretation: VR has a higher "measurement sensitivity" in comparison to vignettes
6	Verhoef et al. (2021) b	**Reactive aggression** "Impulsive aggressive response to perceived threat or provocation" **Proactive aggression** "Planned aggressive behavior aimed at obtaining a desired outcome"	**Aggressive SIP assessment in VR**: "two instrumental gain scenarios" + "two provocation scenarios" → Assessment of aggressive behavioural reactions of participants in VR: observation + Self-report of "anger, intent attributions, goals, outcome expectancies, response evaluations" after every scenario	One "SIP assessment" with "six VR scenarios"	**Validity** "Provocation scenarios": VR triggered higher "aggressive SIP" and reactions in comparison to "vignettes"; Increased predictive validity: VR assessment ("assessment of aggressive SIP" and aggressive reactions) demonstrated an additive predictive significance superior to the "vignette assessment" in the four VR scenarios regarding predicting "real-life aggression" (2 - 12% additive variance explained) and "reactive and proactive motives" toward aggression (3 - 12% additive variance explained); Compared to vignettes, VR did not revealed more individual dissimilarities in "aggressive SIP" and reactions

7	Alsem et al. (2021)	**Reactive aggression** "aggression in response to perceived threat or frustration"	**"Weekly report measure"** Three items (rated by children and parents): 1) "This week I/my child fought with someone," 2) "This week I/my child kicked or beat someone," and 3) "This week I/my child called someone names"	Pre-treatment (week 1); post-treatment (week 10)	**Effectiveness** **Rated by parents** ↓ Reduction of aggression between the first and tenth week **Rated by children** No reduction of aggression between the first and tenth week
8	Barreda-Angeles et al. (2021)	Not specified	**Empathy for a victim** "7-item auto-administrated scale specifically designed to measure empathy towards victims during bullying episodes"	Pre-, post-measurement	**Effectiveness** ↑ Significant increase in empathy, "t(34) = 2.72; p = .01; d = 0.46."
9	Beidel et al. (2019)	Not specified	**Self-Monitoring** "Throughout treatment patients kept a log of daily behavioral ratings to monitor severity of anger"	Pre-, mid-, post-treatment, 3-month follow-up, 6-month follow-up	**Effectiveness** Anger ratings after "Virtual reality exposure therapy (VRET)": ↓ Significant reduction of anger; treatment successes at 6-month follow-up: sustained

10	Hasler et al. (2021)	Not specified	"Moral justification of soldiers' actions" (three items); "Engagement in active perspective-taking" (three items); "Empathetic emotions": participants evaluate their degree of empathy/sympathy/compassion	One assessment after watching the video	**Effectiveness** Participants of VR condition rated "soldiers' actions as significantly less justified and moral" in comparison to participants of "2D video condition", "$F(1, 97) = 7.40$, $p = .01$, $\eta^2 = .07$"; "Engagement in active perspective-taking" and "empathetic emotions": no significant difference between VR condition and 2D video condition "$F(1, 97) = 1.55$, $p = .22$"; "$F(1, 97) = .60$, $p = .45$".
11	Klein Tuente et al. (2020)	Not specified	**"Primary outcome – Aggression"** SDAS; AVL **"Secondary outcomes"** RPQ; BDHI-D; STAXI-2; NAS-PI); BIS-11; HIBT	Baseline (T1), post-treatment (T2), 3-month follow-up (T3)	**Effectiveness** Significant improvement in "hostility, anger control, and non-planning impulsiveness" in VRAPT condition in comparison to control condition at T2; no significant decrease in "aggressive behavior" after VRAPT in comparison to a waiting list control group

12	Romero-Ayuso et al. (2020)	Not specified	**"Emotional regulation and Cognitive Regulation"** NEPSY-II	Pre-, Post-Assessment, 6-month follow-up	n.a
13	Smeijers et al. (2021)	**Aggressive behavior** "Any behavior directed to another person, object, or animal with the intention to cause harm and can be divided into in an impulsive and a deliberate subtype"	**Primary outcome measures** SDAS; DEQ **"Secondary outcomes measures"** BIS/BAS scale; RPQ; AQ; STAS; VVDT; HIBT	Pre-, halfway, post-treatment	**Effectiveness** No significant difference between "VR-GAIME" and control game in decreasing aggressive behaviour and anger
14	Sultana et al. (2021)	**Agitation** "Inappropriate verbal, vocal, or motor activity that cannot be otherwise explained" **Aggression** "Deliberate, overt, and harmful acts toward	CMAI; GRC	Pre-, post-measurement	**Effectiveness** ↑ Increasing agitation (not for "verbal aggressive and non-aggressive domain")

		another person, object, organism, or oneself"			
15	Ventura et al. (2021)	Sexual harassment (SH) "occurs when people-mostly women-are targets of unwanted sexual comments, gestures, or actions"	ES, ATG-S, IOS, PT-S	Pretest (T1), posttest (T2)	**Effectiveness** "360° Video and narrative": ↑ Significant increase in empathy but higher levels of "empathy after the 360° video" compared to "after the narrative" ("marginally significant"); significant decrease in ↓ "violent attitude" but "differences between conditions" was not significant; "Sense of oneness and perspective taking" ↑ "significantly higher after the 360° video" compared to "after the narrative"

Note. The presented conceptualizations are sometimes also based on others works, referenced, or cited by the included studies; Social Dysfunction and Aggression Scale (SDAS), Reactive-Proactive Questionnaire (RPQ), Aggression Questionnaire (AQ), Hostile Interpretation Bias Task (HIBT), Barratt Impulsiveness Scale (BIS-11), Aggression Questionnaire (AVL), Buss-Durkee Hostility Inventory-Dutch (BDHI-D), Novaco Anger Scale and Provocation Inventory (NAS-PI), State Trait Anger Expression Inventory (STAXI), State-Trait Anger Expression Inventory-2 (STAXI-2), Discrete Emotions Questionnaire (DEQ), Behavioral Inhibition System/Behavioral Activation System (BIS/BAS) scale, State Trait Anger Scale (STAS), Virtual voodoo doll task (VVDT), Children's Neuropsychology Assessment Battery (NEPSY-II), Parent Adolescence Communication Inventory (PACI), Interpersonal Reaction Index (IRI), Differentiation of Self Inventory-Revised (DSI-R), Empathy Scale (ES), Attitude Toward

Gender-Based Violence Scale (ATG-S), Inclusion of Other in the Self Scale (IOS), Perspective-Taking Scale (PT-S), Cohen-Mansfield Agitation Inventory (CMAI).

Discussion

Answers to Research Questions and Links to Previous Research

Regarding study characteristics, following key findings can be presented. At first, it can be concluded that various research designs were applied. This could indicate that the VR aggression research field was motivated to investigate the topic of current interest in various ways to gain a diverse spectrum of insights and perspectives. Most studies examining VR as an assessment instrument, applied a counterbalanced within-subject design. A between-subject design and a preliminary feasibility test were discovered as well. Compared to that, most studies examining VR as an intervention for treating aggression, applied a randomized controlled trial (RCT). Experimental studies with a counterbalanced within-subject design, feasibility studies, a protocol study for a RCT and a single site case series were also discovered.

Regarding investigated populations, the comprehensive review by Dellazizzo et al. (2019) discovered various populations with aggression-related issues. The current scoping review secondly concludes that contemporary research on the current topic investigated various populations as well. Overall, the populations were adults without a violent history, children with varying degrees of aggression issues and adults with various types of aggression issues. An explanation for the various populations might be the broad variety of factors which can cause aggression-related issues, such as a deficiency to experience empathy for a recipient of aggressions (Dellazizzo et al., 2019). Besides that, when considering all 15 studies of this review, most studies addressed exclusively male populations. Some research suggested that men can be considered as being overall more aggressive compared to women (Zeichner et al., as cited in Lobbestael & Cima, 2021). Therefore, men could possibly be considered as a more important target group in aggression research.

Thirdly, this review concludes, that in contemporary VR aggression research mostly immersive VR technology is used. One component of immersive VR is the usage of head-mounted displays (HMDs) (Rizzo et al., 2018), applied by most studies in this review. The VR treatment studies mostly used headphones as well. Through the visual and auditory immersion in a virtual environment created through immersive VR technology, a perceptual experience can be created comparable to a visual and auditory perceptual experience of the real world (Rizzo et al., 2018). Supported by Diemer et al. (2015), immersive VR induces a higher degree of feeling present and more effectively triggers emotions. VR seem to provide the opportunity to confront perpetrators within computer-generated surroundings which are actually capable to trigger aggressive expressions (Fromberger et al., 2018). Therefore, it

might be valuable that contemporary VR aggression research seem to mainly use immersive VR technology, since a limitation of contemporary treatment methods is the restricted possibility to expose clients to provoking stimuli (McGuire, 2008). Exposing clients to provoking stimuli might help them to acquire experiences and skills in regulating other peoples' and their own anger in actual life conditions (McGuire, 2008).

Furthermore, various studies of this review used different kind of controllers. Controllers establish the possibility for users to actively engage with and manipulate the virtual environment (Rizzo et al., 2018). Moreover, some reviewed studies used predetermined spaces for free movement. In VR research this is established through HMDs and body-tracking sensors, which support user's interaction with a virtual environment since the virtual environment alters automatically based on the body movements of the user. Body-tracking sensors track the spot and motions of users and at the same time transfer those data towards a calculation system. Based on the transferred data, perceptual stimuli are adjusted for the user. The continuous sensing of the motions of users and the almost simultaneous adjustment of the presented virtual world establishes an immersive encounter with a virtual world (Rizzo et al., 2018). Therefore, controllers and predetermined spaces were also valuable technologies that were used by some reviewed studies since they might support the feeling of being present as well and could also contribute to effectively trigger emotions because they enhance the interaction with virtual environments.

Fourth, this review concludes, that reviewed studies did not use a clear overarching conceptualization of aggression. That might be in line with some prior research, which indicated that in research no overarching conceptualization of violence is applied (Rampling et al., 2016). This could indicate that research has not yet agreed on a clear overarching definition for aggression. In this review, four slightly different conceptualizations were discovered. Conceptualizations differed mainly regarding two aspects. Regarding the first aspect, only one conceptualization incorporated that the recipient of aggression wants to prevent hurt that might result from aggressive acts (Lobbestael & Cima, 2021). The motivation of the recipient of aggression to prevent hurt might be relevant for conceptualizing aggression since there can be contexts where the recipient does not have the motivation to prevent certain acts that result into hurt. An example could be a medical treatment that causes pain. Thus, when the recipient of aggression does not have the motivation or wish to prevent acts that cause hurt, hurt is not considered to be aggressive (Anderson & Bushman, 2002). In regard to the second aspect, definitions of aggression differed regarding if there is an intention to cause harm. Most studies incorporated this aspect in their conceptualizations. That might be

essential, because aggressions of humans must incorporate an intention to hurt someone else in order to be considered as aggressions. That is the case, because of the existence of "accidental harm", where there is no intention to harm anyone (Anderson & Bushman, 2002).

Furthermore, most reviewed studies did not define aggression as an overall construct. A reason could be that different studies referred to different kind of aggressions which have their own specific conceptualizations. At last, no study in this review conceptualized violence. Since violence is a severe form of aggression (Anderson & Bushman, 2002), it might not happen so often in the life of a single individual. The rare occurrence of violence might make it too difficult to assess this construct. That could explain why no reviewed study used an outcome measure for violence. Since it was not assessed, no study conceptualized violence.

Fifth, this review concludes, that various proximal and distal outcome measures were applied and that reviewed studies mostly did not use the same outcome measures (see Table 4). That might be the case since there is some disorientation in research regarding measuring aggression. Some research seems not to consider the multifaceted constitution of aggression and therefore makes use of different measurement instruments to assess specific elements of the construct and eventually use those measurement instruments as if they are the same measurements (García-León et al, 2002). This might suggest that studies in this research area should mainly use multiple and similar measurement instruments, so that aggression is assessed as the same multifaceted construct. This could be of value to be able to actually make conclusions about aggression after treatment. As an example, the RCT by Klein Tuente et al. (2020) incorporated different measurements for assessing different facets of aggression. They assessed anger and hostility separately. This might be of value since anger and hostility are sub traits of aggression (Buss & Perry, 1992). Anger is the emotional facet and hostility the cognitive facet of aggression (García-León et al, 2002). Those facets can also be measured through the Aggression Questionnaire (AQ), which has sufficient psychometric properties (Buss & Perry, 1992), and which was also used by several reviewed studies. Therefore, some studies used valid measurements for aggression. However, other studies used items specifically created for their purpose, which were not validated in validation studies before (e.g. Hasler et al. (2021)). This might be in line with some prior research which indicates a restricted existence of valid measurements for aggression (Wigham et al., 2022).

Sixth, this review concludes, that overall participants in the various studies had a high motivation and acceptability for VR. Surprisingly, forensic psychiatric patients practiced with and were deeply engaged in VR, obtained problem insight, and remembered learning insights. Therefore, VR seems to be motivating for populations, which are normally difficult to involve

in therapy (Klein Tuente et al., 2020). Possibly, VR promoted central treatment mechanisms such as motivation and engagement. Individuals' motivation to participate in therapy, where they have to carry out repetitious and, in some cases, uninteresting exercises can be enhanced through VR, since exercises can be integrated into game comparable surroundings. Being engaged can be considered as being captivatingly attentive or to captivatingly execute certain tasks. That is valuable for an active interaction with clinical interventions (Rizzo et al., 2018). That VR could have also promoted engagement, and therefore participants' motivation for VR, could be because most interventions in this review were delivered through immersive VR, which induces a higher degree of feeling present and more effectively triggers emotions (Diemer et al., 2015). In support of this, Klein Tuente et al. (2020) reported that VR triggered emotional and behavioural expressions, suggesting that participants were capable of practicing and were deeply engaged in the virtual surroundings. Deep engagement in VR could then possibly also explain why forensic patients obtained problem insight and remembered learning insights (e.g. Smeijers et al., 2021). Those findings are promising since forensic psychiatric patients are assumed to have restricted reflective abilities (Howells & Day, as cited in Smeijers et al., 2021). The findings could also suggest that VR can support clients to translate what they have learned in therapy into their actual life, which forensic psychiatric patients normally struggle with (Klein Tuente et al., 2020).

Seventh, this review concludes that VR was effective in positively influencing proximal determinants like anger, impulsivity, and hostility as well as distal determinants like functional communication, moral judgement, empathy, sense of oneness and perspective taking. The review by Dellazizzo et al. (2019) also discovered, that VR is effective in positively influencing anger, impulsivity, and empathy. A clear overarching explanation why VR had those positive effects cannot be drawn, since the reviewed studies investigated distinct, through VR administered, interventions. Besides that, the therapeutic mechanisms inherent in VR interventions are considered as rather unexplored (Sygel & Wallinius, 2021). However, a possible mechanism could be exposure (Rizzo et al., 2018). Exposing patients to aggressively stimulating scenarios in VR could trigger aggressive reactions and could establish the possibility to try out and learn alternative ways of behaving (Klein Tuente et al., 2018). The immersive nature of most VR interventions could have promoted the exposure process since immersive VR more effectively triggers emotions (Diemer et al., 2015). However, VR was not that effective in reducing aggressive behaviour directly. A clear explanation for this finding cannot be provided, since the two studies which reported this finding provided several study specific reasons (Klein Tuente et al., 2020; Smeijers et al., 2021).

Lastly, it can be concluded that VR might be favorable to assess reactive aggression, aggressive SIP of children, aggressive characteristics of persons and dysfunctional communication types in certain interpersonal contexts. The effectiveness of VR in assessing certain types of aggression and aggression related constructs might be related to immersive VR technology as well, since immersive VR technology more effectively triggers emotions (Diemer et al., 2015). In this context aggressive emotions and corresponding behaviours.

Study Limitations and Strengths

As a first limitation of this scoping review, the inter-rater reliability must be questioned. No other researcher was incorporated during the process of screening and determining the eligibility of research studies. Therefore, the review's study selection process had a reduced reliability. Secondly, most reviewed studies exclusively addressed male populations. Therefore, the review's findings cannot be generalized to more general populations, incorporating females (Lobbestael & Cima, 2021). At first glance, a limitation could finally be the general stop point of 15 relevant studies that had to be selected for study inclusion due to time constraints. In ASReview, less than ten percent of the uploaded records from EndNote were screened. Possibly, further relevant studies were missed. However, during the study selection it was noticeable that closely to the amount of 15 relevant studies, studies were not so relevant anymore. A higher number of study titles and abstracts had to be screened until ASReview suggested a relevant study. Besides that, the screening of the titles from study 15 to 30 on the final list of prioritized studies revealed after the study selection, that those studies should not be relevant for the review's aim. Therefore, in combination with the time constraints and the general stop point, this review might have actually incorporated almost all the relevant studies that could have been incorporated. This might be a strength of this review and might also present ASReview as a defendable strategy since most relevant studies were discovered in a time efficient way.

Directions for Future Research

Research and clinical practice might profit, when future research would use VR interventions and VR assessment instruments simultaneously in aggression treatment. According to Klein Tuente et al. (2018), it seems complicated to assess in an objective and reliable way if clients have actually acquired the ability to control their aggression. However, within a VR environment there is the possibility to investigate afterwards if clients have acquired improved capabilities to regulate their aggressive expressions (Klein Tuente et al., 2018). For example, VR could be applied as an instrument for triggering and assessing

aggressions in condemned perpetrators who are in a preparation stage for re-joining the public (Lobbestael & Cima, 2021). VR aggression assessment instruments could be applied for such variable purposes, however some of those need further revisions. For example, Lobbestael and Cima (2021) identified that their proactive aggression VR exercise had a restricted validity (see Table 4). Therefore, more advancements in this research area are needed.

This review discovered that VR aggression research was conducted with various populations. This is further suggested since various populations suffer from aggression-related issues. For example, research indicates an increased probability for aggression in people diagnosed with schizophrenia, where aggression seems to be mainly associated with psychosis and impulsivity (Pompili et al., 2017). VR research should also further invest into treating children with aggression-related issues, since obstinate and rebellious behavioural tendencies in early childhood can develop into moderate and serious patterns of aggression in youth and early adulthood (Dahlberg & Potter, 2001). At last, future research should incorporate females, so that findings can be better generalized. This might be also of value, since VR aggression assessment exercises have the potential to develop into instruments for revealing dissimilarities in aggression between genders (Lobbestael & Cima, 2021).

Moreover, in only two reviewed studies therapists directly interacted with participants within the VR environment. Those studies used a microphone with a voice transformer so that the therapist can interact with participants through avatars with another voice. One study was from Klein Tuente et al. (2020), applying VRAPT. VRAPT could exemplify coming developments of customizable interventions for the treatment of aggression (Dellazizzo et al., 2019). The extent of customizability of VR interventions towards patients' needs seem to rely upon the amount to which therapists play an active role in the virtual environment. If therapists can control virtual characters in actual time, a VR intervention might be considered as more customized compared to a VR intervention, where a therapist does not have to exert as much control over the virtual characters (Sygel & Wallinius, 2021). Such customizable VR interventions are desired to establish a decrease in violent behavioural expressions in prone populations (Dellazizzo et al., 2019) and are therefore suggested. However, in some contexts such customizable interventions could be not efficient enough since they might demand a considerable amount of time from a therapist.

Further suggestions for future aggression research are that it should be agreed on a clear overarching conceptualization of aggression to establish conceptual clarity. Besides that, many studies in this review did not conceptualize any form of aggression. Providing conceptualizations is suggested to establish transparency regarding which constructs are

investigated. Furthermore, the therapeutic mechanisms inherent in VR interventions should be investigated, since those are rather unexplored (Sygel & Wallinius, 2021). Moreover, follow-up interviews after VR aggression interventions and assessments could be suggested to obtain further insights into the usability and feasibility of VR in aggression research.

Despite limitations, the current scoping review has provided an overview of the current state of the art regarding VR interventions for treating aggression in diverse populations and therefore has updated the previous comprehensive review by Dellazizzo et al. (2019). The review by Dellazizzo et al. (2019) was conducted, since back then, there was a restricted amount of research regarding the treatment of violence through VR. Their review discovered only 12 studies from 2002 to 2019, where violence-related constructs were addressed through VR. Compared to that, the current review discovered 10 additional studies from 2019 to 2022. Furthermore, the current review has provided an overview regarding research investigating the assessment of aggression through VR, which has been identified as a seemingly new direction in aggression research (e.g. Lobbestael & Cima, 2021). Six studies were discovered regarding VR aggression assessment instruments. The amount of newly discovered studies from the last three years might suggest that VR aggression research seems to have comparatively risen. Therefore, a shortened time duration towards a next literature review can be suggested. Concluding, this scoping review has provided promising results regarding the treatment and assessment of aggression through VR in diverse populations.

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ACKNOWLEDGEMENTS

The author thanks Roberto Cruz Martinez for his support in using ASReview for conducting this scoping review.