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Virtual and augmented reality to develop empathy: a systematic literature review

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Abstract
Recent research suggests that Virtual Reality (VR) and Augmented Reality (AR) as immersive technologies are effective in developing empathy. The main reason behind this assumption is that immersive technologies allow people to experience perspective-taking. However, there is a lack of systematic literature reviews that summarize the current state of research on VR and AR to elicit empathy. This paper reports a systematic literature review of 37 academic papers published between 2007 and 2023. The following categories were analyzed in this review: field of education, data collection instruments, sample size, statistically significant results, technologies used, research design, advantages, limitations, and future research. The main findings of this review provide an overview of the current state of research on immersive technologies to elicit empathy and the future challenges in this field. Some of the main findings involve: VR/AR immersion devices are effective and appealing to participants; the Interpersonal Reactivity Index was found to be the most relevant self-report measure; and larger sample sizes (over 100 participants) are vital in VR/AR-based empathy research to provide a quantitative perspective on participants distribution.

Keywords Virtual reality · Augmented reality · Empathy · Systematic literature review

1 Introduction

The rise of disruptive technologies has redefined patterns of social interaction, showcasing an adaptation in the ways individuals engage with one another. Virtual reality (VR) is a collection of hardware, including computers, head-mounted displays (HMD), and sensors, designed to experience telepresence [1]. Moreover, VR is also considered a computer system that enables users to create artificial environments in which they can interact, navigate, and immerse themselves in a three-dimensional space [2]. Augmented Reality (AR) is a technology that allows a real-time combination of virtual

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objects and real objects so that it seems that the virtual objects are part of the real world [3]. The main difference between VR and AR is that in VR the participant is completely immersed in a computer-generated visual environment and everything that the participant sees is artificial while in AR the participant sees the real world with some virtual objects superimposed that seem to co-exist in the real world.

VR and AR have emerged as cutting-edge tools that allow users to immerse themselves in simulated environments and experience sensory sensations that simulate real life. Considering this, VR and AR often refers to "enhanced user interfaces." This encompasses viewing and navigating a 3D environment and interacting with its components in real time. For these creators, the user's interactive experience in the real world can be received through stimulation of the five human senses (sight, hearing, touch, taste, and smell). In the same line of thought, VR and AR can be an enhancer of prosocial behaviors through empathy, using tools intertwined with current technological developments. In other words, VR enables immersion in a simulated environment like real life, and through interaction with this sensory environment, it can strengthen communication and understanding of others' perspectives [4]. In that regard, VR has been considered a medium for perspective-taking [5]. It allows users of this technology to directly experience feelings and perspectives in a controlled and safe environment. Thus, VR can be understood as a set of computer technologies that provide access to simulated spaces through visual devices, where a person can acquire the sensation of presence, interact within that space and be in the shoes of others.

AR and VR can be used in different contexts for creating empathy and pro-social behaviors [6, 7]. From an etymological perspective, empathy can be understood from its Greek root Παθεῦν (epathón, to feel) and the prefix εν (an inseparable preposition meaning within). The origin of the term empathy dates back to 1873 when the philosopher Robert Vischer used the German term "Einfühlung" (feeling into) as an expression in art appreciation. Later, the term was used in English in the book "Lectures on the Experimental Psychology of the Thought-processes" in 1909, with a meaning of "feeling oneself into the other, being interpenetrated" [8, p.1].

Empathy can be initially defined as the emotional communication between one person and another, responding assertively within their social environment. Empathy is the ability to identify one's own emotions and those of others and respond to them constructively [9, p.40]. In other words, the development of these skills not only influences personal well-being but also has a significant impact on various areas of individual adjustment. In simpler terms, it can be understood as the process by which an individual has the ability to understand the feelings of others, allowing them to perceive reality from the other person's perspective rather than their own. Empathy is usually divided into emotional empathy and cognitive empathy [10]. One the one hand, emotional empathy means that the person is emotionally moved by a situation. On the other hand, cognitive empathy involves understanding thoughts and the emotion of others and this has been regarded as perspective taking.

It is worth mentioning that applications of VR and AR to develop empathy, while diverse and booming in various fields of study, lack extensive systematic research that reviews data from multiple individual studies to determine a general estimation of the effects of interventions, scope, limitations, variables of interest, and to assess the consistency and variability of results among individual studies. Therefore, it is of methodological importance to conduct a systematic review of current technological trends in various areas and fields of research where VR has been used as a medium for empathy development.

In alignment with this perspective, the present systematic review seeks to comprehensively address 11 research inquiries aimed at elucidating the correlation between exposure to immersive experiences in virtual reality (VR) or augmented reality (AR) and the cultivation of empathy. These 11 research questions have been categorized into four dimensions for the sake of facilitating understanding, organization, and presentation of information. The ensuing research questions steer the course of this review:

Application-domain related research questions The primary objective of these inquiries is to delineate how AR and VR have been employed to foster empathy across diverse professional domains and to ascertain the prevalence of significant findings in related studies. The relevance of these research questions lies in their capacity to enable researchers to pinpoint specific professional fields wherein AR/VR could potentially be applied to nurture empathy. Additionally, they aid in identifying research lacunae within various professional domains. The consequential significance of results in these studies provides valuable insights for researchers to recognize potential benefits conferred by these immersive technologies.

1. What are the professional fields of study where virtual reality or augmented reality have been used to promote empathy?
2. How many studies have reported statistically significant effectiveness percentages in research utilizing virtual reality or augmented reality to foster empathy?

Research questions about methodological aspects the objective of this set of research questions is to elucidate the methodological intricacies employed in studies investigating the promotion of empathy through AR and VR. The significance of these research questions lies in their capacity to provide insights into the methodologies utilized within the field. This comprehension is instrumental in evaluating the robustness and reliability of findings, fostering a deeper understanding of the research landscape in this domain.

3. What data collection instruments have been most used in studies utilizing virtual reality or augmented reality to foster empathy?
4. How many participants or research sample have been used most frequently in studies where virtual reality or augmented reality has been used to foster empathy?
5. What research design has been predominantly employed in studies where virtual reality or augmented reality has been used to foster empathy?
6. What percentage of studies have been reported as scientific articles versus conference papers?

Advantages, limitations and future research directions this set of research queries seeks to elucidate the merits, constraints, and prospective avenues for further investigation as documented in the literature pertaining to the application of AR and VR in empathy development. These inquiries hold significance as their responses encapsulate a concise overview of primary discoveries within the field, the principal constraints and challenges encountered, and the potential avenues for future research endeavors. Exploring these research questions contributes to a comprehensive understanding of the current state of

knowledge, facilitating informed discussions on the advancements, challenges, and potential future directions in the domain of AR and VR's impact on empathy.

7. What advantages have been described in studies where virtual reality or augmented reality has been used to foster empathy?
8. What limitations have been reported in studies where virtual reality or augmented reality has been used to foster empathy?
9. What have been the most frequent recommendations for future research in studies utilizing virtual reality or augmented reality to foster empathy?

Technology-related research questions this set of questions seeks to ascertain the specific technological hardware and software utilized in studies focused on the utilization of AR and VR in empathy development. The intent behind these questions is to discern the capabilities of particular devices and explore potential avenues for further enhancement, aligning with the imperative for increased research in this domain emphasized by Ventura et al. [11].

10. What equipment or technological tools have been used for immersion in virtual or augmented reality in the analyzed studies?
11. Which software has been used to develop immersive environments in research studies where virtual reality or augmented reality has been used to foster empathy?

In essence, the research team has formulated this set of research questions with the aim of delineating the research landscape concerning empathy development through AR and VR applications. From our standpoint, these research questions serve the purpose of offering a comprehensive survey of studies within this domain, enabling fellow researchers to pinpoint existing gaps in the literature and identify potential avenues for further research.

The rest of this paper is organized as follows: Section 2 describes the related work; Section 3 describes the method followed to conduct the systematic literature review. Section 4 presents the results organized by each research question. Section 5 presents the risk of bias analysis. Section 6 discuss the results obtained in this review. Section 7 describes the limitations of this review. Finally, Section 8 describes the implications of this review for education and training and Section 9 presents the conclusions of this study.

2 Related work

There is a large and growing body of literature that has demonstrated that VR can be effectively utilized as a tool for the development of social and emotional skills, such as empathy. In this context, various studies have investigated the viability of virtual reality in enhancing empathy in individuals. In this section, we present a summary of similar systematic reviews and meta-analysis on VR and empathy and we show how our systematic review extend previous studies in the field and how the systematic review fills a gap in the literature. Table 1 shows a summary of previous studies in the field.

Overall, previous systematic reviews, surveys and meta-analysis on VR and empathy have shown an overview of how VR has been used to create empathy and how some associated

Table 1 Related work

Author		Main findings and differences with the present article
Ventura et al. [14]	Virtual Reality as a Medium to Elicit Empathy: A Meta-Analysis.	Provoking empathy through virtual reality is a field of research that has grown exponentially. According to the meta-analysis, VR tasks seem to be more effective for improving attitudes towards prosocial behavior in comparison with traditional interventions. Moreover, the mean effect size on the effect of VR on perspective taking is moderate (d = 0.51). The sense of presence and the sense of embodiment seem to have a positive effect on perspective taking. This study is different from our review because it's a meta-analysis and covers literature up to 2020.
Martingano et al. [15]	Virtual reality improves emotional but not cognitive empathy: A meta-analysis.	There are multiple moderators of the effect of virtual reality on empathy. VR has a positive effect on emotional empathy. Cognitive empathy seems to require more effort and VR does not provide a shortcut. Some implications for the design of VR applications to foster empathy are presented in the paper. Violent content, did not have this positive effect on empathy and even lead to more aggressive results. The researchers also recommend to investigate possible cultural differences in the effectiveness of empathy interventions with virtual reality. This study is different from the present study because it is a meta-analysis and covers literature up to 209.
Seinfeld et al. [16]	Editorial: Virtual reality and empathy	There are three ways in which VR has been used to create empathy: (1) simulating intergroup encounters; (2) perspective-taking of discriminative behaviors; (3) perspective-taking of discriminative behaviors from the perspective of an outgroup member. The editorial provides an overview of some studies in the field but lacks a summary of quantitative data from these studies to provide a more accurate view of the current state of research in the topic and was not included in the current systematic review because we did not included scoping or other systematic reviews in our review. This article is an editorial and not a systematic review of literature. In that regard, it differs from the present article.

Table 1 (continued)

Author		Main findings and differences with the present article
Lara and Rueda [17]	Virtual Reality Not for "Being Someone" but for "Being in Someone Else's Shoes"	The authors show an important approach to immersive technologies in perspective taking but only from a conceptual perspective so it lacks an intervention and results that verify the applicability and impact that virtual and augmented reality may have on empathy. Employing virtual reality (VR) for the embodiment of another person poses considerable challenges due to the inherent disparity between the two individuals engaged in the experience and the observer's limited access to the pertinent prior experiences and sensations crucial for a profound comprehension of what it truly entails to embody that other person. Virtual embodiment, in essence, succeeds only in rendering these experiences "more experientially vivid" than the conventional practice of merely imagining the other's perspective through traditional perspective-taking methods.
Dhar et al. [18]	A scoping review to assess the effects of virtual reality in medical education and clinical care	In their comprehensive literature review, they identified 28 studies pertinent to the utilization of virtual reality (VR) in medical training, patient education, and clinical care, spanning diverse domains including mental health and rehabilitation. The results underscored the safety, efficacy, and participant engagement facilitated by VR systems. Nevertheless, notable variations were observed across the studies concerning design, content, devices, and evaluation methodologies.Moreover, the establishment of interdisciplinary teams encompassing researchers, the VR industry, and healthcare professionals is advocated as a strategic approach to augment comprehension in content development and simulation practices.
Gerry et al. [11]	Empathic Skills Training in Virtual Reality: A Scoping Review.	Exploratory review aiming to compile existing information on the use of Virtual Reality (VR) to train empathy and compassion. The reported findings indicate that existing applications for training empathy in VR tend to narrowly focus on a single component of empathy rather than combining multiple perspectives, such as emotional, cognitive, and behavioral aspects.

Table 1 (continued)

Author		Main findings and differences with the present article
Lee et al. [19]	Effective virtual patient simulators for medical communication training: A systematic review.	A systematic review exploring the design and effectiveness of medical communication skills training systems based on Virtual Patients (VP). The most common training scenarios using VP were taking medical histories and delivering bad news. It was found that effective VP systems include well-designed instructional interventions, human feedback, and reflection after the activity, but they are not solely dependent on the technology used. Thus, it is concluded that the use of virtual patients in medical education is a useful and effective strategy for developing communication skills, provided they are appropriately designed and implemented. This study differs from our study because the focus of our study is more general in nature and is not focused in medical education.
Foxman et al. [20]	Defining empathy: Interconnected discourses of virtual reality's prosocial impact.	In the course of their systematic review, the researchers scrutinized the nexus between virtual reality (VR) and empathy by analyzing a compendium of both popular and academic articles. The results illuminated a prevalent portrayal of empathy as an aspirational concept, a theme recurrently highlighted by both journalists and researchers. The emphasis was particularly placed on the transformative potential of immersive media, notably VR, in fostering prosocial change. This study bears relevance to our systematic review, as it delves into VR from a diverse array of sources, underscoring the significance accorded to empathy and the facilitation of prosocial change through a spectrum of immersive media. Without delving into this concept more profoundly, empathy will persist as a term that merely characterizes a potential future rather than constituting a vital and active component of it

Table 1 (continued)

Author		Main findings and differences with the present article
Tassinari [12]	The use of virtual reality in studying prejudice and its reduction: A systematic review.	A systematic literature review on how intergroup biases can influence behavior towards members of a specific group. Intergroup bias is defined as "an overall discrepancy in favor of the ingroup over the outgroup, while discrimination refers to biased behavioral intentions and/or overtly performed behavior that upholds the outgroup's disadvantaged position" [19, p. 7]. Although prejudice seems to be a relevant factor that might mediates or moderates the effect of VR on empathy as shown in the systematic review by Tassinari et al. [12], in our systematic review we did not focus on prejudice to avoid overlapping other systematic reviews such as [12, 13]. Instead, in the present systematic review we provide a more general landscape of the research done on AR and VR to increase empathy so that other researchers can identify research gaps and possibilities of further research.
Christofi et al. [13]	Virtual reality for inducing empathy and reducing prejudice towards stigmatized groups	A systematic exploration of the literature pertaining to virtual reality (VR) as a tool for eliciting empathy reveals a predominant focus on mitigating racial bias in the studies encompassed by the survey. Notably, the majority of these studies rely on self-reported instruments, highlighting a conspicuous dearth in research utilizing neuroscientific methods and biosensors to gather data concerning empathy and prejudice. While the survey provides an overview of ongoing research in VR concerning empathy and prejudice, our systematic review offers a more recent perspective, extending up to 2023, encompassing augmented reality (AR) as an immersive technology, and adopts a systematic approach, facilitating the presentation of quantitative measures depicting the current state of research in this domain. It is noteworthy that our systematic review does not duplicate the survey conducted by Christofi [14] but rather builds upon and extends their findings. The survey by Christofi [14] was excluded from our systematic review based on predefined criteria, which exclude surveys from the systematic analysis.

Table 1 (continued)

Author		Main findings and differences with the present article
Estrada et al. [21]	State of the art on immersive virtual reality and its use in developing meaningful empathy.	A systematic review of 34 articles published between 2015 to 2020 in the field of VR to develop empathy. The authors found that some of the studies in the field have some issues such as the quantity and diversity of participants as well as difficulties when quantifying empathy. The authors also found that the changes in empathy might be attributed to the novelty of the technology or the constant exposure to the intervention so the results should be interpreted with caution. Another finding was that it still not clear if perspective-taking with VR is more effective than other methods. Our review differs from the review by Estrada et al. [21] in two aspects: (1) in our review, we examine articles published up to 2023 as an update of the systematic review by Estrada et al.; (2) in our review we also included AR as another immersive technology with a potential to increase empathy. The research conducted in recent years has yet to provide adequate evidence to definitively ascertain whether immersive technologies significantly enhance learning processes or represent a more effective method for certain training processes. This ambiguity arises partly due to their emergent nature and recent integration into education. Additionally, the scarcity of studies focusing on their application in educational settings contributes to the lack of conclusive evidence regarding their efficacy and significance in enhancing learning experiences.

factors such as prejudice and intergroup bias might mediate or moderate the influence of VR on empathy. However, the systematic review presented in this article extend previous reviews by updating the research up to 2023 and addressing research questions that have not been addressed in previous reviews. The systematic review presented in this paper holds significant importance in the academic domain as its primary objective is to address aspects that have not been thoroughly explored in other systematic reviews, surveys or meta-analysis such as the ones reported in [11–13]. Particularly, by providing detailed information, it establishes a solid foundation for future investigations, facilitating the path for researchers who seek to consult tools and technologies utilized within the study's context, as well as identifying statistically significant impacts on empathy. Moreover, a rigorous examination of limitations encountered in previous research is proposed to establish a critical and reflective framework concerning the current frontiers of knowledge in the field. Considering the above, this systematic literature review contributes to the body of knowledge in the field of VR and AR to develop empathy and is a valuable resource to guide and suggest future research, offering clear and well-founded recommendations that will contribute to the advancement of this field.

The main contribution of this paper is that it summarizes previous research done on the use of VR and AR to develop empathy. This literature review updates previous literature reviews and surveys on VR to develop empathy and, to the best of our knowledge, is the first literature review that also summarizes research on AR to develop empathy.

3 Method

Following the guidelines outlined by Botella and Zamora [22], a systematic literature review is structured as follows:

1. Problem Formulation
2. Study Search
3. Study Coding
4. Analysis and Interpretation
5. Publication

Figure 1 depicts the PRISMA flow diagram. This diagram was generated based on the PRISMA 2020 statement [23]. It depicts the process of study identification and selection for the current systematic review. First, a total of 738 records were found after conducting the search. By excluding those published prior to 2007, those written in a language different to English or Spanish, and those different to articles, conference papers or book chapters, the dataset resulted in 636 records. Following the screening process, 58 records were excluded as the key terms (empathy and AR/VR) were merely mentioned in the paper but did not constitute the primary focus. Instances included references to AR and VR technologies without the main topic centering on empathy, or the co-occurrence of empathy, AR, and VR terms without the primary objective of fostering empathy through these technologies. Consequently, 578 records underwent evaluation for eligibility. During this phase, the authors meticulously reviewed the abstracts of each document to confirm its relevance to the designated topic. If the abstract did not provide sufficient clarity regarding the study's suitability, a comprehensive examination of the full text was undertaken to determine inclusion in the review. Ultimately, 37 studies met the criteria for inclusion. The authors then scrutinized the full text of these 37 articles to extract pertinent information and address the research questions.

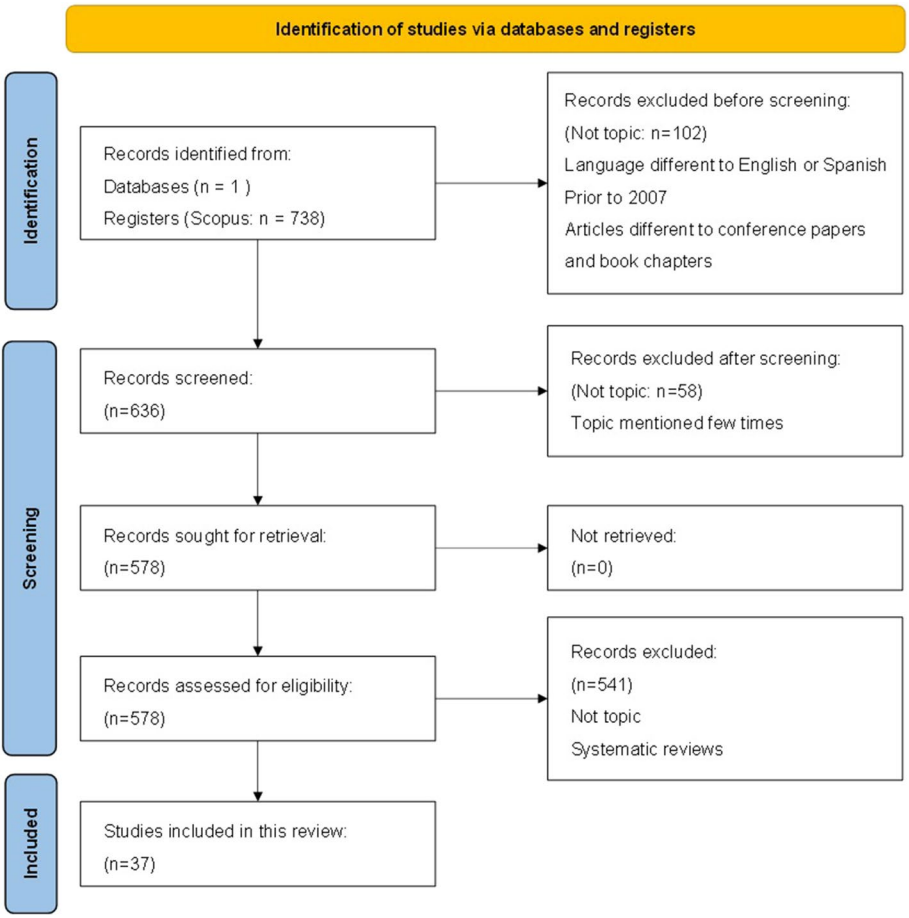

Fig. 1 PRISMA flowchart and selection of bibliographic material

It should be noted that the three authors of this article were in charge of collecting the articles (identification phase in Fig. 1) and the screening process. Then, two of the authors coded the selected articles through a matrix where all the inclusion and exclusion criteria were established. Then the third author also validated the coding process.

Taking into account the aforementioned aspects and the model proposed by Botella and Zamora [22], the impact of VR and AR to develop empathy was addressed through a systematic literature review of 37 articles retrieved from SCOPUS, using the search string (TITLE-ABS-KEY (“virtual reality”) OR TITLE-ABS-KEY (“augmented reality”)) AND TITLE-ABS-KEY (“empathy”). Scopus was selected as the primary database for retrieving studies because it is one of the largest abstracts and citation databases with a high quality of indexed publications. In this systematic review, we did not consider other databases because we had restrictions in accessing other databases such as Web of Science. Other databases such as APA PsycArticles were not included because the pilot searches did not retrieve relevant results for the scope of this systematic review.

In this review, we did not include any other term related to empathy because in the pilot searches before conducting the final search the inclusion of other terms such as prejudice, intergroup, perspective-taking among others restricted the number of results obtained and the results overlapped other existing systematic reviews. In that regard, we decided to maintain a more general search string to collect articles on the topic of VR and AR to develop empathy. In this way, we are able to provide a more general landscape of research instead of a more focused review that might overlap previous reviews.

The inclusion criteria considered in the systematic review were as follows:

- Studies conducted between 2007 and 2023. The timeframe was selected and studies before 2007 were not included because the pilot searches conducted prior to the main search for this systematic review showed that the articles before 2007 provided important background and foundations on the use of VR to develop empathy but did not provide insights into the effect of VR to develop empathy due to the maturity of VR before 2007.
- Research about the use of virtual reality and/or augmented reality to develop empathy.
- Studies written in English or Spanish.
- Journal papers, conference papers and book chapters.

Exclusion criteria was:

- Studies in languages other than English and Spanish, studies prior to 2007.
- Other systematic reviews (these were reported in the related work of this paper), and those that did not involve virtual reality and/or augmented reality as technologies for fostering empathy.
- Book reviews, notes, erratum, editorials, letters to the editor, doctoral theses, master's dissertations, and other non-scientific documents.

The 37 articles were thoroughly read and analyzed by two of the authors and each article was coded according to the categories defined by the researchers to consolidate and answer the research questions. The categories emerged from the research questions. Table 2 shows the 11 research questions grouped into the four dimensions (as presented in the introduction) and each research question has the category that was used to code each study.

Once the analysis categories were defined, they were coded into two groups based on their unit of measurement. On one hand, categories that could be numerically evaluated were included, organizing them into subcategories and tallying the number of identified studies and their respective percentages. This process was carried out using software such as Excel and JASP. On the other hand, categories with nominal characteristics that required interpretation were considered as the second group for coding, thus providing answers to the research questions. It is important to note that the coding matrix design and article consolidation were conducted by two researchers and validated by a third party.

4 Results

This section in the systematic literature review answers the research questions previously formulated. Through a detailed analysis of the existing scientific literature, relevant data has been collected and subsequently encoded according to the categories defined to be presented in the form of tables and structured subcategories with

Table 2 Categories for review

Dimension	Research question	Category
Application-domain related research questions	What are the professional fields of study where virtual reality or augmented reality have been used to promote empathy?	Professional study areas where virtual and/or augmented reality has been used to develop empathy.
	How many studies have reported statistically significant effectiveness percentages in research utilizing virtual reality or augmented reality to foster empathy?	Studies that have reported statistically significant percentages of effectiveness.
Research questions about methodological aspects:	What data collection instruments have been most used in studies utilizing virtual reality or augmented reality to foster empathy?	Data collection instruments have been used more frequently in studies.
	How many participants or research sample have been used most frequently in studies where virtual reality or augmented reality has been used to foster empathy?	Number of participants in each study
	What research design has been predominantly employed in studies where virtual reality or augmented reality has been used to foster empathy?	Type of research design adopted in the studies
	What percentage of studies have been reported as scientific articles versus conference papers?	Number of studies that have been reported as scientific articles or conference papers.
Advantages, Limitations and future research directions	What advantages have been described in studies where virtual reality or augmented reality has been used to foster empathy?	Reported advantages of using VR/AR to develop empathy.
	What limitations have been reported in studies where virtual reality or augmented reality has been used to foster empathy?	Reported limitations of using VR/AR to develop empathy.
	What have been the most frequent recommendations for future research in studies utilizing virtual reality or augmented reality to foster empathy?	Reported future research directions in the field of VR/AR to develop empathy.
Technology-related research questions	What equipment or technological tools have been used for immersion in virtual or augmented reality in the analyzed studies?	Equipment or technological tools used for immersion in virtual or augmented reality. Software used to build the immersive environments.

corresponding percentages. These tools allowed for a clear and comparative visualization of the results, facilitating the understanding of the patterns and trends identified in the research. The percentage analysis provides a deeper understanding of the data distribution and enables significant conclusions to be drawn regarding the research questions. This was achieved by dividing the frequency of each subcategory by the total number of subcategories mentioned and multiplying by 100 to obtain the percentage value. The following sub-section presents the results in detail, offering a comprehensive and rigorous overview of the collected data organized for each research question.

4.1 Application-domain related research questions

4.1.1 What are the professional fields of study where virtual reality or augmented reality have been used to promote empathy?

Table 3 describes the areas where studies on virtual and/or augmented reality have been reported, along with their respective nominal quantity of studies and percentages.

The analysis examined the different areas in which virtual or augmented reality has been used to promote empathy. The results revealed that research has been conducted in fields such as Experimental Psychology, Medicine, Education, Organizational Psychology, Social Psychology, Art, Marketing, and Neuroscience. When looking at the percentages, it was observed that most of the studies focused on Education (29.73%), followed by Experimental psychology (24,32%), and Medicine (16.22%).

4.1.2 How many studies have reported statistically significant effectiveness rates in research where virtual reality or augmented reality has been used to foster empathy?

Table 4 shows the results obtained for studies that have reported statistically significant results, as well as those where, due to the nature of the research, such significance does not apply.

The percentages mentioned address the question regarding the number of studies that have reported statistically significant effectiveness in research using virtual reality or augmented reality to foster empathy. It is noteworthy that 59.46% of the reviewed studies reported statistically significant differences. On the other hand, only 2.70% reported that there were no statistically significant differences.

Table 3 Areas of professional study where virtual and/or augmented reality has been used

Areas	Number of studies	Percentage (%)
Art	1	2,70%
Education	11	29,73%
Historical-contextual	2	5,41%
Marketing	1	2,70%
Medicine	6	16,22%
Neurosciences	1	2,70%
Experimental psychology	9	24,32%
Organizational psychology	2	5,41%
Social psychology	4	10,81%

4.2 Research questions about methodological aspects

4.2.1 What data collection instruments have been most used in studies utilizing virtual reality or augmented reality to foster empathy?

Table 5 shows the data collection instruments used, as well as the number of studies that report them and their respective percentages.

Table 5 reveals valuable information regarding the data collection instruments used in empathy studies. The Interpersonal Reactivity Index (IRI) stands out with a significantly high percentage of 18.75%, indicating its relevance and frequent use in empathy assessment. Furthermore, the results highlight the importance of two research approaches: the Likert-type surveys and interviews, both of which obtained similar percentages around 16,67%. This suggests that these methods are considered significant in measuring and understanding empathy. On the other hand, categories such as Multidimensional empathy scale, Virtual reality quiz, Cognitive and affective empathy test, Jefferson Empathy Scale (JSE) questionnaire presented lower percentages, approximately ranging from 2,08–4,17%. Additionally, other instruments such as questionnaires accounted 14.58%.

4.2.2 How many participants or research sample have been used most frequently in studies where virtual reality or augmented reality has been used to foster empathy?

Table 6 shows the number of participants in virtual reality or augmented reality studies, along with their respective percentages.

The participants were classified into different categories based on sample size. The category with the highest percentage corresponds to studies that included more than 100 participants, representing approximately 35.14% of the total. On the other hand, there were groups with lower representation, such as those with less than 51–75 and cases of 76–100 participants both with a percentage 8,11% and 10,81%, respectively. The intermediate categories show a range where sample size was not applicable due to the type of study,13,51% and, the studies with a range of participants between 25 and 50, accounting 16,22%.

4.2.3 What research design has been predominantly employed in studies where virtual reality or augmented reality has been used to foster empathy?

Table 7 contains the information on the percentages of research design types where virtual reality or augmented reality has been used to foster empathy.

Regarding the methodological design, five different types of research were found in the total number of studies reviewed. In terms of classification by types, experimental studies

Table 4 Studies that have reported statistically significant percentages of effectiveness in research where virtual reality or augmented reality has been used to promote empathy

Subcategories	Studies	Percentage (%)
Yes	22	59,46%
Not specified	12	32,43%
Does not apply	2	5,41%
No	1	2,70%

Table 5 Data collection instruments in studies where virtual reality or augmented reality has been used to promote empathy

Instruments	Studies	Percentage (%)
Interpersonal Reactivity Index for Empathy Measurement (IRI)	9	18,75%
Interviews	8	16,67%
Likert-type surveys	8	16,67%
Not specified	7	14,58%
Questionnaire	7	14,58%
Jefferson Empathy Scale (JSE) questionnaire	2	4,17%
Cognitive and affective empathy test	2	4,17%
Questionnaire of Empathy towards People with Intellectual Disabilities (EMP-ID)	1	2,08%
Perspective Taking Scale (IRI-PTS)	1	2,08%
Empathic Concern Scale (IRI-ECS)	1	2,08%
Virtual reality quiz	1	2,08%
Multidimensional empathy scale	1	2,08%

A higher overall score is added because multiple studies encompass various assessment instruments

Table 6 Number of participants or research sample that has been used more frequently in studies where virtual reality or augmented reality has been used to promote empathy

Participants	Studies	Percentage (%)
25<	6	16,22%
25–50	6	16,22%
51–75	3	8,11%
76–100	4	10,81%
100>	13	35,14%
Does not apply	5	13,51%

accounted for a total of 19 studies, representing 51.35% of the total studies reviewed. Following that, descriptive studies accounted for 7 studies, accounting for 18,92%. Qualitative studies accounted for a total of 4 studies, with an equivalent average of 10.81%. Quasi-experimental and mixed methods came next, each comprising 3 studies, and a percentage of 8.11%. Finally, Exploratory methods studies accounted for 1 article representing 2,70%.

4.2.4 What percentage of studies have been reported both as scientific articles and conference papers?

Table 8 shows a summary of the studies reviewed classified according to the typology as journal articles, conference papers or book chapters.

Regarding the analyzed articles that used virtual or augmented reality for empathy enhancement, there is a percentage of 83.78% of studies reported as journal articles, which represents a total of 31 articles from all the reviewed documents. This is followed by 4 conference papers, equivalent to 10.81%, and finally, two book chapter with a percentage value of 5.40%.

Table 7 Research design that has been used in studies where virtual reality or augmented reality has been used to promote empathy

Research design type	Studies	Percentage (%)
Experimental	19	51,35%
Descriptive	7	18,92%
Qualitative	4	10,81%
Quasi experimental	3	8,11%
Mixed	3	8,11%
Exploratory	1	2,70%

4.3 Advantages, limitations and future research directions

4.3.1 What advantages have been described in studies where virtual reality or augmented reality has been used to foster empathy?

Regarding the advantages described in studies where virtual reality or augmented reality has been used to foster empathy, it has been found that statistically significant changes occurred in various empathy-related aspects, increasing participants' ability to understand others' perspectives through the alteration of their virtual bodies. This is supported in the study by Wilding et al. [4], where participants gained a greater understanding of the challenges faced by individuals with disabilities when experiencing frustration within the virtual world.

Furthermore, Fisher [24] argues that although empathy in virtual reality is not directly established between a user and the subject of a real-life experience, the medium's capacity to place a body within a new space provides an opportunity for enhanced understanding of others through empathic realities. Additionally, statistical results and user testimonials reveal that the functionalities and elements implemented in the developed application contribute to the promotion of empathy compared to conventional methods of visualization and annotation in 360-degree videos. Findings indicate that experiencing news through a head-mounted display for 360-degree videos resulted in higher self-location and co-presence compared to interacting with the same video on a desktop or reading a textual version. Therefore, the use of virtual reality as a medium to support empathy generation holds promise due to the benefits and advantages it offers.

It is worth noting the significant contributions that VR offers to educational spaces, particularly in terms of additional pedagogical considerations regarding the use of VR in historical education, including incorporating virtual reality into constructivist approaches. According to Castaño & Gonzalez [25], university students attribute importance to AR and VR in the educational context: it improves academic performance, changes the way of teaching and learning, enables more experimental learning, increases the level of understanding, offers models of relevant experiences, and enhances possibilities for engagement

Table 8 Percentage of studies that have been reported as both scientific articles and conferences

Journal/Conference	Studies	Percentage (%)
Journal	31	83.78%
Conference	4	10.81%
Book chapters	2	5,40%

and interaction in the educational context. Furthermore, by generating a highly stimulating space for understanding the reality faced by others, a sense of shared frustration and pain is incorporated within the virtual world, leading participants to gain a greater understanding of the challenges faced by individuals with disabilities, autism, among others.

Parra Vargas et al. [26] illustrate the potential of a new VR organizational environment combined with machine learning to discriminate empathy dimensions. Additionally, this multi-method approach can increase knowledge about attention and behavior patterns and decision-making processes carried out by workers with different levels of empathy in complex work situations. Furthermore, unlike most assessments that use subjective self-report measures, this method combines neuroscience with VR, attributing greater objectivity and ecological validity to the results.

In summary, the findings suggest that augmented reality (AR) and virtual reality (VR) hold significance in enhancing individuals' capacity to comprehend others' perspectives. A primary advantage of AR and VR lies in their capability to immerse individuals in novel environments, fostering a deeper understanding of others' thoughts and conditions. Additionally, the heightened levels of interaction facilitated by AR and VR surpass the efficacy of 360-degree videos in empathy development. Finally, the integration of artificial intelligence methods with AR and VR technologies introduces novel possibilities for empathy cultivation, as applications can adapt to individual participants, offering more personalized scenarios to enhance empathic experiences.

4.3.2 What limitations have been reported in studies where virtual reality or augmented reality has been used to foster empathy?

Regarding the limitations evidenced in studies where virtual reality or augmented reality has been used to foster empathy, several aspects have been identified. One limitation is the sample size, as in many cases, the total number of participants was not significant enough to establish generalizability of the findings. This lack of a representative sample also reflects limited socio-demographic information, and in some instances, the absence of a control group, pretest and posttest data, and long-term follow-up of the results. Additionally, participants' unfamiliarity with virtual reality tools was detected, which were often presented in foreign languages or with proprietary licenses that limited their use. Furthermore, difficulties related to the COVID-19 pandemic were reported in studies that started before the preventive isolation measures were implemented. These studies had to change their initially planned methodology, requiring new organization and logistics to carry out the interventions in a timely manner, as mentioned by Villalba [27].

In terms of the content and format of empathy-building interventions, problems have been identified. Previous studies have shown that people exposed to persuasive messages can experience a psychological reaction, perceiving these messages as a threat to their freedom. As a result, a "boomerang" effect can occur, where the recipient acts in the opposite direction to that advocated by the message. This limitation implies not fully utilizing all emotions, as participants' responses may be influenced by individual differences or previous experiences with the displayed content, resulting in a poor and somewhat biased understanding of empathy and prosocial moral reasoning.

In line with the issues, inadequate methodologies have been implemented, which in turn present inconveniences. This includes qualitative data being used inappropriately,

risking objectivity, and studies that are solely descriptive, making it impossible to compare theory and practice to validate theoretical assumptions. Additionally, studies solely relying on self-reported measures limit researchers' ability to draw conclusions about how the use of virtual reality devices influenced participants' behavior, particularly their ability to empathetically communicate with individuals experiencing auditory verbal hallucinations (AVH). Since self-reported measures are based on participants' subjective perceptions, it cannot be certain if the perceived changes in empathetic communication would translate into empathetic behavior in real life. As mentioned by Libera et al. [28], researchers face challenges in drawing conclusions about how the use of devices influenced participants' behavior, especially their ability to empathetically communicate with individuals experiencing AVH. Due to the subjective nature of self-reported measures, it is uncertain whether these perceived changes in empathetic communication would translate into empathetic behavior in real-life situations.

In summary, the limitations identified in the reviewed studies revolve around factors such as small sample sizes, impeding the generalizability of results and the demonstration of genuine effects. The absence of long-term follow-ups and a scarcity of studies employing longitudinal research designs further underscore limitations within the research landscape. These findings align with Ventura et al.'s [11] observations. Additionally, the restricted familiarity with augmented reality (AR) and virtual reality (VR) equipment hampers the potential impact of these technologies on empathy, complicating researchers' efforts to measure their effects. The influence of individual differences on participants' responses introduces another layer of complexity, potentially leading to unexpected results in the effects of AR and VR. Lastly, the reliance on self-reported measures in some studies introduces a potential source of bias, as these measures may not fully capture participants' attitudes.

4.3.3 What have been the most frequent recommendations for future research in studies that have used virtual reality or augmented reality to promote empathy?

Regarding the recommendations for future research, one is to conduct longitudinal studies that assess empathy [29]. In longitudinal studies, the novelty of the technology effect can be controlled and determine the real affordances of VR and AR to develop empathy. Additionally, for upcoming research on virtual tools, empathy, and prosocial moral reasoning, these studies can be conducted with larger sample sizes and implemented in other countries to determine the effect of cultural differences on empathy. It is also emphasized the importance of research that integrates VR embodiment with clinical assessments and patient experiences, as stated by Aya Briñez et al. [30]. Embodiment is relevant for perspective-taking because the participant can take the body of another person and have a better experience that might increase empathy. Furthermore, future research is needed to explore the use of virtual reality for disability advocacy. On a different note, there were some comments about technical issues, such as interruptions during the presentation due to network problems or getting lost in the virtual world, especially for those who experienced VR for the first time. Li & Kyung Kim [31] suggest that future work should further examine the distinctions between visual perspectives and perspective-taking in virtual reality.

4.4 Technology-related research questions

4.4.1 What equipment or technological tools have been used for immersion in virtual reality or augmented reality in the analyzed studies?

Table 9 shows the technological means used for immersion in virtual reality environments, along with the number of related studies for this analysis and their respective percentages.

In this research question, the sub-category with the lowest number of studies were "Mobile AR", "Augmented Reality Cards", "Oculus Go 360", "Google Cardboard" and "NVIS nVisor SX111" each accounting for 2.70% of the studies. "360 Immersion Device" is the category with the highest percentage of studies after "Not specified," representing 18,92% of the total. Moreover, the subcategory "Not specified" has the highest number of studies, accounting for 37.84% of the total. An explanation of this result might be that some of the articles reviewed are theoretical so in the research the authors did not use a particular device.

4.4.2 Which software has been used to develop immersive environments in research studies where virtual reality or augmented reality has been used to foster empathy?

Table 10 shows the software that have been used to build immersive environments in research studies where virtual reality or augmented reality has been used to promote empathy.

Regarding programming languages and software, we found that software developed by Embodiedlabs*, Autopano Video, ImercyVE, AR Foundation, Optitrack Arena Motion, Ataturk, Skybox, Unreal, and AR Core accounted for only 2.5%, with each being the focus of a single study. Unity was used in 6 articles, representing a percentage of 15%. Additionally, it is found that 22 articles did not specify the programming language, or the tool used to develop de immersive experience, accounting for 55%. Finally, the software developed by https://www.embodiedlabs.com is mentioned, which was present in two of the reviewed articles, resulting in a percentage of 5%.

Table 9 Equipment or technological tools have been used for immersion in virtual or augmented reality

Equipment/Technology	Studies	Percentage(%)
Not specified	14	37,84%
360-degree video	7	18,92%
Oculus Rift	4	10,81%
Oculus Quest	5	13,51%
HTC Vive VR	2	5,41%
NVIS nVisor SX111	1	2,70%
Google Cardboard	1	2,70%
Oculus Go 360	1	2,70%
Augmented Reality Cards	1	2,70%
Mobile AR	1	2,70%

A higher aggregation is added due to multiple studies covering various technological tools

Table 10 Software that have been used to build immersive environments in research where virtual reality or augmented reality has been used to promote empathy

Software	Studies	Percentage (%)
Not specified	22	55%
Unity	6	15%
Avatar SDK	2	5%
Developed by Embodiedlabs*	2	5%
Autopano Video	1	2,5%
ImercyVE	1	2,5%
AR Foundation	1	2,5%
Optitrack Arena Motion	1	2,5%
Ataturk	1	2,5%
Skybox	1	2,5%
Unreal	1	2,5%
AR Core	1	2,5%

*https://www.embodiedlabs.com/

A higher overall score is added because multiple studies included various programming languages

5 Risk of bias analysis

A risk of bias analysis of the selected literature was carried out using the analysis tool proposed by Sterne et al. [32]. To perform this analysis, both qualitative and quantitative research designs, including experimental, non-experimental, and correlational designs, were considered. This is because these types of designs can be assessed using the tool, and a total of 32 articles were analyzed and the results are shown in Table 11. In this table, 5 dimensions are assessed by using a group of criterions and finally the overall bias for each study is calculated. Table 11 shows the average score obtained for each dimension for the total of articles analyzed Fig. 2.

The Table 11 with the case analysis shows the percentage values of the categories or dimensions and the slight biases.

On one hand, it can be observed that all the dimensions analyzed by the instrument meet or exceed the 74,1% threshold for low risk of bias overall. However, it is relevant to note that the dimensions of randomization, measurement of the outcome, and selection of the reported outcome show a percentage of medium risk or are categorized as 'some concerns,' with a maximum of 22,2% for the first, 3,7% and 7,4% for the latter two, respectively. It is important to highlight that only one study, in a single dimension

Table 11 Bias analysis

Level of bias	Randomization process	Deviations from intended interventions	Mising outcome data	Measurement of the outcome	Selection of the reported result	Overall Bias (in percentage)
Low risk	77,8	96,3	100	92,6	92,6	74,1%
Some concerns	22,2	0	0	3,7	7,4	22,2%
High risk	0	3,7	0	0	0	3,7%

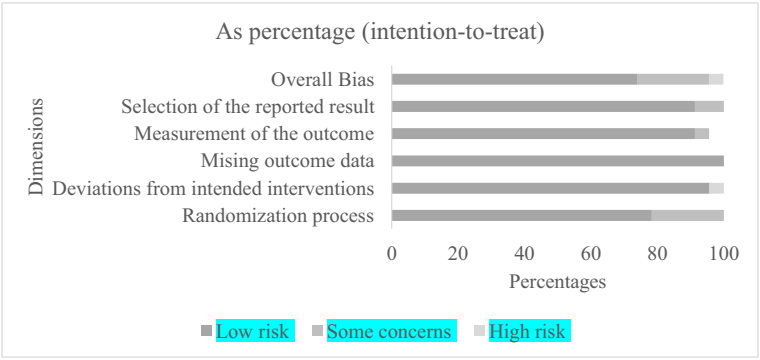

Fig. 2 Risk of bias analysis

(variation in the intervention), presents a high risk of bias due to a lack of information when assessing research criteria.

In general, a predominantly low risk of bias trend was obtained in the studies analyzed, with at least 74,10% assessed by both the researchers and the instrument's algorithm. However, the remaining 25,90% of the studies analyzed presented a moderate or high risk of bias. These studies may be more susceptible to systematic errors that could influence the results and conclusions, emphasizing the importance of caution when interpreting these findings and considering potential limitations in the available evidence.

6 Discussion

Although the different bibliographical sources consulted differ slightly in their focus of interest, such as the systematic review by Lee et al. [19], who explored the design and effectiveness of virtual patient-based medical communication skills training systems through 14 mostly quantitative studies, finding that effective virtual patient systems include well-designed educational interventions, human feedback, and reflection after the activity. Similar results to the systematic review presented in this paper are presented because it confirms that virtual reality increases and improves empathy processes, a result that is also present in the meta-analysis by Ventura et al. [14] whose main interest is focused on clarifying the existing research on virtual reality as a means to provoke empathy. The results reveal statistically significant positive changes in perspective taking after VR exposure. Likewise, Gerry et al. [11] investigated the efficacy of VR training for empathy and compassion. These components correspond to three key design characteristics of immersive VR technologies: biofeedback, perspective taking, and simulation, thus demonstrating that empathy can be trained and promoted thanks to different immersive technologies. This is something that is intended to be emphasized throughout this systematic review. Finally, Foxman et al. [20] propose that empathy is

a term that journalists and researchers aspire to show the potential of immersive media for prosocial change, building on fundamental research in the field. However, it is not the only field of interest. Therefore, our systematic review seeks to delve into various areas such as the arts, education, marketing, neurosciences, and other previously mentioned areas in which VR, AR, and empathy are treated as an area of interest. The main purpose of this systematic literature review is to show an overview of the research done in the field of VR and AR to promote empathy. In this section, the results and identified trends are interpreted, the effects and relationships found will be examined, as well as the differences or similarities between subgroups and analyzed variables. Furthermore, these results will be contextualized with the existing literature, allowing for the establishment of connections and significant contributions to the field of study.

6.1 Is AR and VR effective for fostering empathy?

By analyzing current research in the field of AR and VR to develop empathy, the main conclusion is that: It is premature at this early stage to consider VR as a medium that generates empathy over other media such as film, television or photography. This finding is also in line with the findings by Sora-Domenjó [33]. This finding is also supported by previous research stating that there still a lack of empirical support for the popular claim of VR as the "ultimate empathy machine" [34]. It is clear from the research that, under certain conditions, alterations in one's own digital representation of oneself can have a significant impact on how a person behaves in a virtual environment and that also affects their behaviors and attitudes, promoting some of the qualities of empathy. The results also indicate a lack of consensus when considering VR as a narrative medium that provokes empathy due to its immersive qualities. Empathy is a complex phenomenon where cultural and personal implications can affect VR experiences, modulating and differentiating empathy awareness depending on each person.

As shown in this article, some VR experiences designed to elicit empathy could generate negative and counterproductive effects in relation to the outgroup, depending on the subjects and the experimental design. It has been widely demonstrated that empathy in virtual reality films includes, at a minimum, social, cultural, and physical biases that can hinder empathic responses, and that different technical configurations may also be related to these affective responses. The role of interactivity and action in arousing empathy in virtual reality experiences using current technical configurations does not appear to be particularly relevant.

Furthermore, although some results suggest that VR cinematic experiences can modulate emotions and empathy in a short period of time for a specific group of people, the long-term effects of exposure with VR is still unclear, as researchers point out [33]. Based on the previous effects of mobile and web exposure, one can predict that immersive virtual reality technologies could eventually have similar or even worse results, affecting the same limbic areas involved in sympathetic resonance.

A related comment has been made about the need to consider the "conceptual position of the subject" in relation to the personal narratives developed (especially in VR social films) and the audience. Furthermore, at these stages of VR development, the reflection on the future consequences of using VR is necessary because the impact of VR on society is difficult to predict [33]. According to Sora-Domenjó [33], VR experiences could be defined as part of a collective reflection. In that regard, co-design and co-creation methodologies

could be effective so that stakeholders can actively participate in the design and development process so that VR experiences can be more effective to develop empathy in certain fields.

6.2 Methodological aspects of studies about AR and VR to develop empathy

It is important to contrast the results considering the findings by Dhar et al. [18], where it is stated that virtual reality immersion devices are safe, effective, and appealing to participants despite their interdisciplinary variations. From this perspective, it can be confirmed that these findings demonstrate the wide range of areas, especially education and medicine, that have explored the potential of virtual and augmented reality as tools for fostering empathy in a transdisciplinary manner, as evidenced in the Section 4 (Table 3). Additionally, the importance of considering multiple data collection instruments in the study of empathy is highlighted, with the IRI report being the most relevant. This result echoes the findings by Mestre Escrivá et al. [35]: "The Interpersonal Reactivity Index (IRI) (Davis, 1980, 1983) is one of the most widely used self-report measures to assess empathy. It has been applied in different studies to evaluate gender differences in empathic disposition" (p. 255). Furthermore, adapted questionnaires on the use of virtual reality enrich the understanding of this field and have vast potential to be explored as information gathering tools for subsequent social interventions, as presented in Section 4 (Table 5). Moreover, this result is in line with the results of the survey of literature by Christofi [13], who found that most of the research on VR and empathy has used self-reported instruments. An implication of this result might be that future researchers in this field should validate adaptations of the questionnaires to other languages or tailor-made questionnaires to ensure the reliability and validity of the instrument.

Moving on to the population perspective, the reported findings emphasize the need to consider studies with more than 100 participants, as corroborated in Section 4 (Table 6). This is relevant as it underscores the importance of sample size, offering a quantitative perspective on how participants are distributed in the context of fostering empathy through the use of virtual reality, as supported by García-García et al. [36]: "Calculating the number of participants to be included in a study (…) enables researchers to know how many individuals need to be studied to estimate the desired degree of confidence or difference between study groups" (p. 218). A bigger sample size allows researchers to conduct more robust studies that are less sensible to biased, reduce error, and increase precision. According to García-García et al. [36]. "a study with an insufficient sample size will estimate a parameter with low precision or will be unable to detect differences between groups, leading to erroneous conclusions" (p. 218).

Regarding the technological means for virtual immersion, Useche Rodríguez [37] pointed out that "360 videos can be used to present audiovisual content aimed at generating empathy in viewers. The research evaluates the effectiveness of the tool developed to support empathy in 360 videos" (p. 8). These technological means encompass a wide range of equipment used in various disciplines, with the most common being 360° video immersion devices and Oculus Rift mixed reality headsets, as evidenced in the Section 4 (Table 9). A possible interpretation of this result is that 360° videos are easy to deploy in VR devices, are cheaper to produce and provide more realism when compared to the development of a tailor-made VR or AR experience because VR/AR experiences require the support of software developers, and their development is more time-consuming and expensive. Moreover, in 360° videos the interaction is more limited whereas in VR/AR environments the

interaction is higher. Thus, we call for more research studies that involve the development of VR/AR experiences to really exploit the potential of this technologies and uncover the real affordances of the technology to foster empathy.

Another finding in this review of literature deals with the reporting of statistically significant results in research where virtual reality or augmented reality has been used to foster empathy. In total 45.95% of the studies (as shown in Table 4) report statistically significant results. This finding is in line with previous research that has found that VR is effective for perspective-taking but there are still some inconclusive results regarding empathy [14] so further research is needed. Connected to this idea, according to Ordoñez [38], some of the advantages of VR and AR include "multisensory learning (sight, sound, touch), cognitive improvement, effective combination of physical and virtual worlds, high-quality 3D content and animations in real space, elimination of geographical and temporal limits, content enrichment, and user-friendliness" (p.13). In this literature review, we confirmed that another advantage of VR and AR is that these technologies are effective for developing empathy and this finding contributes to the body of knowledge on the advantages of these technologies.

Experimental research designs have been used in studies of VR and AR to develop empathy (Table 7). Experimental research design can be useful to identify the affordances and benefits of VR and AR to foster empathy when compared to other technologies or strategies. Moreover, changes in empathy can be identified by using pre-post tests in experimental research designs. We recommend that, in future studies, researchers use experimental research designs and more robust statistical methods such as Structural Equation Modeling (SEM) to identify some predictors of empathy during VR and AR experiences that are used to foster empathy. Moreover, there is still a lack of research on the features of VR and AR that positively influence empathy and the personal traits that might moderate the factors that influence empathy. Thus, further research is needed in this aspect.

Additionally, it is highlighted that 83.78% of the research has been published in academic journals (31 out of 37 studies reviewed as depicted in Table 8) and only 4 studies were published in conference papers and 2 in book chapters. This result shows that most of the research conducted in the field has been peer-reviewed and this ensures the quality of the findings in each paper.

Research has demonstrated the potential of the new organizational context of VR combined with machine learning to distinguish empathy dimensions. Unlike most evaluations that use subjective self-report measures, this approach combines neuroscience with VR, providing greater objectivity and validity to the results. This, in turn, facilitates systematic reviews analyzing the role of these techniques in the importance of immersion in different contexts, as mentioned by Parra Vargas et al. [26].

6.3 Technological aspects

In this review, we identified some technologies used to create experiences in VR and AR to develop empathy. A remarkable result is that most of the studies analyzed in this review used 360° video in VR headsets. This means that participants were, in most of the cases, passive subjects in the VR experience and therefore the effect on empathy might have been diminished as a result of the lack of interaction with some elements in the experience. However, a positive aspect of using 360° videos is that the VR experience is closer to the reality. Previous research have demonstrated that social presence (which involves the sense of being there in VR) in 360° videos has a positive effect on prosocial behaviors

[39]. In that regard, future studies in which the participants' sense of presence can be maximized could contribute to a better experience increasing the levels of empathy. Moreover, another feature of VR that can be exploited for developing empathy is embodiment. Previous research has shown that empathy might increase when some features of embodiment are present [40]. The engagement and sense of presence created by VR experiences might intensify some emotional reactions such as empathy [41]. According to Ventura et al. [14], further research should determine if the sense of presence is better than the embodiment or not. The use of other VR headsets or fully immersive VR experiences is still limited so further research on the effect of highly interactive VR experiences (apart from 360° video) might provide more insights into the real effect of VR on empathy. To date, it is unclear which device would be the most effective for presenting VR or AR experiences and this is line with the call for more research stated by Ventura et al. [14].

Research on AR or Mixed Reality (MR) to develop empathy is still in its infancy. There are few studies that use AR or MR as immersive technologies to create empathy when compared to the number of studies using VR. An interpretation of this result might be that VR as a more immersive technology could be seen as a more powerful to develop empathy when compared to less immersive technologies such as AR or MR. However, further research needs to be conducted to determine the affordances of AR and MR to develop empathy. Mobile AR could be a more affordable way of creating experiences to develop empathy because smartphones are, in general, cheaper than VR headsets and most people own smartphones that can be used to deploy mobile AR apps. Mobile AR can be used to situate experiences in the user's context to develop empathy in certain physical contexts instead of recreating the entire context in VR.

Regarding the software used to develop immersive experiences to create empathy, most of the studies do not specify the software used and some other studies use general purpose commercial software. In that regard, there are no open source frameworks for designing and developing immersive experiences to create empathy. We call for more research to fill this gap in the literature so that the software allows to configure certain parameters to effectively create the experiences and save time in the development process.

Finally, the combination of VR/AR/MR technologies and artificial intelligence (AI) for training empathy is another field that deserves more research. The possibilities offered by generative AI might provide more personalized and adaptive experiences for empathy development and current research in this aspect is still in its infancy.

6.4 Limitations and future research directions

Finally, we found some limitations in the reviewed studies. First, the sample size was not significant, which affected the generalizability of the findings. In this sense, we suggest that future research consider larger research samples. Stavroulia & Lanitis [42] conducted a study with 69 participants. On the other hand, regarding the instructions given, some were not given adequately, guaranteeing that the participants understood and complied with them, causing confusion among the participants during the execution of the test. Additionally, in terms of descriptive studies, 9 studies were used (Table 7), which received negative criticism since the authors suggest that they reflected deficiencies such as the qualitative use of data, which prevented a comparison between theory and theory. the practice.

However, as a future recommendation, delving into qualitative studies is suggested since this methodology also has valuable theoretical support. According to Quecedo & Castaño [43], "a qualitative study allows us to know the personal aspect, inner life, perspectives,

beliefs, concepts (…) successes and failures, moral struggle, efforts," which are close and congruent traits when fostering empathy.

7 Limitations of this review

The main limitation of this study is that some papers might have been published in other bibliographic databases such as Web of Science and those papers were not included in this review. The categories considered in this review of literature are not unique. Other categories might be considered in the systematic literature review to obtain more information about the current state of research in the field of VR and AR to develop empathy.

8 Implications for education and training

In the realm of education, it is well-established that basic empathy is a trainable trait rather than an inherent quality [44]. This implies that individuals do not possess a predetermined amount of empathy at birth but instead develop and acquire this attribute over time. Consequently, the pivotal implication drawn from the review presented in this paper is that virtual reality (VR) emerges as an effective medium for training and fostering empathy across various educational levels, including primary, secondary, and higher education. VR's unique capabilities allow for intricate and nuanced empathy training programs that surpass the possibilities offered by other technologies [45]. Such training programs hold significant potential for students, teachers, and society at large, fostering better relationships within the educational community, cultivating prosocial behaviors among students, broadening perspectives, promoting understanding of global inequalities, and contributing to conflict resolution and mediation.

While there exists an expanding body of literature on empathy training within healthcare, medicine, and related disciplines [46], a noticeable research gap is observed in the training of empathy within other educational domains such as psychology, marketing, and art. Consequently, future research endeavors should concentrate on investigating how empathy can be effectively trained in these diverse fields, exploring the unique variables that influence this trait within specific disciplines.

Within this review, the Empathy Index (IRI) emerged as the most employed instrument for measuring empathy. However, future studies in the realm of education and training should consider validating this instrument within educational contexts or developing new instruments tailored to educational settings. In accordance with Villalba et al.'s [27] recommendations, a periodic revision of the IRI instrument is suggested to incorporate current discussions and advancements in empathy research. Additionally, the incorporation of physiological measures and eye-tracking technologies holds promise in offering a more objective assessment of the impact of VR on empathy.

Despite the progress in research on empathy development utilizing augmented reality (AR) and VR, a notable research gap persists in understanding how to effectively train empathy across different educational levels using these technologies. Thus, an additional implication derived from this review is the imperative need for further research dedicated to elucidating mechanisms, frameworks, and methodologies for empathy training across diverse educational levels.

9 Conclusions

This systematic review underscores the potential of VR and AR as effective tools for fostering empathy in various domains. It emphasizes the importance of larger sample sizes, validated questionnaires, and rigorous research designs to advance our understanding of the VR/AR-empathy relationship and shed light on the specific factors and personal traits that influence empathetic experiences in virtual environments. It is important to note that there is a lack of research on the use of AR or MR to develop empathy and this is a gap in the literature that requires more attention. This systematic review presents a comprehensive analysis of the relationship between VR/AR and empathy, yielding significant findings:

VR/AR immersion devices are not only safe but also effective and appealing to participants, corroborating previous research. These results confirm the broad application of VR and AR in fostering empathy, particularly in education and medicine. However, more research is needed to identify the real affordances of VR/AR to develop empathy.

To study empathy, it is crucial to employ multiple data collection instruments, with the IRI report emerging as the most relevant self-report measure. However, we suggest that future research can combine self-reported instruments with more objective measures such as physiological measurements to have more insights into the effect of AR/VR technologies on empathy.

The use of adapted questionnaires tailored to VR/AR enhances the understanding of the field and holds potential as information-gathering tools for social interventions. Future researchers should validate questionnaire adaptations in different languages or develop customized instruments to ensure the reliability and validity of the assessment.

Large sample sizes (over 100 participants) are vital in VR/AR-based empathy research to provide a quantitative perspective on participant distribution. Robust studies with larger sample sizes minimize biases, reduce errors, enhance precision, and facilitates generalizability of results.

Technological means for virtual immersion, such as 360° videos and VR headsets, have gained popularity in fostering empathy across diverse disciplines. While 360° videos offer cost-effective and realistic experiences, VR environments provide higher interaction possibilities. Furthermore, the noticeable absence of research on augmented reality (AR) and mixed reality (MR) for empathy development becomes apparent in the studies scrutinized. Consequently, it is imperative for future research endeavors to delve deeper into and explore the untapped potential of AR or MR experiences in promoting and enhancing empathy.

Approximately 45.95% of the studies reported statistically significant results regarding the effectiveness of VR or AR in fostering empathy. However, the field still lacks conclusive evidence, necessitating further research to gain a comprehensive understanding of the impact of VR/AR/MR on empathy.

VR and AR offer various advantages, including multisensory learning, cognitive improvement, content enrichment, and user-friendliness. This review adds to the body of knowledge by highlighting their effectiveness in developing empathy.

Experimental research designs have commonly been employed in VR/AR empathy studies to identify the affordances and benefits of these technologies. Pre-post tests in experimental designs enable the identification of changes in empathy. Future studies should utilize experimental designs and robust statistical methods, such as Structural Equation Modeling (SEM), to identify predictors of empathy during VR/AR experiences and explore the influential features and personal traits.

Appendix

Table 12 List of papers included in the systematic literature review

#	Authors	Title	Reference
1	Stavroulia, K. and Lanitis, A.	The role of perspective-taking on empowering the empathetic behavior of educators in VR-based training sessions: An experimental evaluation	[42]
2	Wilding, C., Young, K., Cummins, C., Bowler, C., Dean, T., Lakhani, A., Blackberry, I.	Virtual reality to foster empathy in disability workers: A feasibility study during COVID-19	[4]
3	Hu, S. and Lai, B.	Increasing empathy for children in dental students using virtual reality	[44]
4	Cummings, J., Tsay-Vogel, M., Cahill, T. and Zhang, L.	Effects of immersive storytelling on affective, cognitive, and associative empathy: The mediating role of presence	[34]
5	Vázquez, J.	Realidad Virtual y desarrollo de competencias de reconocimiento y empatía contra la violencia de género	[45]
6	Estrada, E., San Martín, A., Jacques-García, F.	State of the art on immersive virtual reality and its use in developing meaningful empathy	[27]
7	Gil, K., Rhim, J., Ha, T., Doh, Y., Woo, W.	AR Petite Theater: Augmented reality storybook for supporting children's empathy behavior	[46]
8	Fisher, J.	Empathic Actualities: Toward a Taxonomy of Empathy in Virtual Reality	[24]
9	Bertrand, P., Guegan, J., Robieux, L., McCall, C., Zenasni, F.	Learning Empathy Through Virtual Reality: Multiple Strategies for Training Empathy-Related Abilities Using Body Ownership Illusions in Embodied Virtual Reality	[40]
10	Arbol, L. and Nielsen, M.	Immersion and empathy: the question of the adoption of virtual reality	[47]
11	Kizhevska, E., Ferreira-Brito, F., Guerreiro, T., Luštrek, M.	Using Virtual Reality to Elicit Empathy: a Narrative Review	[48]
12	Banchoff, C., Fava, L., Martin, E.	Realidad aumentada y realidad virtual aplicadas a proyectos con fines sociales	[49]
13	Van Loon, A., Bailenson, J., Zaki, J., Bostick, J., Willer, R.	Virtual reality perspective-taking increases cognitive empathy for specific others	[7]
14	Sora-Domenjó, C.	Disrupting the "empathy machine": The power and perils of virtual reality in addressing social issues.	[33]
15	Archer, D. and Finger, K.	Walking in Another's Virtual Shoes: Do 360-Degree Video News Stories Generate Empathy in Viewers?	[50]

Table 12 (continued)

#	Authors	Title	Reference
16	Seinfeld, S., Hortensius, R., Arroyo-Palacios, J., Iruretagoyena, G., Zapata, L., de Gelder, B., Slater, M., Sanchez-Vives, M.	Domestic Violence From a Child Perspective: Impact of an Immersive Virtual Reality Experience on Men With a History of Intimate Partner Violent Behavior	[51]
17	Kim, J., Kim, T., Kim, S-I., Jang, S., Lee, E., Yoo, H., Han, K., Hong, H.	The Workplace Playbook VR: Exploring the Design Space of Virtual Reality to Foster Understanding of and Support for Autistic People	[52]
18	Bard, J., Chung, H., Shaia, J., Wellman, L., Elzie, C.	Increased medical student understanding of dementia through virtual embodiment	[53]
19	Elzie, C., Shaia, J.	A Pilot Study of the Impact of Virtually Embodying a Patient with a Terminal Illness	[54]
20	Jiang, Z., Meltzer, A., Zhang, X.	Using virtual reality to implement disability studies' advocacy principles: uncovering the perspectives of people with disability	[55]
21	Patterson, T., Han, I., Esposito, L.	Virtual reality for the promotion of historical empathy: A mixed-methods analysis	[56]
22	Wang, Y., Chen, C., Nelson, M., Sar, S.	Walk in my shoes: How perspective-taking and VR enhance telepresence and empathy in a public service announcement for people experiencing homelessness	[57]
23	Galvão, D., Biazzi, R., de Morais, G., Miranda, C.	Women in science: a Brazilian experience through immersive narratives in 360° videos	[58]
24	Hasler, B., Landau, D., Hasson, Y., Schori-Eyal, N., Giron, J., Levy, J., Halperin, E., Friedman, D.	Virtual reality-based conflict resolution: The impact of immersive 360° video on changing view points and moral judgment in the context of violent intergroup conflict	[59]
25	Li, B., Kyung Kim, H.	Experiencing organ failure in virtual reality: Effects of self- versus other-embodied perspective taking on empathy and prosocial outcomes	[31]
26	Parra, E., García, A., Torres, S., Carrasco-Ribelles, L., Marín-Morales, J., Alcañiz Raya, M.	Virtual reality stimulation and organizational neuroscience for the assessment of empathy	[26]
27	Bacca-Acosta, J., Avila-Garzon, C., Sierra-Puentes, M.	Insights into the Predictors of Empathy in Virtual Reality Environments	[60]
28	Della, C., Goosse, M., Larøi, F., Willems, S.	Examining the impact of experiencing auditory verbal hallucinations from a first-person perspective on the degree of empathy and stigmatization in a group of psychology students: A study using 360° immersive videos	[28]

Table 12 (continued)

#	Authors	Title	Reference
29	Peng, X., Wu, L., Xie, X., Dai, M., Wang, D.	Impact of Virtual Dementia Tour on empathy level of nursing students: A quasi-experimental study	[29]
30	Marques, A., Gomes Veloso, P., de Almeida, R., Correia, A., Pereira, J., Queiros, C., Pimenta, R., Pereira, A., Silva, C.	Impact of a Virtual Reality-Based Simulation on Empathy and Attitudes Toward Schizophrenia	[61]
31	Tassinari, M., Aulbach, M., Jasinskaja-Lahti, I.	Investigating the Influence of Intergroup Contact in Virtual Reality on Empathy: An Exploratory Study Using AltspaceVR	[62]
32	Zamin, N., Khairuddin, F., Rambli, D., Ibrahim, E., Soobni, M.	Building Empathy in Young Children Using Augmented Reality: A Case Study in Malaysia	[63]
33	Vázquez, J.	Realidad Virtual y desarrollo de competencias de reconocimiento y empatía contra la violencia de género	[45]
34	Çakiroğlu, U., Aydin, M., Köroğlu, Y., Ayvaz Kina, M.	Looking past seeing present: teaching historical empathy skills via augmented reality	[64]
35	Schutte, N., Stilinović, E.	Facilitating empathy through virtual reality	[41]
36	Jones, S., Dawkins, S.	Walking in someone else's shoes: creating empathy in the practice of immersive film	[65]
37	López-Faican, L., Jaen, J.	Design and evaluation of an augmented reality cyberphysical game for the development of empathic abilities	[66]

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflicts of interest/Competing interests There is no conflict of interest.

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