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Advancing prosociality in extended reality: systematic review of the use of embodied virtual agents to trigger prosocial behaviour in extended reality

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Attention has increasingly been focused on the potential of Extended Reality (XR) and Embodied Virtual Agents (EVAs) to significantly influence human behaviour. While an expanding body of literature explores the individual impacts of XR and EVAs, there is a noticeable gap in the literature regarding their combined influence on eliciting prosocial behaviour in humans. The purpose of this systematic review is to explore this intersection, offering insights into their multifaceted effects on human prosocial behaviour and the implications for future research and development of EVAs in XR. Our systematic review adopted a scoping approach due to the limited number of studies directly focused on EVAs (i.e., autonomously computer-controlled entities). Despite this, we observed the use of various forms of virtual characters (VCs) to elicit prosocial behaviour. An in-depth analysis of 15 selected studies indicates complex patterns in how XR and VCs affect users' prosocial behaviour and interactions. Our review suggests that there is promising potential for EVAs to promote prosocial behaviour. However, further research is necessary to identify the design and interaction-related attributes that enhance the effectiveness of these technologies, particularly for socially interactive EVAs in XR environments.

KEYWORDS

extended reality, embodied virtual agents, prosocial behaviour, systematic review, human-agent interaction

1 Introduction

Prosocial behaviour, characterised by actions that benefit others without personal gain, is the cornerstone of thriving societies. Yet, nurturing prosociality in an increasingly digital world presents a unique challenge. In addressing this challenge, Extended Reality (XR), encompassing Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), provides opportunities to further enhance Embodied Virtual Agents' (EVAs) traits and interaction capabilities (Derek Hart et al., 2021). This systematic review examines the potential for interaction with EVAs in XR to influence and strengthen the users' intention to engage in prosocial behaviour, encouraging them towards more cooperative and altruistic actions.

In Human-Computer Interaction (HCI), prosociality holds a multifaceted position, involving designing interactions that encourage users to engage in helpful, supportive, or sharing behaviours (e.g., donating, volunteering, or collaborating) (Staub, 2013). Through persuasive technologies that utilise principles of social psychology such as trust, reciprocity, and authority, designers in the field of HCI have the potential to influence user choices through subtle nudges, information presentation, and even interface elements, potentially steering them toward prosocial actions (IJsselsteijn et al., 2006). Understanding the diverse motivations behind prosocial behaviours (Harvey et al., 2014), becomes especially critical in economic contexts, where decisions can influence individual and collective wellbeing.

Traditional views of human decision-making, often described through the lens of homo economicus (Thaler, 2000), suggests that individuals are rational actors primarily motivated by self-interest, striving to maximise gains and minimise losses (Steven and List, 2008; Simpson and Willer, 2015). Yet, this model tends to understate the crucial roles of emotional, reciprocal, and social normative factors, alongside individuals' concerns about how their choices portray them to themselves and others in decision-making processes (Oliveira et al., 2021; Litvinova et al., 2023). This complexity emphasises the potential for XR and EVAs to reshape our understanding of prosocial decisions, suggesting that these technologies could influence decision-making processes in ways that traditional models cannot fully predict.

Building on this, research on the antecedents of prosocial behaviour has illustrated critical motivational (Hepach and Warneken, 2018; Paulus, 2018), emotional (Buchanan and Preston, 2014), cognitive factors of prosocial decision-making (Will and Güroğlu, 2016), and personality-related aspects (Zhao et al., 2016; Heilman and Kusev, 2020) influencing the propensity to act prosocially. Studies have outlined the malleable nature of prosocial behaviour, advocating for several training approaches to encourage the development of prosocial skills (Böckler et al., 2018; Paulus, 2018; Tountopoulou et al., 2021). Experiments with economic games and theoretical frameworks in controlled settings have shown that factors such as communication (Burton-Chellew and West, 2013; Caviola and Faulmüller, 2014; Zhao et al., 2016), reciprocity (Allidina et al., 2019; Hsieh et al., 2023), reputation and reward (Hauert, 2010; Wang et al., 2012), as well as time constraints (Haley and Fessler, 2005; Kümmerli et al., 2010; Yamagishi et al., 2017), can significantly impact prosocial actions.

Recent advances in EVAs and Virtual Environments (VEs) have been crucial in eliciting empathy, perspective-taking, embodied cognition, alterations of self-representation, and sensory enhancements (Shriram et al., 2017; Attar et al., 2022; Sora-Domenjó, 2022; Armstrong et al., 2023; Hansdotter, 2023; Shoshani, 2023) and some explored the use of these tools within organisational settings (Kandaurova and Lee, 2019; Parra Vargas et al., 2022). These findings facilitate a deeper understanding of how individual tendencies and situational factors converge to influence prosocial behaviour (Paiva et al., 2018; Paiva, 2022).

Integrating virtual humans into VEs falls within the broader category of Virtual Characters (VCs), which includes avatars and EVAs represented by humanoid or non-humanoid forms. Avatars are digital representations of users, controlled by the user themselves (Jeremy and Blascovich, 2004; Piumsomboon et al., 2018; Hussain et al., 2019), providing a sense of virtual embodiment and making the user feel as if the avatar is an extension of their physical body (Spanlang et al., 2014). EVAs, on the other hand, are computer-controlled characters that exhibit some degree of autonomy (Sun et al., 2012). They range from simple scripted agents, such as video game Non-Player Characters (NPCs), to sophisticated cognitive agents capable of natural language communication. However, recent advances in large language models (LLMs) blur this distinction with technology (Zhang et al., 2024), allowing control of an avatar to switch between a human user and an LLM-driven EVA.

The emerging field of immersive collaboration has explored the potential of EVAs for high-presence communication, emotional elicitation, and prosocial behaviour (Gillath et al., 2008). The immersive capabilities of VR and AR, supported by multimodal stimuli like body-swapping (Roel Lesur et al., 2020) and social inhibition (Mostajeran et al., 2022), emphasise the role of human-agent interaction in XR. EVAs, through role modelling, empathy development, and social presence, can significantly influence emotional connections and motivate prosocial responses (Paiva et al., 2017). This highlights the importance of personalised interactions and tailored interventions for prosocial change (Van Erp and Toet, 2015).

Despite this expanding knowledge base, significant gaps remain in understanding EVAs' role within VEs in promoting prosocial behaviour. Studies have shown the positive impact of EVAs equipped with emotional, communicative and adaptive abilities (Paiva et al., 2017), yet the mechanisms and efficacy of these agents in virtual and real-world settings needs further exploration. This research gap presents an exciting opportunity to explore (1) the specific characteristics of EVAs that promote prosocial actions, such as the impact of emotional expression and social presence, (2) the modulating effects of immersion and interactivity, and (3) the potential of XR interventions to address societal challenges such as social isolation, empathy towards marginalised groups, and environmental consciousness. By systematically investigating these dimensions, we can uncover the transformative potential of EVAs in XR, paving the way for impactful applications in virtual and physical realms.

1.1 Understanding prosocial behaviour and its significance

The term "prosocial behaviour" encompasses a broad spectrum of actions characterised by their intent to benefit others (Rodrigues and Hewig, 2021). The ambiguous nature of this term arises partly due to the absence of a clear separation between prosocial behaviour, emotions, and motivations (Batson et al., 2015). Central to the discourse on prosociality are empathy and altruism. Empathy, often defined as a prosocial emotion, involves sharing another's experience through emotional mirroring and cognitive understanding. This dual perspective manifests in two forms: emotional empathy, where we vicariously feel their emotions, and cognitive empathy, where we mentally step into their shoes (Davis, 2018). On the other hand, altruism (as opposed to egoism) is a motivational state that leads individuals to engage in acts aimed at benefiting others, such as through donations or volunteering (Eisenberg and Miller, 1987; Social Learning and Powell, 2003).

Exploring the intricate relationship between empathy, altruism, and prosociality reveals a complex web of attributes that influence these behaviours (Pfattheicher et al., 2022). Individual preferences, motivations, and emotions (Simpson and Willer, 2015) together with external factors such as rules and reputations interact in multifaceted ways to encourage cooperation. This complexity suggests that the motivation behind an action, whether altruistic or egotistical, does not solely determine its prosocial nature (Batson and Ahmad, 2009). Further describing prosocial behaviour, the research identifies three key dimensions for understanding its various conceptualisations: the intentions and motives behind the actions, the associated costs and benefits, and the societal context (Pfattheicher et al., 2022). Such a framework allows for a nuanced understanding of prosocial actions beyond simplistic classification.

Defining prosocial behaviour in this paper aligns with voluntary actions intended to benefit others without any expectation of immediate reward (Eisenberg and Spinrad, 2014), aligning with definitions in evolutionary biology (Trivers, 1971) and economics (Fehr and Fischbacher, 2003), where any benefits to the helper are incidental and not the primary intention of the act. A recent study further refines this concept by identifying three facets: altruistic (prioritises others' wellbeing, even at a personal sacrifice), norm-motivated prosocial behaviour (upholding social norms through costly enforcement mechanisms, such as punishment), and self-reported behaviour (perceiving oneself as moral, generous, and helpful) (Böckler et al., 2018). Understanding these aspects is crucial to better understand the role of EVAs in promoting prosociality.

The positive annotation of prosocial behaviour becomes more complex within the realm of moral decision-making. Moral dilemmas present situations with conflicting actions in which an agent must choose between mutually exclusive actions, each backed by moral reasons. Utilitarianism, exemplified in Trolley problems (Jarvis Thomson, 1984), advocates maximising overall welfare even if it harms an individual (McConnell, 2002). However, such dilemmas, whether epistemic (unclear priority among conflicting moral principles) or ontological (all principles hold equal merit), challenge the simple classification of such actions as prosocial. The Trolley problem, for instance, exemplifies an ontological dilemma, highlighting the need for a deeper ethical framework when considering choices between obligation and prohibition. These frameworks include deontology (following moral principles) and utilitarianism (focusing on societal benefits) (Frede and Lee, 2003). Furthermore, the variability in moral judgments based on cultural, situational, and individual factors further complicates the perception of prosocial behaviour.

This comprehensive examination of prosocial behaviour, empathy, altruism, and their interplay within moral contexts lays the foundation for understanding the multifaceted nature of prosocial actions. It highlights the complexity of categorising behaviours as prosocial, emphasising the need for a nuanced approach to understanding the dynamics of human social interaction.

1.2 Benefits of prosociality

Evolutionary forces have shaped human nature in ways that favour prosociality, not just for individual gain but for the collective good. This is evident in public goods dilemmas, where sacrificing individual benefits for the common welfare, despite the inherent cost, can lead to societal flourishing. Interpersonal communication (Keith et al., 2014), suggests that empathy, other-regarding concerns, and social norms serve as psychological mechanisms that promote alignment and cooperation within and between human groups. Such mechanisms uniquely seen in humans allow us to engage in larger-scale cooperation. Similarly (Fehr and Gächter, 2000), argues that the core function of prosocial mechanisms are to align individuals with others. Empathy and other-regarding concerns foster interpersonal attunement, while norms facilitate group cohesion. This alignment, they propose, is crucial for the large-scale cooperation that defines human societies.

Social interdependence, characterised by prioritising group needs and goals over individual pursuits, has influenced critical variables such as resource allocation (Batson et al., 2011). Research suggests that situational factors, such as social cues, can modulate the expression of prosocial behaviour, leading to increased engagement in public interest actions like donation (Van Hoorn et al., 2016). However, the results have been mixed concerning prosociality's role in public goods. In comparison, some studies suggest that increased awareness of the benefits of cooperation to others can paradoxically reduce cooperative behaviour (Burton-Chellew and West, 2013). Others, probing beyond purely selfish or prosocial explanations, show that humans can fall short of full cooperation when it maximises self-interest (Kümmerli et al., 2010). This suggests that imperfect behaviour driven by psychological factors, not solely prosocial preferences, plays a significant role. On the other hand, some propose that prosocial behaviour might be best understood as an individual-level trait, similar to how risk aversion (i.e., preference for certain outcomes over one that's uncertain) influences decisions under uncertainty (Mullett et al., 2020).

1.3 The role of prosociality in human-agent interaction in XR

Originating from the immersive concept of "cyberspace" in William Gibson's Neuromancer (Gibson, 1984), Extended Reality (XR) has progressed from mere science fiction to a tangible reality. XR is an umbrella term for Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), and its immersive capabilities offer a unique and powerful tool for fostering prosocial behaviour. The potential of VR to be used as an "Empathy Machine" has been widely explored. Recent studies suggest that integrating EVAs into VR can enhance empathy by encouraging perspective-taking with the illusion of body ownership and agency, which leads to stronger emotional responses and a deeper understanding of others' experiences (Barbot and Kaufman, 2020).

EVAs, through their design and behaviour, can elicit emotional responses in users that are more congruent with the user's or another agent's emotional state in the interaction. An EVA's characteristics, including its physical appearance, level of autonomy, expressiveness in conveying an affective state, multimodal capabilities, and the complexity of its simulated mental processes, must be carefully designed, especially if the EVA has a human-like embodiment (Paiva et al., 2017). As such, avatars are designed as highly realistic virtual representations, often personalised to reflect an individual's unique characteristics or preferences. By placing users in simulated environments that mirror the lived experiences of those in need, VR technology has been shown to evoke empathy and understanding through vicarious experiences. This approach, known as "perspective-taking," has been shown to increase environmental awareness effectively (Bolt et al., 2021; Zhang et al., 2022), reduce prejudice (Crone and Kallen, 2022), and encourage altruism, particularly when users are immersed in VR (Shriram et al., 2017). For example, VR simulations of poverty or homelessness have been shown to significantly increase an individual's charitable donations and volunteerism, suggesting that VR can be a powerful tool for engaging audiences and promoting social good during the experiment (Ou and Qiu, 2023).

While the observed context-sensitivity of prosocial behaviours poses challenges for the creation of a unified theoretical framework, this also opens new questions for future research as it highlights the dynamic interplay between situational factors and prosocial actions. Recognising the influence of individual traits and environmental factors, as research suggests (Davis et al., 1999; Wei and Bramwell-Dicks, 2022), we can now envision interactive environments and EVAs tailored to guide and nudge individuals toward prosocial choices. This aligns with findings that spontaneous cooperation is more likely in individuals with a prosocial orientation (Mischkowski and Glöckner, 2016), suggesting that by shaping the interactive environment, prosocial inclinations can be encouraged (Brian, 1999). Prosocial design within the realm of HCI, with a focus on creating interactive features of EVAs to elicit prosocial behaviours, is a relatively unexplored and inconclusive domain in terms of its actual effectiveness (Harvey et al., 2014; Paiva et al., 2018).

XR, by seamlessly merging the real and virtual worlds, goes beyond simply manipulating emotion. Within these immersive experiences, EVAs act as catalysts for prosocial behaviours across both realities, enhancing immersion and enabling deeper user connections. Research suggests that users readily connect and resonate with EVAs exhibiting prosocial characteristics, leading to significant shifts in their emotional and behavioural responses (Paiva et al., 2017). This phenomenon offers exciting possibilities for promoting positive social impact, as VR experiences featuring empathic EVAs can cultivate genuine empathy for others and encourage prosocial actions in real-world settings. Supporting this (Felnhofer et al., 2018), found that empathy significantly predicts prosocial behaviour, while social avoidance is not influenced by social presence, empathy, physical presence, anxiety or stress. However, participants exhibited greater social avoidance and prosocial behaviour towards avatars than computer-controlled agents. This could be explained by the Media Equation Concept (Reeves and Nass, 1996), which suggests that people treat EVAs like real people; however, more complex emotions like empathy might influence responses based on "agency" (whether controlled by a human or not).

Additionally, the importance of culturally appropriate behaviour in EVAs has been emphasised by (Obaid et al., 2012), who found that users experience higher physiological arousal towards agents whose behaviours diverge from their cultural backgrounds. Further (Huang et al., 2022), observed that users respect the personal space of EVAs, with responses varying based on their perceived gender. Exploring the social effects of AR (Miller et al., 2019), demonstrated that virtual content can impact task performance, nonverbal behaviour, and social connectedness. Collectively, these studies highlight the critical role of social and cultural factors in the design and implementation of EVAs within XR.

Recent investigations into human-agent interaction in immersive settings highlight VR's role as an empathy-enhancing tool, especially through embodied experiences that allow for perspective-taking of EVAs, thereby fostering prosocial behaviours among users (Paiva et al., 2018; Tassinari et al., 2022). For instance, research has shown that taking the perspective of EVAs can influence human behaviour, with participants behaving more altruistically towards robots when they adopt the help-receiver view (Hang et al., 2022) and can enhance closeness and empathy experiences in VR games (Ho and Ng, 2022; Kambe and Nakajima, 2022). Notably, the perceived agency of other players in immersive environments, whether human-controlled avatars or computer-controlled EVAs, can also influence prosocial decision-making (Wei and Bramwell-Dicks, 2022).

Acknowledging the capability of XR, especially VR, to enhance empathy, researchers have investigated its use in improving deeper understanding and connection with others (Davis, 2018). Academics across various disciplines have explored the efficacy of XR in promoting empathy (Piumsomboon et al., 2017; Herrera et al., 2018; Shin, 2018; Kandaurova and Lee, 2019). This diverse range of work on prosocial behaviour in XR has evidenced that people's reactions in VEs can be indicative of their real-world behaviour (Gillath et al., 2008). This is especially apparent within a social group (intergroup) helping situations, where the helper's expectations about the person in need can influence their engagement (D'Errico et al., 2019). Intergroup prosocial behaviour involves actions such as helping individuals from a different ethnic background. A study by (Parra Vargas et al., 2022) primarily focused on assessing participants' helping decisions based on the EVAs' social and ethnic backgrounds, aiming to explore the subtleties of prosocial behaviour in a controlled yet realistic setting. Such behaviour goes beyond helping people within one's group and transcends typical social boundaries to promote positive intergroup relations (D'Errico et al., 2019).

Furthermore, nonverbal cues such as gaze patterns significantly differentiate emotional understanding, perspective-taking, and empathetic stress, suggesting the potential for sophisticated analysis of prosocial behaviour based on subtle cues of gaze patterns and interaction choices such as collaborative decision-making or competing with team members (Parra Vargas et al., 2022). While these studies showcase the potential of EVAs in eliciting prosocial behaviour, the mixed results reported in the literature caution against drawing definitive conclusions. Addressing the inconsistencies in current literature, our study employs rigorous methodologies to refine our understanding of EVAs' influence on prosociality in XR, marking a critical step forward in utilising these technologies for social good.

This research focuses on the main components of EVA architecture outlined by Paiva et al. (2021) (Paiva et al., 2021), including perception, decision-making, and integrating computational processes to build empathy and prosociality in social agents. Their framework features different components critical to fostering empathy within agents: an empathy mechanism (emotion generation), empathy modulation (regulation and degree), and empathic responses (expression and action). This framework integrates low- and high-level functions, acknowledging that empathic responses can arise from both affective and cognitive processes.

1.4 Research questions and goals

This paper aims to (a) summarise existing quantitative research on the potential of EVAs in XR for enabling prosocial behaviours, (b) assess their quality and effectiveness to inform future research directions, and (c) identify potential applications of EVAs designed to elicit such behaviours. Specifically, we will examine whether interacting with EVAs can promote users' intentions and engagement in prosocial actions. To achieve this, we analysed different contexts in which EVAs had been implemented in XR, focusing on scenarios requiring individuals or groups to make prosocial decisions. We then categorised each study's outcomes regarding EVAs' effectiveness in promoting user engagement in prosocial actions.

We formulated three main research questions (RQs) to guide our investigation and inform our data analysis strategy:

RQ1: How does the integration of XR and EVAs influence users' prosocial behaviour?

- 1a: What methodological strengths and limitations are observed in the relevant literature?
- 1b: How do individual factors, such as demographics and personality traits, influence the effectiveness of EVAs in eliciting prosocial behaviour across different XR settings?

RQ2: Within which contexts are XR and EVAs utilised to encourage prosocial behaviour among users?

- 2a: What type of tasks are undertaken?
- 2b: What social scenarios are investigated for evaluating the motivational role of EVAs in fostering prosocial behaviour in XR environments?

RQ3: Which prosocial behaviours are examined in the studies?

- 3a: What effects on social interactions and group dynamics have been documented?
- 3b: What characteristics of EVAs (e.g., embodiment) are effective in promoting prosocial behaviour?

2 Methods

Employing a systematic approach guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2015), we conducted a systematic review. We then adopted a scoping approach due to the limited number of studies directly focused on EVAs (i.e., autonomously computer-controlled entities). This section presents the detailed processes, including the databases searched, keywords used, screening criteria applied, and procedures for resolving disagreements, which ensured the identification and selection of relevant papers for inclusion in this study.

2.1 Search strategy and eligibility criteria

To retrieve relevant literature, we conducted an automated search across different databases, including ACM Digital Library, Engineering Village, ScienceDirect, Taylor and Francis, IEEE Xplore, and PubMed. After analysing the selected papers identified from these databases, we found other relevant papers cited by the selected studies that were not captured by our original search. The identified keywords and index terms, according to the research questions, were used to construct a search string and Boolean operators (AND, OR). The search strings include (virtual reality OR augmented reality OR mixed reality) AND (prosocial OR cooperation OR collaboration) AND (virtual agents OR virtual characters OR avatars). The focus was extended to include terms that include the nuances of human interactions, behaviours, and cooperation dynamics influenced by EVAs in XR technologies. Furthermore, we limited the inclusion of papers in this review according to the defined criteria presented in Table 1.

2.2 Studies selection and quality assessment

The process of records selection and quality assessment was conducted in five steps. The first step, referred to as preliminary selection (S1), involved applying the search string in the search mechanism of the digital libraries used as sources of publications. The search scope was set to cover the title and abstract. The selected publications were stored in Rayyan[1], a tool used for precise screening and selection of studies. In the second step, referred to as duplications removal (S2), publications indexed in more than one search engine were identified in Rayyan, and duplications were eliminated.

The third step, eligibility assessment (S3), involved identifying eligible articles using a two-stage technique by three independent reviewers. Conflicts were resolved by reaching a consensus (elaborated upon in Section 2.3). In the fourth step, referred to as the selection of relevant publications—first filter (S4), titles and abstracts retrieved through the search strategy were evaluated, considering the defined inclusion and exclusion criteria in Table 1. This step facilitates the exclusion of irrelevant studies based on our predefined criteria. This step yielded potentially eligible studies. Finally, in the fifth step, referred to as the selection of relevant studies—second filter (S5), the full text of the publications selected in S4 was read and analysed, considering the listed inclusion and exclusion criteria. This step aimed to narrow down the selection further and ensure that only relevant studies were included in the final review.

1 For more information, see https://www.rayyan.ai/.

TABLE 1 The inclusion and exclusion criteria.

Criteria	Inclusion criteria	Exclusion criteria
Topic	Research focused on HCI in XR, specifically involving EVAs	Studies not primarily focused on HCI with EVAs in XR
Study Design	Quantitative studies with a clear methodology, measurements, and outcomes	Qualitative studies, reviews, or studies without a clear quantitative analysis
Language	Studies published in English	Non-English studies
Prosocial behaviour	Research exploring the impact of EVAs on users' intention and engagement in prosocial behaviours	Studies not specifically examining the role of EVAs in influencing prosocial behaviours
Publication Type	Peer-reviewed articles from journals and conferences	Non-peer-reviewed sources, grey literature
Date	Studies published between 1 January 2013 and 31 January 2024	Studies published before 1 January 2013 or after 31 January 2024

2.3 Coding and data extraction

Following the final study selection, we systematically extracted relevant data from each study. This process included information based on (1) extrinsic categories: country of first author, funding information, ethical approval status, publication year, and venue (conference or journal) and (2) methodological characteristics: sample size, female percentage, participant age mean, task used, presence and composition of control group, type of interaction, number of humans and agents, EVAs used and their embodiment (human-like, animated characters, or other).

Data related to the classification of the impacts of interaction with EVAs on prosocial behaviour was collected, focusing on (a) dependent and independent variables, (b) the extent to which dependent variables were related to the virtual entity itself (e.g., helping the virtual entity) or the community and (c) operationalisation of prosocial behaviour which involves specifying behaviours in terms of specific actions, interventions, and conditions within each study. We also presented a summary of the key findings for each paper included in this review.

To evaluate the quality of included studies, we employed the quality assessment coding scheme (Connolly et al., 2012), considering the following criteria: (1) suitability of the research design, methods, and data analysis strategy for addressing the study's aims, (2) evaluated the extent to which the results could be generalised to the target population in the research, and (3) relevance of the study's focus with the research questions and goals of this review. Each article received a one to five score on each criterion, yielding a 3–15 overall quality score (3 lowest and 15 highest). Two primary coders, with expertise in data science and psychology, respectively, independently assessed the papers. A third coder with a design engineering background resolved any disagreements. All three coders participated in the initial data extraction process to establish a unified coding scheme.

To measure inter-coder agreement, we calculated Krippendorff's alpha (α) for each category of the coding scheme (Krippendorff, 2011). Across all categories, strong consistency was observed among coders, exceeding the recommended statistical thresholds (including individual α values for each category). We observed strong agreement (94%) regarding the study's research design, methods, analysis strategy, and how well its focus addressed the research questions. Similarly, we observed high agreement 88% for the generalisation of findings. The high level of inter-coder agreement suggests a strong consensus among coders, leading to confidence in the reliability and validity of our coding scheme.

Our systematic search yielded a limited number of studies that met our inclusion criteria due to inconsistent methodologies and diverse variables across existing research. To provide a more comprehensive overview of the field in light of these challenges, we adopted a broader scoping review approach as outlined by (Peters et al., 2015) (See Figure 1). This approach allows us to identify promising directions for future research.

3 Results

3.1 Characteristics of the studies

The review includes 15 publications, out of which eight of them received approval from an Ethical Board. Similarly, eight acknowledged receiving funding, with two of these being partially funded. These publications mostly focused on analysing prosocial behaviour in interactions with Virtual Characters (VCs). Moreover, 12 of the publications were written by authors from countries described as having highly individualistic cultures, including Austria, France, Germany, Japan, Spain, Switzerland, United Kingdom, and the United States, with scores ranging from 57 to 81[2]. Higher scores suggest that society values individual achievement and autonomy, while lower scores indicate a preference for group cohesion and interdependence. The three remaining studies were published by authors from countries with low scores for individualism (below the middle point of scale), namely, Italy and Hong Kong. Figure 2 presents the number of articles published each year. The majority of publications included in this study were published in high-ranked journals (*Q1; 13*)[3] mostly in areas of human behaviour and psychology. The remaining studies were published in the

2 The classification was performed according to the scores for the dimension of *Individualism* for each country, advanced by the Hofstede Model. For more information, see https://www.hofstede-insights.com/country-comparison-tool.

3 According to the Scimago's h-index and quartile ranking system, see https://www.scimagojr.com/.

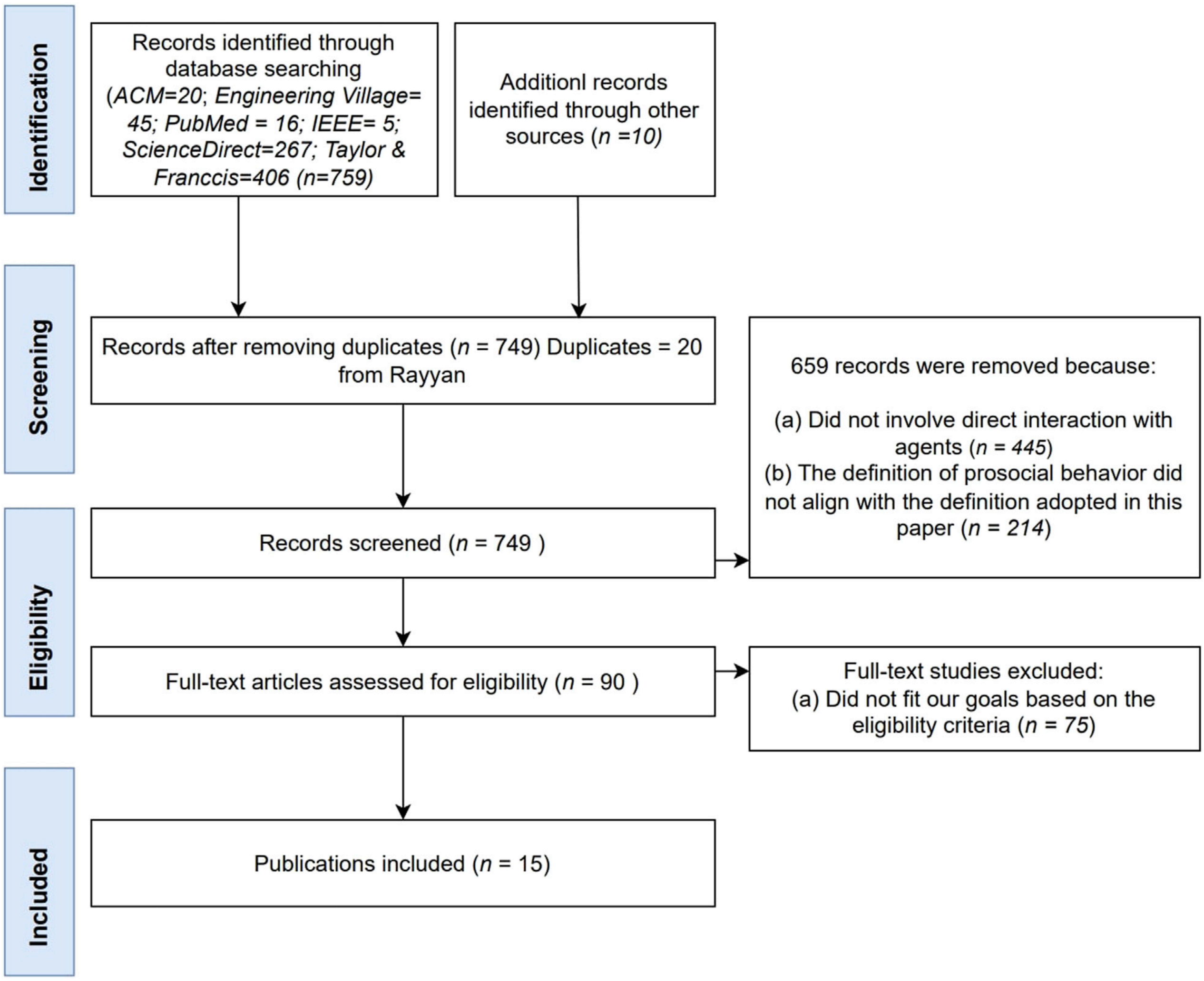

FIGURE 1
PRISMA methodology presenting the study selection process.

proceedings of conferences dedicated to HCI. Figure 3 lists the journals and conferences in which the studies were presented.

Overall, this review includes various studies that report original empirical research involving a total of 1,114 participants. Among the participants, 50.17% were female (*n* = *559*). Regarding the participants' occupation, 12 publications reported results based on a sample of university students of different academic backgrounds, three did not mention, one study involved college students in their late teens to early twenties, one study included the general public from a museum, and one study examined school students aged between 12 and 15 years old from eighth and ninth grade.

We initially planned a systematic review to explore how EVAs influence prosocial behaviour in XR. However, limited research specifically focused on EVAs in this context came to light during our search. In response, we broadened our scope to encompass all VCs, a category that includes both avatars and EVAs. This broader approach allows us to comprehensively examine the diverse applications of virtual entities in XR, regardless of user control over the entity. To illustrate various applications and settings explored in the current literature, we present the following examples. These include virtual gender swap (Bolt et al., 2021), social influences (Litvinova et al., 2023), stress responses (Felnhofer et al., 2018), perspective-taking to induce empathy (Van Loon et al., 2018; Ho and Ng, 2022) or to promote prosocial behaviour towards a robot (Chenlin et al., 2023), and empathy development (Lopez-Faican and Jaen, 2023) in XR settings. Figure 4 provides examples of various XR applications and their corresponding VCs.

3.2 Influencing prosocial behaviour through XR and EVAs (RQ1)

The majority of the reviewed studies were assessed to be of high quality, with the mean score of *M* = *13.68* and *SD* = *1.21*. The studies' focus on the relevance of research questions and goals scored the highest rate (*M* = *4.6*; *SD* = *0.46*). Similarly, the research design, methods, and data analysis strategy were deemed suitable (*M* = *4.64*; *SD* = *0.59*). However, the generalisability of results to the target population received an average rating (*M* = *4.16*; *SD* = *0.71*).

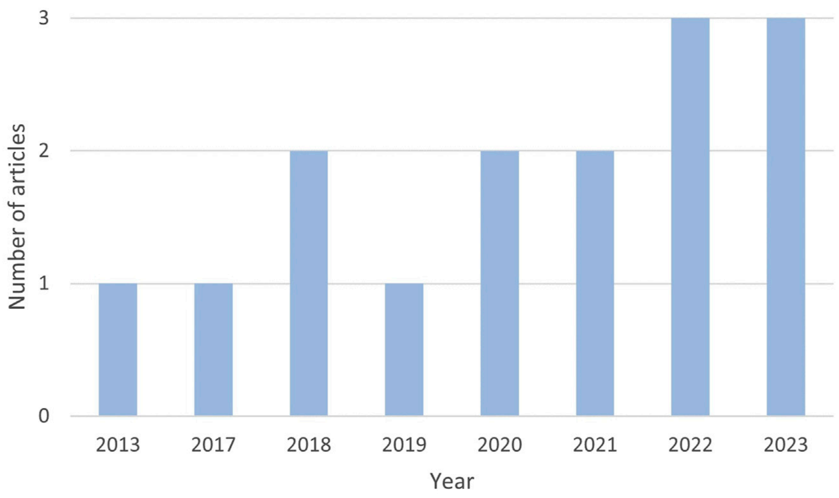

FIGURE 2
Studies published by year.

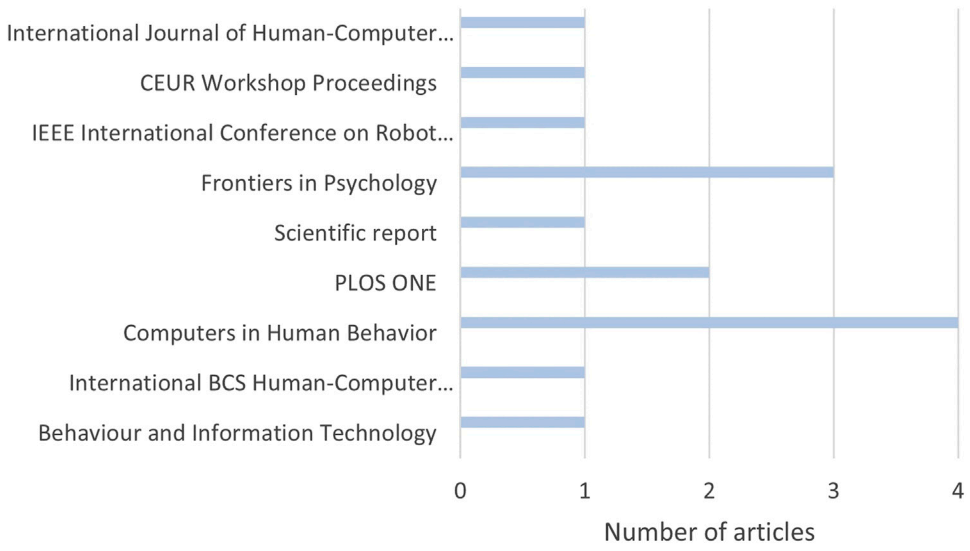

FIGURE 3
Studies by journal/conference name.

Given the significant heterogeneity in study design and control group composition across the studies included the approach by (Oliveira et al., 2021) suggests that an interaction with an EVA is considered successful if its results outperform those of the respective comparison group. However, in cases where the results of interacting with EVAs are inferior to those observed in the control or comparison condition, the findings are considered inconclusive.

Three studies reported inconclusive or non-significant results regarding the impact of VCs on prosocial behaviour (Van Loon et al., 2018; Roel Lesur et al., 2020; Litvinova et al., 2023). These studies looked at various dimensions. One study found that virtually experiencing life as someone from a different social group had little impact on people's attitudes towards transgender individuals. Another study explored honesty in VR and found that avatars did not significantly influence truthful behaviour, possibly due to the complexities of how people see themselves. Additionally, research on perspective-taking showed it to be ineffective in changing helpful actions in economic simulations. Interestingly, none of these studies found a strong connection to people's overall moral behaviour, decision-making, or collaborative tendencies.

Subsequent studies reported positive results in favour of VCs. For instance, several studies, including (Ho and Ng, 2022; Hang et al., 2022), focused on how the perspective-taking abilities of VCs can enhance understanding and empathy towards a victimised character. Similarly (Chenlin et al., 2023), examined how

FIGURE 4
Usage of avatars and EVAs in various XR applications: **(A)** female avatar moving in front of a full body displaying mirror in VE (Bolt et al., 2021), **(B)** giving a presentation to a virtual class (Van Loon et al., 2018), **(C)** help-receiver perspective in robots (Chenlin et al., 2023).

perspective-taking in VR influences prosocial behaviour towards VCs through an altruistic VR task that allows participants to experience the task from the help-receiver and help-provider perspective. However, a study by (Parra Vargas et al., 2022) revealed that while avatars enhance empathy in certain contexts, their effectiveness varies across different scenarios, such as collaborative decision-making (Felnhofer et al., 2018; Wei and Bramwell-Dicks, 2022). examined how dynamics of interaction between the agent and the avatar conditions within VR influence prosocial actions (Kothgassner et al., 2017). also found that avatars are more effective than agents at eliciting prosocial behaviour from participants.

Several studies, such as those from (Roel Lesur et al., 2020; Bolt et al., 2021), investigated how embodiment affects social attitudes (Parra Vargas et al., 2022). evaluated the use of machine learning and VR to discriminate empathy and predict attitude change. They classified individuals based on their level of empathy dimensions, such as perspective-taking, emotional understanding, empathetic stress, and empathetic joy, while also including eye-gaze behavioural patterns. They investigated the influence of avatar personality traits on empathic behaviour and decision-making within a virtual group setting. Participants interacted with avatars exhibiting varying personality traits, including self-confidence and a predisposition to understand others' perspectives. While the results suggest the potential of these tools to differentiate the empathy dimensions, the limitations imposed by the small sample necessitate caution in generalising these findings to the broader population.

In the social support intention context (Collange and Guegan, 2020), showed virtual social interaction with avatars induced a feeling of gratitude for both inter and outgroup members (i.e., those belonging to another social group). In addition (Yoo et al., 2015), found that the virtual representation's ageism (elderly vs young) influences prosocial behaviour and attitudes. Participants who interacted with elderly avatars showed more positive attitudes and higher donation intentions in the VR shopping scenario (Lopez-Faican and Jaen, 2023). showed the effectiveness of AR game after four gameplay sessions, tasks embedded within an AR game increased children's level of prosocial behaviour when helping a target avatar. These findings suggest that the EVA's potential to influence attitudes is profound yet context-dependent.

3.3 Contexts and applications of XR and EVAs in eliciting prosocial behaviour (RQ2)

In terms of the research scenario used to study prosocial behaviour, most of the studies included in this review took place in controlled settings ($n = 13$), whereas one took place in a museum (Roel Lesur et al., 2020) and another in a schoolyard (Lopez-Faican and Jaen, 2023).

In the context of avatar embodiment on prosocial behaviour (Yoo et al., 2015), found that the aged appearance of the avatars embodied by participants had a significant impact on behaviour and persuasion outcomes. Participants who operated elderly avatars tended to walk slower and choose products related to the elderly in a virtual shopping place. They also displayed higher prosocial intentions, such as befriending, donating, and volunteering for a non-profit organisation. In contrast, embodying a virtual avatar of a different gender led to less prosocial behaviour in both men and women, particularly women in male avatars. This suggests that factors beyond gender stereotypes influence economic decision-making in VR (Bolt et al., 2021).

While it is common to explain prosocial behaviour in terms of individual predisposition traits such as empathy or altruistic personality, prosocial behaviour can be encouraged by seemingly simple interventions such as writing a narrative about a person (Shriram et al., 2017). Similarly (Roel Lesur et al., 2020), investigates the impact of VR embodiment on prosocial attitudes towards transgender individuals in museum settings. While the study did not find direct changes in prosocial attitudes, age emerged as a significant factor, with younger participants experiencing stronger illusionary embodiment effects. Another study found that simply seeing one's avatar or seeing others working together was insufficient to introduce more honest or less antisocial behaviour in the hybrid work context (Litvinova et al., 2023). Rather, seeing avatars that resemble one's appearance and experiencing the sense of others' focused intentions is necessary to enact moral conduct. These findings highlight the need for further research exploring the nuanced interplay between VR embodiment, individual factors, and context in promoting prosocial attitudes towards diverse groups.

Researchers have been studying the effects of Virtual Reality Perspective-Taking (VRPT) on prosocial behaviour. While a study by (Bolt et al., 2021) showed that VRPT effectively increased participants' empathy towards a specific partner, it did not directly translate to prosocial behaviour in economic games in the real world. This suggests a disconnect between emotional understanding and actual action. Further investigation is needed to better understand the specific factors that influence empathy in VR intergroup interactions. Supporting this notion (Rosenberg et al., 2013; Spagnolli et al., 2021), revealed that the use of humanoid avatars increased participants' propensity to help in moral decision-making scenarios. Collectively, these studies highlight the potential of EVAs to promote positive social norms and behaviours in interactions with VCs.

Another study analysed how manipulating perspective (helper vs receiver) within VR robot interaction tasks affects prosocial behaviour towards the robot (Chenlin et al., 2023). The study found that participants who assumed the perspective of a person in need of assistance exhibited significantly higher levels of prosocial behaviour compared to those in the helper role. This suggests that VRPT in human-robot interactions can be a promising tool for fostering positive social engagement and promoting positive relationships with robots. However, they found no significant differences in participants' willingness to share resources (prosocial behaviour) or trust towards the virtual robot. This was measured using the "dictator game" (Engel, 2011), a well-established economic experiment used to assess altruism. This implies a nuanced interplay between VR-mediated perspective-taking and prosocial actions, which could be influenced by both the specific task context and individual factors like nationality.

Ongoing research is currently investigating how VR, avatar identification, and social image influence prosocial behaviour (Litvinova et al., 2023). One study found that people who do not strongly identify with their avatars may be less likely to consider how their actions impact on actions and image concerns. Conversely, simply feeling a close connection alone is not always enough to promote honest behaviour; it may depend on a sense of positive similarity with the avatar and perceived belonging within a virtual audience. The presence of interactive observers could potentially amplify these effects. Another study (Kothgassner et al., 2017) showed that virtual ostracism, whether inflicted by avatars or agents, equally threatened participants' fundamental needs. However, those ostracised by avatars felt higher levels of sadness and were less helpful than those ostracised by computer-controlled agents. This suggests cognitive evaluation may shape emotional and behavioural responses to avatar-based exclusion. This evaluation aligns with the Media Equation Concept, demonstrating that individuals apply emotional and behavioural responses similar to human-human interactions to their interactions with a VC that resembles a human.

Research in prosocial behaviour has shown that VR is a useful tool for investigating helpfulness in various contexts. Studies have explored its application in scenarios related to the bystander effect, outgroup discrimination in helping behaviour, and the influence of spatial proximity on prosocial motivation. For example, a study by (D'Errico et al., 2019) found that white participants demonstrated increased attention and engagement when presented with VCs in need of help who did not fit traditional stereotypes, such as outgroup members or Black actors. This suggests that VR can uncover unconscious biases and their potential impact on prosocial behaviour toward diverse groups. Another study by (Collange and Guegan, 2020) showed that receiving help from avatars, regardless of their group affiliation, can induce gratitude and increase prosocial intentions toward them in human participants, mediated by perceived warmth and closeness experienced during the interaction. The positive social experiences with avatars can cultivate prosocial behaviour, even if it is a brief interaction. Additionally, interacting with a virtual benefactor from an outgroup has the potential to enhance intergroup relations. However, further research is needed to confirm its impact beyond individual interactions.

Of particular relevance, a study by (Spagnolli et al., 2021) demonstrated that co-location in VR positively influences prosocial behaviour. Participants sharing a VR environment with a virtual victim exhibited increased helping behaviour, regardless of the emergency type (plea for assistance or ongoing virtual fire). This finding suggests that spatial proximity within VR significantly influences prosocial responses and highlights the potential of VR to explore the role of spatial factors in real-life emergency situations. Table 2 presents the overview of the included studies in this review.

3.4 Types and effects of prosocial behaviour (RQ3)

Studies were analysed in terms of prosocial behaviour and categorised as agent-related, community-related, and other. Agent-related prosocial behaviours include behaviours that aim to help EVAs or avatars. Community-related prosociality includes behaviours that intend to benefit the wider community or specific individuals who are not part of the interaction dyad or group. Eight studies analysed situations in which the aim was to induce prosocial actions toward EVAs. The type of help provided to EVAs included helping an avatar (Wei and Bramwell-Dicks, 2022; Lopez-Faican and Jaen, 2023), social interaction (Felnhofer et al., 2018), helping pick up pencils (Kothgassner et al., 2017), and presence (Litvinova et al., 2023). Interaction with a virtual robot includes volunteering to complete a task for a robot (moving cubes) (Chenlin et al., 2023) and saving a robot (Ho and Ng, 2022). Several studies have examined different scenarios to promote helping behaviour, such as assisting an avatar as a superhero (Rosenberg et al., 2013), sharing the space with a victim and providing help (Spagnolli et al., 2021), making decisions about helping based on ethnicity and social appearance (D'Errico et al., 2019), and to help an individual belonging to an outgroup member in terms of ethnicity (D'Errico et al., 2019).

In (Van Loon et al., 2018), it was found that target-specific perspective-taking can increase empathy, but it may not necessarily lead to an increase in prosocial behaviour as measured through the Trust Game. Another study by (Roel Lesur et al., 2020) found no significant differences in implicit and explicit bias toward outgroup members (who embody a transgender narrative) or embodiment. Additionally, virtual gender swaps did not appear to have any influence on prosocial decision-making behaviours (Bolt et al., 2021).

In terms of embodiment, most of the studies used VCs with varying degrees of human likeness. However, a few studies require more in-depth research. For instance, in a study conducted by (Lopez-Faican and Jaen, 2023), animated avatars were used to

TABLE 2 Summary of context and applications of XR and VCs interventions affecting prosocial behaviour.

Study	XR hardware	Setting	Type of EVA	Task	Social scenario	Prosocial behaviour
Chenlin et al. (Chenlin et al., 2023)	Oculus Quest 2 VR	Laboratory setting	Avatar	Dictator game (helping virtual robot)	Perspective-taking	Improved altruistic behaviour
Litvinova et al. (Litvinova et al., 2023)	HTC Vive VR HMD	Laboratory environment	Humanoid avatar	Cognitive task	Collaborative learning	Increased helping behaviour
Faican et al. (Lopez-Faican and Jaen, 2023)	Mobile AR	Schoolyard	Animated avatar	Multi-user EmpathyAR game (helping, stopping a fight, comforting and sharing)	Social interaction involving collaboration and communication	Promoted empathic in terms of prosocial behaviour
C.F. Ho and Ng (Ho and Ng, 2022)	HTC Vive™ VR HMD	VR game (firefighting)	Virtual robot	Helping virtual character	Simulated one-sided interaction	Induced perspective-taking and empathy
Wei et al. (Wei and Bramwell-Dicks, 2022)	HTC Vive VR HMD	Cave maze environment	Avatar	Maze adventure game (request help, provide help)	Social interaction involving problem-solving	Spatial presence and involvement influence social interaction (e.g., helping behaviour)
Vargas et al. (Parra Vargas et al., 2022)	HTC Vive Pro Eye VR HMD	Office and meeting room	Avatar	Interactive tasks like chatting with co-workers and answering emails	Decision-making in social workplace situation	Influenced perspective-taking, emotional understanding, empathic stress and joy
Mado et al. (Bolt et al., 2021)	HTC Vive Pro VR HMD	Laboratory room	Avatar	Interpersonal and intertemporal discounting task	Prosocial decision-making	Reduced prosocial behaviour
Spagnolli et al. (Spagnolli et al., 2021)	Unspecific VR hardware	Laboratory setting Virtual building and garden	Humanoid Character	Helping virtual character	Moral decision making	Increased likelihood to help
Lesur et al. (Roel Lesur et al., 2020)	Oculus CV1 VR HMD	Museum	Avatar	Gender identity narrative	Social bias and cognition	No changes in implicit and explicit bias
Collange et al. (Collange and Guegan, 2020)	Oculus Rift DK2 VR HMD	Virtual building	Avatar	Escape fire (receiving help)	Social support offering	Induced a complex, positive, other-oriented emotion, receiving help from a virtual benefactor
Errico et al. (D'Errico et al., 2019)	HTC Vive VR HMD	Post office building	Avatar	Helping behaviour towards outgroup member	Overcoming prejudice, empathy and perspective-taking	Increased helping behaviour
Loon et al. (Van Loon et al., 2018)	HTC Vive VR HMD	Laboratory room	Avatar	Trust game	Economic decision-making	Increased subsequent propensity to take the perspective of their partner
Felnhofer et al. (Felnhofer et al., 2018)	Sony HMZ-T1 3D Visor VR HMD	Viennese cafe	Avatar	Asking to sit at the table	Social communication involving decision-making	Increased social avoidance and prosocial behaviour
Kothgassner et al. (Kothgassner et al., 2017)	Sony HMZ-T1 VR HMD	Cyberball-Game	Avatar and agent	Helping task	Social exclusion in everyday social interactions	Higher levels of sadness and less helpful behaviour
Rosenberg et al. (Rosenberg et al., 2013)	nVisor SX111 VR HMD	Virtual city	Avatar	Helping virtual character and touring	Decision-making	Improved altruism

represent school teachers who provided help scenarios for each task, such as helping a VC in a real-world setting (schoolyard). Participants who embodied the ability to fly showed better helping behaviour, which facilitated subsequent helping behaviours in the real world (Rosenberg et al., 2013). On the other hand (Wei and Bramwell-Dicks, 2022), demonstrated that people's virtual behaviours are influenced by their personality traits and the perceived agency of the other players. Given the different embodiment of the VCs used, as discussed above, it is difficult to compare the results observed. It seems that agency and its interaction with other variables, such as physical appearance, gender, and age, might affect prosociality. However, more research is necessary to disentangle this potential effect.

From an AI application perspective, in the majority of studies ($n = 14$), researchers developed a limited set of programmed behaviours that were executed based on simple rules. However, there was one study that explored the possible applications of machine learning to distinguish between high and low empathic

TABLE 3 Summary of study findings.

Study	Participants		Main variable		Summary
	N	Age	Dependent	Independent	
Chenlin et al. (Chenlin et al., 2023)	27 (5F)	*M* = 27.3 (SD = 4.2)	Altruistic behaviours	Perspective (help provider view vs help receiver view)	Participants who experienced the robot's perspective exhibited significantly higher prosocial behaviour towards the robot compared to those solely acting as the helper
Faican et al. (Lopez-Faican and Jaen, 2023)	30	*M* = 13.12 (SD = 0.90)	Empathy, perspective-taking, personal distress, and game experience	Educational intervention (Empathy AR game vs traditional strategies)	Playing with AR characters that simulate social issues like bullying and poverty significantly enhanced self-reported prosocial behaviour and empathy scores on two key dimensions (fantasy and concern) compared to traditional learning methods
Litvinova et al. (Litvinova et al., 2023)	171 (57F)	*M* = 21.3	Social image concerns, Self-image concerns, Perception of avatar (similarity and embodiment), Perception of social presence	Virtual image (alone vs with audience vs with mirrors or combination)	Simple cues failed to boost prosociality in the Metaverse, likely due to avatar identification and self-discrepancy effects
Vargas et al. (Parra Vargas et al., 2022)	82 (27F)	*M* = 42 (SD = 3.44)	Emotional understanding, Empathic joy Empathic stress, Perspective-taking, Eye gaze, and decision-making patterns	Empathy dimensions (perspective-taking, emotional understanding, empathic stress, and empathic joy)	Identified significant differences in how individuals with varying levels of emotional understanding, perspective-taking, and empathetic stress interacted with virtual characters
C.F. Ho and Ng (Ho and Ng, 2022)	40 (23F)	*M* = 23.6 (SD = 4.7)	Game immersion, Empathy towards NPCs, Closeness with destroyed robot	Perspective-taking experience	Experiencing a destroyed virtual robot's perspective in VR increased participants' closeness and empathy towards rescued robots and indirectly enhanced immersion
Wei et al. (Wei and Bramwell-Dicks, 2022)	32 (10F)	*M* = 22.69 (SD = 2.39)	Prosocial decision (to help or not)	Perceived agency of other players (human-controlled avatar vs computer-controlled agents)	Participants interacting with perceived virtual avatars reported higher presence compared to those interacting with agents, avatar embodiment enhanced immersion
Mado et al. (Bolt et al., 2021)	99 (51F)	*M* = 23.5 (SD = 3.3)	Prosocial decision-making (sharing)	Gender of the avatar (male vs female), Type of decision-making task (social vs non-social)	Receiving help from avatars, regardless of their group affiliation, increased feelings of gratitude and prosocial intentions towards them in human participants
Spagnolli et al. (Spagnolli et al., 2021)	62 (23F)	*M* = 21.20 (SD = 2.39)	Helping behaviour	Spatial arrangement in VR and Type of emergency	Exploring the influence of co-location in VR, sharing the same virtual space significantly increased prosocial behaviour
Lesur et al. (Roel Lesur et al., 2020)	71 (41F)	*M* = 34.1 (SD = 13.3)	Explicit attitudes towards transgender, Embodiment	Gender Identity Narrative	Participants immersed in VR as a transgender man navigating a museum setting did not exhibit direct changes in prosocial attitudes towards transgender people compared to a control group
Collange et al. (Collange and Guegan, 2020)	80 (61F)	*M* = 21.09 (SD = 2.26)	Feeling of gratitude, Social support intentions, Perceived warmth of the avatar and interpersonal closeness	Receive help from an avatar vs without such interaction	Receiving help from avatars, irrespective of their group affiliation, resulted in feelings of gratitude and increased prosocial intentions towards them in human participants

profiles based on decision-making and eye-tracking assessments during a VR experience (Parra Vargas et al., 2022). For creating interactive VEs and character interactions, most of the studies in this review utilised various versions of the Unity engine, with one implementing the Unreal engine and others employing other programming frameworks, such as C# and Python with OpenGL. For a summary of the studies' findings, refer to Table 3 and Table 4.

4 Discussion

The research on VCs within social VR environments highlights their complex role in shaping user experiences. These VCs enable users to represent themselves through desired avatars, nudging user behaviour towards specific goals and facilitating individual and social change. Despite the evident applications of VCs in VEs in evaluating social interactions and informing design principles, their

TABLE 4 Summary of study findings (Cont.).

Study	Participants		Main variable		Summary
	n	Age	Dependent	Independent	
Errico et al. (D'Errico et al., 2019)	40 (19F)	*M* = 23.76	Attention, distraction and engagement levels	Ethnicity (white vs black), Appearance (businessman vs casual vs beggar)	Participants playing as white helpers in VR scenarios exhibited increased attention and engagement when assisting Black actors in situations that challenged negative stereotypes
Loon et al. (Van Loon et al., 2018)	180 (106F)	*M* = 20.28	Propensity of perspective-taking, Behaviour in real-stakes economic games	Partner perspective vs s perspective vs Neutral, Immersion (high vs low)	While perspective-taking in VR enhanced empathy towards another individual, it did not directly translate into prosocial behaviour in a real-world game
Felnhofer et al. (Felnhofer et al., 2018)	95 (83F)	*M* = 23.34 (SD = 2.72)	Prosocial behaviour, Social avoidance, Presence and stress levels	Type of virtual entity (human-controlled avatars vs computer-controlled EVAs)	Participants interacting with avatars displayed both higher rates of helping behaviours and social avoidance, compared to EVAs
Kothgassner et al. (Kothgassner et al., 2017)	45 (23F)	*M* = 25.71 (SD = 3.92)	Prosocial behaviour in a helping task Seating distance to a confederate, Impact on fundamental human needs and emotional responses	Virtual social exclusion vs inclusion, Agency of social characters (avatars vs EVAs)	Participants who experienced exclusion within a VE, regardless of whether the excluding entities were avatars or EVAs, exhibited decreased prosocial behaviour and increased distance in subsequent real-life interactions
Rosenberg et al. (Rosenberg et al., 2013)	60 (30F)	–	Helping behaviour	Type of virtual experience (flying ability vs ride as passengers in a helicopter), Task in VR (help find a missing child vs touring a virtual city)	Embodying superhero-like avatars in VR significantly enhanced real-world prosocial behaviour compared to passive VR experiences

potential to specifically nurture prosocial behaviour needs further exploration (Kyrlitsias and Michael-Grigoriou, 2022).

Ethical considerations emerged as a critical element when assessing the quality of research studies. In this review, eight studies were approved by an Ethics Board, however, the remaining studies raise ethical concerns. Also, the methodological rigour of these studies varied, often lacking in comprehensive measures of prosociality, control for possible confounding variables, and qualitative insights that could have provided valuable insight into understanding prosocial motivations. Furthermore, the absence of manipulation checks in some studies raises questions about the efficiency of experimental manipulations, especially in studies involving socially interactive agents. While the overall quality of the included papers was good, the reported effects varied, with only half of the studies reporting positive of VCs effects in XR application. This variation likely stems from the different independent variables and the range of prosociality dimensions used by authors.

Our analyses identified two primary themes related to XR's role in modulating user perception. The first theme involves the manipulation of user identity, which is evident in studies that alter avatar age, gender (Roel Lesur et al., 2020), and body swapping (Bolt et al., 2021). The second theme focuses on enhancing empathy and perspective-taking, which includes studies that leverage VR or text narratives to increase empathy towards VCs (Van Loon et al., 2018; Ho and Ng, 2022) and an AR game to promote empathy in children (Lopez-Faican and Jaen, 2023).

Although the studies involving XR manipulations are varied, some of the studies did report manipulation checks and pilot testing (*n* = 7) to ensure the validity of the experiments. This validation is performed through measures of mediating variables or any other measures between the manipulation and the dependent variable measure that may influence the thoughts and behaviours of participants (Hauser et al., 2018). The majority of the studies showed a strong focus on VR as the primary subject area (*n* = *14*). VR is useful in allowing us to manipulate space easily, as evidenced by other studies in the field of psychology that have already adopted VR and the social valence of stimuli (virtual human and non-human) (Iachini et al., 2014). The only study deploying an AR game, EmpathyAR, designed scenarios and tasks that favour the expression of empathy in terms of prosocial behaviour (Lopez-Faican and Jaen, 2023). The level of prosocial behaviour increased in children who played the AR game at the end of four sessions more than the control group. Several works allowed users to experience the perspectives of others from either a first-person perspective or a third-person perspective. For example, embodying a virtual body with different skin colour and appearance (D'Errico et al., 2019). In another study (Ho and Ng, 2022), participants experienced a robot's perspective of being destroyed by fire in VR. Contrary to the previous studies, having players take the perspective of a victim in a prosocial VR game indirectly improved game immersion forcasual gamers and reversed effects on experienced gamers. In (D'Errico et al., 2019), a medium level of immersion and a low level of agency of users in VR were observed.

In addressing our second research question, we observed a predominance of studies conducted in simulated VEs, with just two studies carried out in real-life settings. However, the debate surrounding ecological validity is noteworthy, especially considering whether the results obtained from simulation-based studies correspond to those obtained in real-world scenarios. In fields such as social psychology and VR, experimental realism and presence have been proven to be a useful proxy, respectively (Dole and Ju, 2019). Furthermore (Delgado Rodriguez et al., 2023), suggested that indirect VR studies, such as using VR for real-world training, can achieve higher internal and external validity.

The exploration of our third research question revealed three main interaction tasks: 1) Conversational interactions, participants interact with the VCs through verbal communication; 2) Perspective-taking tasks, in which participants complete tasks alongside the VCs or by adopting the VC's point of view, and 3) Games, participants engage in games designed to elicit prosocial actions. The diversity of these tasks included conversational interactions such as in studies by (D'Errico et al., 2019; Felnhofer et al., 2018). Other studies have used text-based interactions (Ho and Ng, 2022), voice-only interactions (McVeigh-Schultz et al., 2019), or presenting to a virtual class (Van Loon et al., 2018).

Several studies examined experiments in which humans and socially interactive VCs complete a task through non-verbal communication. These studies included tasks such as confederate avatars opening doors and waving to another avatar behind closed doors (Collange and Guegan, 2020), moving cubes to help a virtual robot (Chenlin et al., 2023), grab and touch (Roel Lesur et al., 2020), picking up objects and placing them in their designated spots (Van Loon et al., 2018). Others simulated flying (Shoshani, 2023) and discounting tasks which involve choosing between generous and selfish options (Bolt et al., 2021), and navigating a virtual shopping site and meeting a salesperson (Yoo et al., 2015). While VCs show potential for empathy research and therapy, limitations in empathy measurement and sample homogeneity require further investigation. We need to better understand the connections between agency, social responses in immersive VR and how individual experiences influence prosocial behaviour (Felnhofer et al., 2018).

Some studies adopted games to examine prosocial behaviour. Games are widely used in HCI and human-robot interaction (Deterding et al., 2011), as they enhance the user experience and engagement compared to traditional experiments. In this specific context, the use of games has mostly been restricted to behavioural economics games, such as Trust (Van Loon et al., 2018) and the Dictator game (Chenlin et al., 2023). However, other games, including Cyberball (Kothgassner et al., 2017), Mind (Litvinova et al., 2023), Maze Adventure (Wei and Bramwell-Dicks, 2022), and EmpathyAR (Lopez-Faican and Jaen, 2023) have been used to study prosociality with varying degrees of success. These games were designed to promote empathic skills, allow users to interact with virtual co-players, and provide a first-person perspective. The utilisation of XR and games as tools for prosociality research holds significant promise. Their extensive use, coupled with a high level of effectiveness in enhancing interactive experiences, presents an interesting research area to further understand prosocial behaviour.

The intersection of technology-induced prosociality and moral considerations remains underexamined. Delving into moral dilemmas, such as the Trolley problem and Mad Bomber scenario, reveals the complex dynamics at play when technology interfaces with ethical decision-making. For instance (Niforatos et al., 2020), suggests that experiencing these dilemmas in VR leads individuals to make more utilitarian choices (i.e., make decisions that save the most people, even if that harms an individual), highlighting the importance of conscientious design in VR experiences that involve moral decision-making. These principles should consider how immersive experiences influence decision-making and potential biases.

4.1 Limitations

It is important to acknowledge that there is other research in the field of technology-aided prosociality extending beyond the scope of this review. Importantly, the domain of robotic interfaces has shown promise in positively impacting user perceptions, with robots exhibiting prosocial conduct gaining favourable views in terms of their social attributes, especially in domains such as education and healthcare (Sari et al., 2021; Spatola and Wudarczyk, 2021).

The field of embodied conversational agents (i.e., EVAs outside XR contexts) has been rapidly evolving. This growth is driven by new technologies and insights into simulating human behaviour. Key to these advancements is the integration of emotions, sentiments, and affect into interactions, highlighting the importance of continued research in this area (Kusal et al., 2022). However, the specific scope and focus of this review may limit the exploration of diverse applications and implications of these agents as the field expands, making it challenging to maintain comprehensiveness. While the study acknowledges the latest advancements in the field, future research could benefit from a more comprehensive and detailed examination of the depth of integration of empathic features in these agents through a multi-layered approach that incorporates both human emotion sensing and environmental awareness (DiPaola and Yalçin, 2019).

Furthermore, the insights from (Lugrin et al., 2022) highlight the critical need for an interdisciplinary approach across domains (e.g., AI, XR, affective computing) in developing socially interactive agents. Interestingly, studies have found that users can perceive emotions and intentions even in agents with abstract appearances, not just realistic human-like ones (de Borst and de Gelder, 2015). These findings apply to various conversational technologies like chatbots, helper robots, and even self-driving cars. As we develop these tools to improve our lives, it's crucial to consider ethical principles for AI development. These principles, known as Trustworthy AI, focus on aspects like fairness, transparency, privacy, and environmental responsibility (Liu et al., 2022). Integrating these principles can make these agents more empathetic and have a positive impact on society in the coming years.

This review acknowledges several limitations in the current research landscape on XR and EVAs, particularly concerning technological integration challenges. One critical area is the balance between realism and real-time rendering within XR environments. Real-time performance requirements, such as low end-to-end latency and high frames per second, often necessitate compromises in the quality of EVA simulations, which can adversely affect user perception and experience. Additionally, accurately portraying the subtleties of social cues and complex interactions—like nuanced facial expressions—poses a significant challenge for current EVA designs. These technological constraints underscore the difficulty in creating autonomous meta-human representations that are both realistic and responsive within XR settings.

4.2 The future of prosocial design in XR

The fields of XR and EVAs are advancing rapidly, and their impact on our social fabric presents unprecedented opportunities and challenges. Recognising the power of XR to shape human behaviour, researchers are now exploring its potential to foster prosociality, which can lead to creating a more compassionate and collaborative future. The research highlights the importance of aesthetics, embodied affordances, social mechanics, and norm-shaping tactics in shaping individual prosocial behaviour within VEs (McVeigh-Schultz et al., 2019), necessitating a thorough grasp of both physical and social dimensions for understanding XR-enhanced collaboration (Rivera et al., 2022).

Future inquiries into AI's societal impacts, especially concerning EVAs in the context of this paper, should emphasise developing AI agents that actively encourage prosocial behaviour, collaboration, and social action (Paiva, 2022). Building on insights from (Paiva et al., 2021) on empathy and prosociality in social agents, this paper extends this discussion by examining the applications of EVAs architectures within the immersive environments of XR, where the physicality and agency of EVAs can be leveraged to a greater effect. We suggest the exploration of adaptive and context-aware EVAs that not only respond to the users' emotional state but also actively participates in shaping prosocial narratives and experiences.

One of the key challenges is augmenting EVAs' human interaction capabilities, which can be addressed by focusing on dialogue systems that facilitate more engaging and context-aware exchanges, ensuring plausible physical and emotional behaviours (Schmidt et al., 2020). While employing EVAs holds significant promise in shaping prosocial tendencies, their impact is influenced by factors such as the user's identity, empathy levels, perceived agency, and social context. Future studies should delve deeper into expanding the dimensions of prosocial behaviour that EVAs can induce in humans.

XR technologies are increasingly deployed in various applications to encourage altruistic actions, enhance collaboration, decision-making, and mutual comprehension, and mitigate racial and gender biases, significantly affecting people's attitudes, behaviours, and understanding of others' perceptions. Future research should seek to validate whether XR can induce prosocial attitude changes and address their theoretical, methodological, ethical, and practical implications.

Current XR research is predominantly conducted in controlled settings, focusing on short-term prosocial impacts. However, we urge researchers to also consider investigating its long-term effects on prosocial attitudes and behaviours in real-world contexts. With XR technology becoming more mature and increasingly accessible to broader audiences, it would be timely to study XR embedded in people's everyday lives with ethnographic methods such as diary studies and observations. Exploring XRs in games and task-based interactions may present a promising avenue for further understanding the long-term effects of such interventions on real-world prosocial behaviour.

Integrating EVAs into XR holds the potential to influence human behaviour towards social good. Envisioning these agents nudging or warning users to make prosocial decisions or take actions that contribute positively to society and the environment, such as encouraging responsible consumption patterns or promoting environmentally friendly behaviours, offers promising possibilities (Cornelissen et al., 2008). However, current XR technologies still fall short of introducing a convincing "social dimension" into virtual worlds. Creating lifelike virtual representations of oneself and others, along with conveying meaningful and appropriate social cues, remain a challenge for future development (Roth et al., 2015). However, with the rapid increase in computing power, breakthrough hardware, and algorithm optimisation, advancements are swiftly being made in both academia and industry.

Furthermore, the broader ethical implications of the widespread use of EVAs require careful consideration around privacy and personal autonomy, with the central concerns being the impacts of continuous behavioural monitoring as these agents become more prevalent in our daily lives. The variance in user behaviours observed within XR applications necessitates the development of specialised algorithms and mechanisms for optimal connectivity, highlighting the importance of both ethical and technical challenges as EVAs become pervasive in everyday scenarios.

Lastly, advancements in real-time rendering and generative AI offer promising solutions to enhance EVA's higher degree of realism without compromising performance. This includes enhancing the simulation of social cues and complex behaviours to create more engaging and authentic user interactions. Moreover, exploring innovative approaches to reduce latency in conversational EVAs could significantly improve the user experience, making these technologies more practical and effective for diverse applications.

5 Conclusion

The integration of EVAs and immersive virtual experiences is transforming the way we interact in our increasingly complex and competitive physical and virtual worlds. The feasibility of immersive environments to track behaviours such as behavioural decision-making and eye-gaze patterns enables better identification of participants according to their level of empathy dimensions. The results suggest that XR, combined with the interactive capabilities of VCs in various visual and behavioural realism, can form positive social interactions and societal wellbeing. The comprehensive analysis of studies included in this review reveals a predominant focus on VR technologies, given their ability to create immersive and controlled environments conducive to studying human behaviour. The findings highlight the importance of incorporating richer social cues into the design of virtual entities that encourage human prosociality. Research indicates that perspective-taking and social interaction with EVAs may contribute to greater immersion within virtual environments. However, this finding is based on a limited number of studies, highlighting the need for further exploration in this area, especially considering the advancements in EVA technology beyond what was explored in the reviewed research. In summary, this review contributes to understanding the potential and limitations of XR and EVAs in promoting prosocial behaviour. As XR and EVAs evolve and become increasingly integrated into our daily lives, their role in shaping human behaviour and societal norms will require careful consideration and ongoing investigation. While positive and negative events can elicit a range of emotions and potentially encourage prosocial behaviours, there can be personal and even group-level costs associated with these actions. This necessitates careful consideration of these potential trade-offs and requires further investigation.

Author contributions

MY: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Software, Supervision, Visualization, Writing–original draft, Writing–review and editing, Project administration, Validation. SC: Data curation, Investigation, Writing–review and editing. SH: Resources, Writing–review and editing. MS: Writing–review and editing, Resources. AR: Funding acquisition, Writing–review and editing. AS: Writing–review and editing, Data curation, Formal Analysis, Validation. TP: Conceptualization, Methodology, Supervision, Validation, Writing–review and editing.

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Author MS was employed by AgResearch Ltd. and Author AR was employed by AgResearch Ltd.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Allidina, S., Arbuckle, N. L., and Cunningham, W. A. (2019). Considerations of mutual exchange in prosocial decision-making. *Front. Psychol.* 10, 1216. doi:10.3389/fpsyg.2019.01216

Armstrong, M., Skiers, K., Peng, D., Selvan Gunasekaran, T., Kundu, A., Person, T., et al. (2023). "Heightened empathy: a multi-user interactive experience in a bioresponsive virtual reality," in *ACM SIGGRAPH 2023 immersive pavilion* (New York, NY: Association for Computing Machinery), 1–2.

Attar, T., Oyekoya, O., and Horlyck-Romanovsky, M. (2022). "Using virtual reality food environments to study individual food consumer behavior in an urban food environment," in Proceedings of the 28th ACM Symposium on Virtual Reality Software and Technology, Tsukuba Japan, 29 November 2022- 1 December 2022, 1–2.

Barbot, B., and Kaufman, J. C. (2020). What makes immersive virtual reality the ultimate empathy machine? discerning the underlying mechanisms of change. *Comput. Hum. Behav.* 111, 106431. doi:10.1016/j.chb.2020.106431

Batson, C. D., Ahmad, N., and Stocks, E. L. (2011). "Four forms of prosocial motivation: egoism, altruism, collectivism, and principlism," in *Social motivation* (Psychology Press), 103–126.

Batson, C. D., and Ahmad, N. Y. (2009). Using empathy to improve intergroup attitudes and relations. *Soc. issues policy Rev.* 3 (1), 141–177. doi:10.1111/j.1751-2409.2009.01013.x

Batson, C. D., Lishner, D. A., and Stocks, E. L. (2015). "13 the empathy–altruism hypothesis," in *The Oxford handbook of prosocial behavior* (Oxford library of psychology), 259–268.

Böckler, A., Tusche, A., Schmidt, P., and Singer, T. (2018). Distinct mental trainings differentially affect altruistically motivated, norm motivated, and self-reported prosocial behaviour. *Sci. Rep.* 8 (1), 13560. doi:10.1038/s41598-018-31813-8

Bolt, E., Ho, J. T., Lesur, M. R., Soutschek, A., Tobler, P. N., and Lenggenhager, B. (2021). Effects of a virtual gender swap on social and temporal decision-making. *Sci. Rep.* 11 (1), 15376. doi:10.1038/s41598-021-94869-z

Brian, J. F. (1999). Persuasive technologie301398. *Commun. ACM* 42 (5), 26–29. doi:10.1145/301353.301396

Buchanan, T. W., and Preston, S. D. (2014). Stress leads to prosocial action in immediate need situations. *Front. Behav. Neurosci.* 5, 5. doi:10.3389/fnbeh.2014.00005

Burton-Chellew, M. N., and West, S. A. (2013). Prosocial preferences do not explain human cooperation in public-goods games. *Proc. Natl. Acad. Sci.* 110 (1), 216–221. doi:10.1073/pnas.1210960110

Caviola, L., and Faulmüller, N. (2014) *Moral hypocrite in economic games—how prosocial behavior is shaped by social expectations.*

Chenlin, H., Ono, T., and Yamada, S. (2023). "Perspective-taking for promoting prosocial behaviors through robot-robot vr task," in 2023 32nd IEEE International Conference on Robot and Human Interactive Communication (RO-MAN) (IEEE), 2100–2105.

Collange, J., and Guegan, J. (2020). Using virtual reality to induce gratitude through virtual social interaction. *Comput. Hum. Behav.* 113, 106473. doi:10.1016/j.chb.2020.106473

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., and Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Comput. Educ.* 59 (2), 661–686. doi:10.1016/j.compedu.2012.03.004

Cornelissen, G., Pandelaere, M., Warlop, L., and Dewitte, S. (2008). Positive cueing: promoting sustainable consumer behavior by cueing common environmental behaviors as environmental. *Int. J. Res. Mark.* 25 (1), 46–55. doi:10.1016/j.ijresmar.2007.06.002

Crone, C. L., and Kallen, R. W. (2022). Interview with an avatar: comparing online and virtual reality perspective taking for gender bias in stem hiring decisions. *PloS one* 17 (6), e0269430. doi:10.1371/journal.pone.0269430

Davis, M. H. (2018) *Empathy: a social psychological approach*. Routledge.

Davis, M. H., Mitchell, K. V., Hall, J. A., Lothert, J., Snapp, T., and Meyer, M. (1999). Empathy, expectations, and situational preferences: personality influences on the decision to participate in volunteer helping behaviors. *J. personality* 67 (3), 469–503. doi:10.1111/1467-6494.00062

de Borst, A. W., and de Gelder, B. (2015). Is it the real deal? perception of virtual characters versus humans: an affective cognitive neuroscience perspective. *Front. Psychol.* 6, 576. doi:10.3389/fpsyg.2015.00576

Delgado Rodriguez, S., Radiah, R., Mäkelä, V., and Alt, F. (2023) *Challenges in virtual reality studies: ethics and internal and external validity.*

Derek Hart, J., Piumsomboon, T., Lee, G. A., Smith, R. T., and Billinghurst, M. (2021). "Manipulating avatars for enhanced communication in extended reality," in 2021 IEEE International Conference on Intelligent Reality (ICIR), 12-13 May 2021 (IEEE), 9–16.

D'Errico, F., Martinez, M., D'Anna, C., Schmid, M., Mastrobattista, S., Parlongo, R., et al. (2019). "'prosocial'virtual reality as tool for monitoring engagement in intergroup helping situations," in *SAT@ smc*, 17–21.

Deterding, S., Sicart, M., Nacke, L., O'Hara, K., and Dixon, D. (2011). "Gamification. using game-design elements in non-gaming contexts," in *CHI'11 extended abstracts on human factors in computing systems* (Association for Computing Machinery), 2425–2428.

DiPaola, S., and Yalçin, Ö. N. (2019). "A multi-layer artificial intelligence and sensing based affective conversational embodied agent," in 2019 8th International Conference on Affective Computing and Intelligent Interaction Workshops and Demos (ACIIW) (IEEE), 91–92.

Dole, L., and Ju, W. (2019). “Face and ecological validity in simulations: lessons from search-and-rescue hri,” in Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems, 1–8.

Eisenberg, N., and Miller, P. A. (1987). The relation of empathy to prosocial and related behaviors. *Psychol. Bull.* 101 (1), 91–119. doi:10.1037/0033-2909.101.1.91

Eisenberg, N., and Spinrad, T. L. (2014). Multidimensionality of prosocial behavior. *Prosocial Dev. A Multidimens. approach* 13, 17–39. doi:10.1093/acprof:oso/9780199964772.003.0002

Engel, C. (2011). Dictator games: a meta study. *Exp. Econ.* 14, 583–610. doi:10.1007/s10683-011-9283-7

Fehr, E., and Fischbacher, U. (2003). The nature of human altruism. *Nature* 425 (6960), 785–791. doi:10.1038/nature02043

Fehr, E., and Gächter, S. (2000). Cooperation and punishment in public goods experiments. *Am. Econ. Rev.* 90 (4), 980–994. doi:10.1257/aer.90.4.980

Felnhofer, A., Kafka, J. X., Hlavacs, H., Beutl, L., Kryspin-Exner, I., and Kothgassner, O. D. (2018). Meeting others virtually in a day-to-day setting: investigating social avoidance and prosocial behavior towards avatars and agents. *Comput. Hum. Behav.* 80, 399–406. doi:10.1016/j.chb.2017.11.031

Frede, D., and Lee, M.-K. (2003) *Plato’s ethics: an overview*.

Gibson, W. (1984). “Neuromancer,” in *Crime and Media* (Routledge), 86–94.

Gillath, O., McCall, C., Shaver, P. R., and Blascovich, J. (2008). What can virtual reality teach us about prosocial tendencies in real and virtual environments? *Media Psychol.* 11 (2), 259–282. doi:10.1080/15213260801906489

Haley, K. J., and Fessler, D. M. T. (2005). Nobody’s watching? subtle cues affect generosity in an anonymous economic game. *Evol. Hum. Behav.* 26 (3), 245–256. doi:10.1016/j.evolhumbehav.2005.01.002

Hang, C., Ono, T., and Yamada, S. (2022). “Perspective-taking of virtual agents for promoting prosocial behaviors,” in Proceedings of the 10th International Conference on Human-Agent Interaction, Pittsburgh, PA, USA, June 14-18, 2010, 236–238.

Hansdotter, Y. (2023). “The affordances of immersive virtual reality for stimulating prosocial behaviour: A. Hansdotter, Ylva,” in *The affordances of immersive virtual reality for stimulating prosocial behaviour: a mixed-methods pro-environmental intervention study* (University College Dublin School of Mechanical and Materials Engineering).

Harvey, J., Golightly, D., and Smith, A. (2014). “Hci as a means to prosociality in the economy,” in Proceedings of the SIGCHI conference on human factors in computing systems, Toronto, Canada, April 26 - May 1, 2014, 2955–2964.

Hauert, C. (2010). Replicator dynamics of reward and reputation in public goods games. *J. Theor. Biol.* 267 (1), 22–28. doi:10.1016/j.jtbi.2010.08.009

Hauser, D. J., Ellsworth, P. C., and Gonzalez, R. (2018). Are manipulation checks necessary? *Front. Psychol.* 9, 998. doi:10.3389/fpsyg.2018.00998

Heilman, R. M., and Kusev, P. (2020). Personal values associated with prosocial decisions. *Behav. Sci.* 10 (4), 77. doi:10.3390/bs10040077

Hepach, R., and Warneken, F. (2018). Editorial overview: early development of prosocial behavior: revealing the foundation of human prosociality. *Curr. Opin. Psychol.* 20, 4–8. doi:10.1016/j.copsyc.2018.02.001

Herrera, F., Bailenson, J., Weisz, E., Ogle, E., and Zaki, J. (2018). Building long-term empathy: a large-scale comparison of traditional and virtual reality perspective-taking. *PloS one* 13 (10), e0204494. doi:10.1371/journal.pone.0204494

Ho, J. C. F., and Ng, R. (2022). Perspective-taking of non-player characters in prosocial virtual reality games: effects on closeness, empathy, and game immersion. *Behav. Inf. Technol.* 41 (6), 1185–1198. doi:10.1080/0144929x.2020.1864018

Hsieh, T.-Yi, Chaudhury, B., and Cross, E. S. (2023). Human–robot cooperation in economic games: people show strong reciprocity but conditional prosociality toward robots. *Int. J. Soc. Robotics* 15, 791–805. doi:10.1007/s12369-023-00981-7

Huang, A., Knierim, P., Chiossi, F., Chuang, L. L., and Welsch, R. (2022). “Proxemics for human-agent interaction in augmented reality,” in Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems, 1–13.

Hussain, M. A., Adam, M. T. P., Chiong, R., Teubner, T., et al. (2019). Avatars and embodied agents in experimental information systems research: a systematic review and conceptual framework. *Australas. J. Inf. Syst.* 23. doi:10.3127/ajis.v23i0.1841

Iachini, T., Coello, Y., Frassinetti, F., and Ruggiero, G. (2014). Body space in social interactions: a comparison of reaching and comfort distance in immersive virtual reality. *PloS one* 9 (11), e111511. doi:10.1371/journal.pone.0111511

Ijsselsteijn, W., De Kort, Y., Midden, C., Berry, E., and Hoven, E. V. D. (2006). “Persuasive technology for human well-being: setting the scene,” in Persuasive Technology: First International Conference on Persuasive Technology for Human Well-Being, PERSUASIVE 2006 Proceedings 1, Eindhoven, The Netherlands, May 18-19, 2006 (Springer), 1–5.

Jarvis Thomson, J. (1984). The trolley problem. *Yale LJ* 94, 1395. doi:10.2307/796133

Jeremy, N. B., and Blascovich, J. (2004) *Avatars. encyclopedia of human-computer interaction*. Berkshire Publishing Group, 64–68.

Kambe, A., and Nakajima, T. (2022). “First person vs. third person perspective in a persuasive virtual reality game: how does perspective affect empathy orientation?,” in International Conference on Human-Computer Interaction (Springer), 375–386.

Kandaurova, M., and Lee, S. H. M. (2019). The effects of virtual reality (vr) on charitable giving: the role of empathy, guilt, responsibility, and social exclusion. *J. Bus. Res.* 100, 571–580. doi:10.1016/j.jbusres.2018.10.027

Keith, J., Vaish, A., and Schmidt, M. F. H. (2014). The emergence of human prosociality: aligning with others through feelings, concerns, and norms. *Front. Psychol.* 5, 822. doi:10.3389/fpsyg.2014.00822

Kothgassner, O. D., Griesinger, M., Kettner, K., Wayan, K., Völkl-Kernstock, S., Hlavacs, H., et al. (2017). Real-life prosocial behavior decreases after being socially excluded by avatars, not agents. *Comput. Hum. Behav.* 70, 261–269. doi:10.1016/j.chb.2016.12.059

Krippendorff, K. (2011) *Computing krippendorff’s alpha-reliability*. Penn collection.

Kümmerli, R., Burton-Chellew, M. N., Ross-Gillespie, A., and West, S. A. (2010). Resistance to extreme strategies, rather than prosocial preferences, can explain human cooperation in public goods games. *Proc. Natl. Acad. Sci.* 107 (22), 10125–10130. doi:10.1073/pnas.1000829107

Kusal, S., Patil, S., Choudrie, J., Kotecha, K., Mishra, S., and Abraham, A. (2022). Ai-based conversational agents: a scoping review from technologies to future directions. *IEEE Access* 10, 92337–92356. doi:10.1109/access.2022.3201144

Kyrlitsias, C., and Michael-Grigoriou, D. (2022). Social interaction with agents and avatars in immersive virtual environments: a survey. *Front. Virtual Real.* 2, 786665. doi:10.3389/frvir.2021.786665

Litvinova, Y., Rilke, R. M., and Guenther, C. (2023). Me, myself, and i: image concerns and honesty in immersive vr. *Comput. Hum. Behav.* 149, 107950. doi:10.1016/j.chb.2023.107950

Liu, H., Wang, Y., Fan, W., Liu, X., Li, Y., Jain, S., et al. (2022). Trustworthy ai: a computational perspective. *ACM Trans. Intelligent Syst. Technol.* 14 (1), 1–59. doi:10.1145/3546872

Lopez-Faican, L., and Jaen, J. (2023). Design and evaluation of an augmented reality cyberphysical game for the development of empathic abilities. *Int. J. Human-Computer Stud.* 176, 103041. doi:10.1016/j.ijhcs.2023.103041

Lugrin, B., Pelachaud, C., André, E., Aylett, R., Bickmore, T., Breazeal, C., et al. (2022) *Challenge discussion on socially interactive agents: considerations on social interaction, computational architectures, evaluation, and ethics*. 1. New York, NY, USA: Association for Computing Machinery, 561–626.

McConnell, T. (2002) *Moral dilemmas*.

McVeigh-Schultz, J., Kolesnichenko, A., and Isbister, K. (2019). “Shaping pro-social interaction in vr: an emerging design framework,” in Proceedings of the 2019 CHI conference on human factors in computing systems, 1–12.

Miller, M. R., Jun, H., Herrera, F., Villa, J.Yu, Welch, G., and Bailenson, J. N. (2019). Social interaction in augmented reality. *PloS one* 14 (5), e0216290. doi:10.1371/journal.pone.0216290

Mischkowski, D., and Glöckner, A. (2016). Spontaneous cooperation for prosocials, but not for proselfs: social value orientation moderates spontaneous cooperation behavior. *Sci. Rep.* 6 (1), 21555. doi:10.1038/srep21555

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., et al. (2015). Preferred reporting items for systematic review and meta-analysis protocols (prisma-p) 2015 statement. *Syst. Rev.* 4, 1–9. doi:10.1186/2046-4053-4-1

Mostajeran, F., Reisewitz, P., and Steinicke, F. (2022). “Social facilitation and inhibition in augmented reality: performing motor and cognitive tasks in the presence of a virtual agent,” in 2022 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW) (IEEE), 323–328.

Mullett, T. L., McDonald, R. L., and Brown, G. D. A. (2020). Cooperation in public goods games predicts behavior in incentive-matched binary dilemmas: evidence for stable prosociality. *Econ. Inq.* 58 (1), 67–85. doi:10.1111/ecin.12796

Niforatos, E., Palma, A., Roman, G., Vourvopoulos, A., and Liarokapis, F. (2020). “Would you do it? enacting moral dilemmas in virtual reality for understanding ethical decision-making,” in Proceedings of the 2020 CHI conference on human factors in computing systems, 1–12.

Obaid, M., Damian, I., Kistler, F., Endrass, B., Wagner, J., and André, E. (2012). “Cultural behaviors of virtual agents in an augmented reality environment,” in Intelligent Virtual Agents: 12th International Conference, IVA 2012 Proceedings 12, Santa Cruz, CA, USA, September, 12-14, 2012 (Springer), 412–418.

Oliveira, R., Arriaga, P., Santos, F. P., Mascarenhas, S., and Paiva, A. (2021). Towards prosocial design: a scoping review of the use of robots and virtual agents to trigger prosocial behaviour. *Comput. Hum. Behav.* 114, 106547. doi:10.1016/j.chb.2020.106547

Ou, Li, and Qiu, H. (2023). “Virtual reality in supporting charitable giving: the role of vicarious experience, existential guilt, and need for stimulation,” in 2023 IEEE Conference Virtual Reality and 3D User Interfaces (VR) (IEEE), 641–647.

Paiva, A. (2022). “From social to prosocial machines: a new challenge for ai,” in 27th International Conference on Intelligent User Interfaces, 2.

Paiva, A., Correia, F., Oliveira, R., Santos, F., and Arriaga, P. (2021). "Empathy and prosociality in social agents," in *The handbook on socially interactive agents: 20 Years of research on embodied conversational agents, intelligent virtual agents, and social robotics volume 1: methods, behavior, cognition*, 385–432.

Paiva, A., Leite, I., Boukricha, H., and Wachsmuth, I. (2017). Empathy in virtual agents and robots: a survey. *ACM Trans. Interact. Intelligent Syst. (TiiS)* 7 (3), 1–40. doi:10.1145/2912150

Paiva, A., Santos, F., and Santos, F. (2018). "Engineering pro-sociality with autonomous agents," in Proceedings of the AAAI conference on artificial intelligence, volume 32, New Orleans, Louisiana, USA, 2-7 February 2018.

Parra Vargas, E., Delgado, A. G., Torres, S. C., Carrasco-Ribelles, L. A., Marín-Morales, J., and Raya, M. A. (2022). Virtual reality stimulation and organizational neuroscience for the assessment of empathy. *Front. Psychol.* 13, 993162. doi:10.3389/fpsyg.2022.993162

Paulus, M. (2018). The multidimensional nature of early prosocial behavior: a motivational perspective. *Curr. Opin. Psychol.* 20, 111–116. doi:10.1016/j.copsyc.2017.09.003

Peters, M., Godfrey, C., McInerney, P., Baldini Soares, C., Khalil, H., and Parker, D. (2015). "Methodology for jbi scoping reviews," in *The Joanna Briggs institute reviewers manual 2015* (Joanna Briggs Institute), 3–24.

Pfattheicher, S., Nielsen, Y. A., and Thielmann, I. (2022). Prosocial behavior and altruism: a review of concepts and definitions. *Curr. Opin. Psychol.* 44, 124–129. doi:10.1016/j.copsyc.2021.08.021

Piumsomboon, T., Lee, G. A., Hart, J. D., Ens, B., Lindeman, R. W., Thomas, B. H., et al. (2018). "Mini-me: an adaptive avatar for mixed reality remote collaboration," in Proceedings of the 2018 CHI conference on human factors in computing systems, 1–13.

Piumsomboon, T., Lee, Y., Lee, G. A., Dey, A., and Billinghurst, M. (2017). "Empathic mixed reality: sharing what you feel and interacting with what you see," in 2017 International Symposium on Ubiquitous Virtual Reality (ISUVR) (IEEE), 38–41.

Reeves, B., and Nass, C. (1996) *The media equation: how people treat computers, television, and new media like real people 10(10).* Cambridge, UK: Cambridge University Press.

Rivera, F. G., Lamb, M., Högberg, D., and Brolin, A. (2022). "The schematization of xr technologies in the context of collaborative design," in 10th Swedish Production Symposium (SPS2022), Skövde, April 26–29 2022 (IOS Press), 520–529.

Rodrigues, J., and Hewig, J. (2021) *Let's call it altruism! a psychological perspective and hierarchical framework of altruism and prosocial behavior*.

Roel Lesur, M., Lyn, S., and Lenggenhager, B. (2020). How does embodying a transgender narrative influence social bias? an explorative study in an artistic context. *Front. Psychol.* 11, 1861. doi:10.3389/fpsyg.2020.01861

Rosenberg, R. S., Baughman, S. L., and Bailenson, J. N. (2013). Virtual superheroes: using superpowers in virtual reality to encourage prosocial behavior. *PloS one* 8 (1), e55003. doi:10.1371/journal.pone.0055003

Roth, D., Erich Latoschik, M., Vogeley, K., and Bente, G. (2015). Hybrid avatar-agent technology–a conceptual step towards mediated "social" virtual reality and its respective challenges. *i-com* 14 (2), 107–114. doi:10.1515/icom-2015-0030

Sari, R. R. N., Heyselaar, E., Müller, B. C. N., and Bosse, T. (2021). Do we take a robot's needs into account? the effect of humanization on prosocial considerations toward other human beings and robots. *Cyberpsychology, Behav. Soc. Netw.* 24 (5), 332–336. doi:10.1089/cyber.2020.0035

Schmidt, S., Ariza, O., and Steinicke, F. (2020). Intelligent blended agents: reality–virtuality interaction with artificially intelligent embodied virtual humans. *Multimodal Technol. Interact.* 4 (4), 85. doi:10.3390/mti4040085

Shin, D. (2018). Empathy and embodied experience in virtual environment: to what extent can virtual reality stimulate empathy and embodied experience? *Comput. Hum. Behav.* 78, 64–73. doi:10.1016/j.chb.2017.09.012

Shoshani, A. (2023). From virtual to prosocial reality: the effects of prosocial virtual reality games on preschool children's prosocial tendencies in real life environments. *Comput. Hum. Behav.* 139, 107546. doi:10.1016/j.chb.2022.107546

Shriram, K., Oh, S. Y., and Bailenson, J. (2017). "Virtual reality and prosocial behavior," in. *Social Signal Processing* 304.

Simpson, B., and Willer, R. (2015). Beyond altruism: sociological foundations of cooperation and prosocial behavior. *Annu. Rev. Sociol.* 41, 43–63. doi:10.1146/annurev-soc-073014-112242

Social Learning Powell, A. A. (2003). Altruism and prosocial behavior. *PERSONALITY Soc. Psychol.* 5, 463–484. doi:10.1002/0471264385.wei0519

Sora-Domenjó, C. (2022). Disrupting the "empathy machine": the power and perils of virtual reality in addressing social issues. *Front. Psychol.* 13, 814565. doi:10.3389/fpsyg.2022.814565

Spagnolli, A., Masotina, M., Furlan, M., Pluchino, P., Martinelli, M., and Gamberini, L. (2021). Sharing the space with the "victim" can increase help rates. a study with virtual reality. *Front. Psychol.* 12, 729077. doi:10.3389/fpsyg.2021.729077

Spanlang, B., Normand, J.-M., Borland, D., Kilteni, K., Giannopoulos, E., Pomés, A., et al. (2014). How to build an embodiment lab: achieving body representation illusions in virtual reality. *Front. Robotics AI* 1 (9). doi:10.3389/frobt.2014.00009

Spatola, N., and Wudarczyk, O. A. (2021). Implicit attitudes towards robots predict explicit attitudes, semantic distance between robots and humans, anthropomorphism, and prosocial behavior: from attitudes to human–robot interaction. *Int. J. Soc. Robotics* 13, 1149–1159. doi:10.1007/s12369-020-00701-5

Staub, E. (2013) *Positive social behavior and morality: social and personal influences*. Elsevier.

Steven, D. L., and List, J. A. (2008). Homo economicus evolves. *Science* 319 (5865), 909–910. doi:10.1126/science.1153640

Sun, J. A., Fox, J., Bailenson, J. N., and Avatars, (2012) *Leadership in science and technology: a reference handbook, 2*, 695–702.

Tassinari, M., Aulbach, M. B., and Jasinskaja-Lahti, I. (2022). Investigating the influence of intergroup contact in virtual reality on empathy: an exploratory study using altspacevr. *Front. Psychol.* 12, 815497. doi:10.3389/fpsyg.2021.815497

Thaler, R. H. (2000). From homo economicus to homo sapiens. *J. Econ. Perspect.* 14 (1), 133–141. doi:10.1257/jep.14.1.133

Tountopoulou, M., Drosos, N., Triantafillopoulou, M.-E., Vlachaki, F., Daras, P., Vretos, N., et al. (2021). Training of prosocial skills to migrant groups through serious games. *Adv. Soc. Sci. Res. J.* 8 (8), 464–483. doi:10.14738/assrj.88.10673

Trivers, R. L. (1971). The evolution of reciprocal altruism. *Q. Rev. Biol.* 46 (1), 35–57. doi:10.1086/406755

Van Erp, J. B. F., and Toet, A. (2015). Social touch in Humanâ€"Computer interaction". *Front. digital Humanit.* 2 (2). doi:10.3389/fdigh.2015.00002

Van Hoorn, J., Van Dijk, E., Güroğlu, B., and Crone, E. A. (2016). Neural correlates of prosocial peer influence on public goods game donations during adolescence. *Soc. cognitive Affect. Neurosci.* 11 (6), 923–933. doi:10.1093/scan/nsw013

Van Loon, A., Bailenson, J., Zaki, J., Bostick, J., and Willer, R. (2018). Virtual reality perspective-taking increases cognitive empathy for specific others. *PloS one* 13 (8), e0202442. doi:10.1371/journal.pone.0202442

Wang, Z., Wang, L., Yin, Z.-Yu, and Xia, C.-Yi (2012). Inferring reputation promotes the evolution of cooperation in spatial social dilemma games. *PloS one* 7 (7), e40218. doi:10.1371/journal.pone.0040218

Wei, S., and Bramwell-Dicks, A. (2022). "Do people matter? presence and prosocial decision-making in virtual reality," in 35th International BCS Human-Computer Interaction Conference 35, 1–10.

Will, G.-J., and Güroğlu, B. (2016). A neurocognitive perspective on the development of social decision-making. *Neuroeconomics*, 293–309. doi:10.1007/978-3-642-35923-1_15

Yamagishi, T., Matsumoto, Y., Kiyonari, T., Takagishi, H., Li, Y., Kanai, R., et al. (2017). Response time in economic games reflects different types of decision conflict for prosocial and proself individuals. *Proc. Natl. Acad. Sci.* 114 (24), 6394–6399. doi:10.1073/pnas.1608877114

Yoo, S.-C., Peña, J. F., and Drumwright, M. E. (2015). Virtual shopping and unconscious persuasion: the priming effects of avatar age and consumers' age discrimination on purchasing and prosocial behaviors. *Comput. Hum. Behav.* 48, 62–71. doi:10.1016/j.chb.2015.01.042

Zhang, J., Dong, Ze, Bai, X., Lindeman, R. W., He, W., and Piumsomboon, T. (2022). Augmented perception through spatial scale manipulation in virtual reality for enhanced empathy in design-related tasks. *Front. Virtual Real.* 3, 672537. doi:10.3389/frvir.2022.672537

Zhang, J., Han, B., Dong, Ze, Wen, R., Lee, G. A., Hoermann, S., et al. (2024). "Virtual triplets: a mixed modal synchronous and asynchronous collaboration with human-agent interaction in virtual reality," in Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '24) (ACM), 8.

Zhao, K., Ferguson, E., and Smillie, L. D. (2016). Prosocial personality traits differentially predict egalitarianism, generosity, and reciprocity in economic games. *Front. Psychol.* 7, 1137. doi:10.3389/fpsyg.2016.01137