

Playing With Embodied Social Interaction: A Thematic Review of Experiments on Social Aspects in Gameful Virtual Reality

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Recently, there has been a burgeoning of immersive virtual reality (VR) applications in a variety of shapes, including gameful social VR. Despite a longstanding tradition of studying social factors in gameful computing, this perspective in the specific experiences of VR is only gaining traction. This highly multidisciplinary area of interest is immensely complex with potential consequences on individuals and social groups alike. To aid in constituting and systematizing this area of research from the early days, this paper explores 14 state-of-art publications on experimental research of social aspects in gameful VR. These were analysed predominantly based on the included manipulations and the studied outcomes resulting in the extraction of five and seven thematic wholes, respectively. Finally, based on the findings, four broad avenues to consider were emphasized as suggested paths for a comprehensive future of embodied gameful social VR application and research across a variety of disciplines.

RESEARCH HIGHLIGHTS

- Although games, virtual social interaction and VR are popular topics, their combination in gameful social VR is a largely unexplored field
- Studies in this area are mainly exploratory and fragmented across a multitude of manipulations and outcomes
- There is a notable dearth of research on the interaction effects of social affordances in VR and environments' gameful aspects
- Several venues for the future are outlined with special consideration of novel technologies

Keywords: virtual reality; games; gamification; agents; players; state-of-the-art

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1. INTRODUCTION

In recent years, there has been a proliferation of social virtual reality (VR) applications, which are being applied in broad range of domains such as work, education, psychotherapy and entertainment. This trend has been primarily supported by both the increasing accessibility of stereoscopic head-mounted

displays (Mehrfard *et al.*, 2019) and interest in harnessing their potential for exciting immersive experiences, more effective and engaging ways for teaching and learning and new ways for communication at a distance. For example, they have been utilized in social skills training (for a review, see Howard & Gutworth, 2020) and collaboration (Pidel & Ackermann, 2020).

In this context, social VR refers to VR environments where a significant emphasis is placed on the social affordances it provides to foster social interaction among users over other forms of activities. These applications often blend games or gamified elements into social immersive spaces, for example commercial offerings such as *VRChat*, *AltSpace* and *Facebook Space*. The social aspects of these experiences have been implemented in various forms ranging from relatively passive virtual agents to rich, multi-user, fully interactive applications. The complex combination of the three factors discussed here in particular—VR, gamefulness and social affordances—is a relatively new phenomenon. The various disciplines engaged with each of those individual areas are accustomed to leveraging the potentials and avoiding the pitfalls through specific design approaches. However, the combination and potential interactions of these three areas are still largely unexplored grounds. Research into social interactions in the fields of computer-mediated communication, virtual agents, games and gameful virtual environments has become increasingly prolific over the past decades. Yet a gap exists in our understanding of social interactions specifically in respect to gameful social VR. This is not to say we have no knowledge of this area; promising evidence exists that known psychological phenomena replicates in virtual environments, and vice versa (Pan & Hamilton, 2018).

These environments are especially interesting from the perspective of embodied social interaction—including, for example, the perception of avatars and agents, and their effects on self and the experience from different perspectives (e.g. Coanda & Aupers, 2020, Hudson & Hurter, 2016, Yee & Bailenson, 2007). The novelty of VR in this context is namely that, compared to on-screen experiences, it enables richer, gameful embodied experiences through the illusion of body ownership or body transfer (Slater *et al.*, 2010, Spanlang, 2014). For example, it has been shown that the illusion itself could positively affect agency (e.g. Shibuya *et al.*, 2017), yet it is unclear whether these effects transfer into game contexts, which are much more cognitively salient and performative than the usual stripped-down laboratory environment (Lugrin *et al.*, 2018). Indeed, gameful environments, when compared to non-gameful ones, bring an added layer of complexity to VR experiences (see e.g. Lugrin *et al.*, 2018). The phenomenon of body ownership illusion in VR, paired with the infinite possibilities of representations of those bodies in various gameful social contexts, brings forth a broad range of unexplored combinations. These include, but are not limited to, such factors as representations, modes of interaction, modes of interpersonal communication, gameful aspects and finally both individual and social effects. However, apart from encompassing a myriad of effects on the VR experience itself, the illusion of body ownership also raises relevant specific considerations for the virtual representations, such as the congruence of identities, body image and body schema between physical and virtual bodies. Playing with the identity of embodied VR avatars has been suggested as having a multitude of social, affective and cognitive effects

such as a reduction in out-group bias (e.g. Lopez *et al.*, 2019), bodily performance (e.g. Kilteni *et al.*, 2012) and emotional experiences (Waltemate *et al.*, 2018). Results such as these largely imply a high relevance of embodied cognition (Shapiro, 2019) in the context of embodied VR.

Accordingly, this literature review aims to explore and map existing state-of-the-art research themes related to social factors in gameful immersive VR. It specifically focuses on experimental research, which investigates the effects of different manipulations of social aspects, for example the representation and perception of self and others, and modes of interaction and communication. Hence, there is a rich potential for the study of gameful embodied social VR research to contribute theoretical implications for e.g. psychology, sociology and human–computer interaction (HCI), as well as practical implications for developing these applications. Although the focus of the review as such might appear quite constrained, it potentially envelops diverse types and aims of applications with far-reaching implications for serious and non-serious gameful social VR experiences alike.

2. METHOD

2.1. Search strategy

A systematic approach to the literature search was used in order to identify all literature that has investigated social aspects of gameful VR environments. The search was conducted in the Scopus repository as it is one of the largest databases of peer-reviewed publications. The database was deemed to be a particularly suitable choice due to its timely indexing of highly relevant publishers in the field, such as IEEE and ACM. Considering that the aim of this work is to review state-of-the-art literature, the time frame was limited to studies published between year 2016 and 2020. The final search was performed in February 2021 so as to include papers published in year 2020 but only indexed during the beginning of 2021.

Following the widely recommended guidelines for systematic literature retrieval (Webster & Watson, 2002) to enable replications, a single composite string was employed for searching in publications' titles, abstracts and keywords. The search string used was as follows:

gam AND social* AND (VR or 'virtual reality')*

The search string consisted of the three parts, with each describing a single relevant facet of the research topic. *Gam** encompassed various variants of base word 'game', such as games, gamification or gamified, serious games, exergames, etc.; *social** ensured that the retrieved literature considered some aspect of social interactions and *VR* presented an attempt to limit the search to immersive VR as opposed to, for example, on-screen virtual worlds, while at the same time ensuring that variations in terminology will be included. Additionally, due

TABLE 1. Inclusion and exclusion criteria employed for literature selection.

Inclusion criteria	Exclusion criteria
Published between years 2016 and 2020	Published before 2016
Uses immersive VR	Uses mobile VR, CAVE or other
Considers the application gameful	Does not define the application as gameful
Manipulates a social aspect	Examines only one version of a social aspect
Reports on manipulation outcomes	Presents only a design for a future study

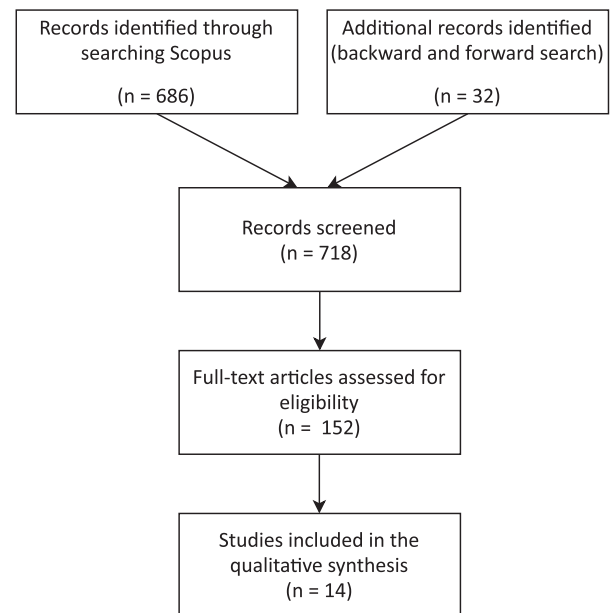
to the researchers' language constraints, only publications in English were included.

2.2. Selection process

A total of 686 results were retrieved based on the search string. The selection process was then conducted in several phases. First, all titles, abstracts and keywords were screened for possible suitability based on the inclusion and exclusion criteria (Table 1); second, the selected full papers were retrieved and scanned following the same criteria; third, a backward and forward search ($n = 32$) of literature was performed in order to ensure the final list of the reviewed literature was as comprehensive as possible. It yielded a total of three additional publications that satisfied the inclusion criteria and were included in the analysis. The inclusion and exclusion criteria refer to the explicit information found in the manuscripts, either as an objective aspect (e.g. technology type) or as claimed by the author(s). For example, inclusion criterion on gamefulness was satisfied if the author(s) would themselves consider and present their stimulus as a *game* or as *gamified*. Overall, the primary reason for excluding a publication was that studies often consider VR to encompass a variety of different, usually on-screen, virtual environments; the second most frequent reason for exclusion was that only a single system was evaluated, which impedes drawing conclusions about the effects of particular aspects of social affordances. In total, 14 full peer-reviewed publications were included in this literature synthesis. The process is presented in an abridged PRISMA (Moher *et al.*, 2009) flow chart (Fig. 1), additionally, a list of the *reviewed literature*, marked with codes R1-R14, is available at the end of this article.

2.3. Analysis

As the aim of a thematic review (Braun & Clarke (2006) is to map the existing veins of research with as few assumptions as possible, pre-determined aspects of the literature (specifically—manipulations and outcomes) were coded and the themes were constructed using an inductive approach. The first step of analysis consisted of familiarization with

**FIGURE 1.** An abridged PRISMA diagram of the screening procedure.

the body of publications and noting their basic information, such as metadata, composition of participant samples and the study designs. The manipulation categories presented in Fig. 2, therefore, represent only slightly abstracted groups of study aspects that help assimilate the variety and scope of the literature. However, in the second step, information on the included manipulations and studied outcomes was collated in an iterative manner, so as to produce relevant broader categories and themes. The first two authors participated in a collaborative sense-making and further abstraction of the collated manipulations and outcomes. As this paper does not attempt to analyse implicit meanings that can be interpreted in various ways, there was no danger of incorrect categories due to biases and prejudices. Rather, the approach implied summarizing the information without losing the nuances but also refraining from presenting themes that are too granular and not meaningful as a thematic overview that would benefit further research. Therefore, it is neither expected nor intended

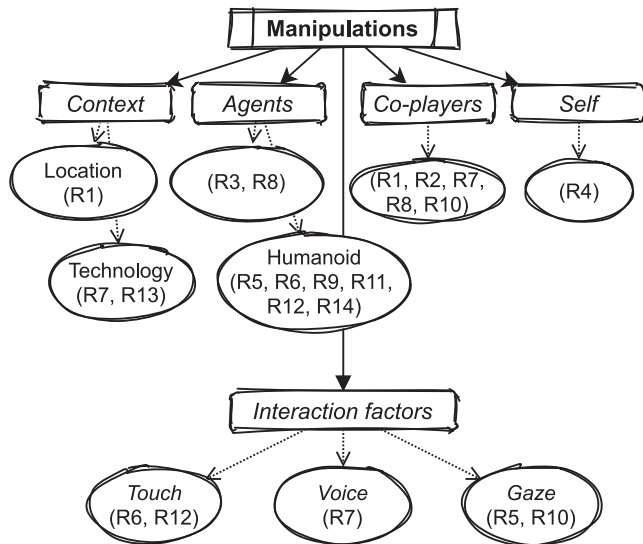


FIGURE 2. Manipulation categories and the respective publications.

that a potential replication study would arrive at the same themes and, in fact, it would be unproductive. These results are an attempt to organize existing and future gameful social VR research in a way that is approachable to a wide audience.

3. RESULTS

3.1. Studies' basic information

In order to gain a general understanding of both the literature and the context of studies, it is first required to interrogate the metadata and basic information about the methods employed. Such information provides valuable insights into the manner in which the field is progressing and what kinds of samples are used. These cues indicate whether the research is, to date, primarily exploratory or if certain aspects are mature enough that the findings are reliable and generalizable to the population. Basic information about the studies is found in Table 2.

Publication metadata The final number of publications meeting the inclusion criteria was somewhat lower than expected. However, what was already apparent from the studies' year of publication was that interest in the social affordances of immersive VR has only begun to gain traction in the past few years. Furthermore, only four of the 14 analysed studies were published as full journal articles, and only in the years 2019 and 2020 (Fairclough & Gilleade, 2012, Högberg *et al.*, 2019, Houzangbe *et al.*, 2018, Hudson & Hurter, 2016). The choice of the publication venue often speaks about the maturity of the research, with these statistics signifying that it is now slowly reaching the stage when fully shaped findings are becoming available.

Studied samples Although the majority of studies included those over the age of 40, participants' mean ages most

frequently were between 23 and 26 years old. This presents a limitation in itself when it comes to applications employing new technology, such as VR; it is likely that the younger population would be both more receptive and display higher degrees of self-efficacy when encountering novel technologies, while the novelty effect is likely to be higher in older populations. Therefore, there is an apparent reason for caution when discussing whether, and to what extent, these effects are generalizable to the wider population.

Gender distribution was slightly skewed towards males, although the majority of studies included both male and female participants. Three studies included only male participants, of these one was due to cultural constraints (Houzangbe *et al.*, 2018) and one was a result of the fact that it investigated professional firefighters (Högberg *et al.*, 2019). Several of the studies reported a single participant identifying as non-binary (Fairclough & Gilleade, 2012, Freeman & Maloney, 2021) and one included 19 participants who had not disclosed their gender identity (Andreassen *et al.*, 2018).

Research design and reporting Almost all of the studies utilized a quantitative approach with self-report measurement tools. This finding is not uncommon when looking at experimental research in the wider field, but is also limiting. Inclusion of other sources of data, such as psychophysiology, log data and post-treatment qualitative data could provide deeper interdisciplinary understanding from different perspectives, including individuals' meaning-making of the different social aspects and interactions.

A further limitation emerging from analysis of the research designs relates to the number of participants per condition, again highlighting an early exploratory approach. Some of the studies included as few as 10 to 15 participants per group (Banakou *et al.*, 2020, Biocca *et al.*, 2003, Botella *et al.*, 2017, Costa *et al.*, 2013, Fairclough & Gilleade, 2012, Freeman & Maloney, 2021), resulting in sometimes using only descriptive statistics. Notably, the highest participant count was found in a study that investigated the influence of photorealism on users' perceptions of game characters: a total of 622 and 175 participants in two consecutive studies (Hudson & Hurter, 2016). Additionally, approximately only half of the reviewed publications reported the observed effect sizes. Considering the complexity and richness of social interactions, effect sizes are of considerable importance as they provide insights into the relevance of different aspects and their practical implications, such as their inclusion in a gameful social VR.

3.2. Manipulations

The publications in this review designed studies with two to five manipulations aimed at contrasting and comparing the effects of modified aspects of social representations and interactions. These studied manipulations and consequent experimental conditions were iteratively coded and clustered in categories. The

TABLE 2. Samples' properties and analysis types for each of the reviewed publications.

Author(s)	Participants		Analysis	
	Sample size, % of females	Age range, mean	Quantitative	Qualitative
Born <i>et al.</i> 2019	88 (45%)	18–56 (M = 24.5)	*	
Dey <i>et al.</i> 2017	26 (27%)	22–41 (M = 30.5)	*	*
Emmerich & Masuch, 2016	81 (51%)	19–48 (M = 26)	*	
Gorisse <i>et al.</i> 2020	36 (28%)	21–47 (M = 23.4)	*	
Hai <i>et al.</i> 2018	10 (20%)	20–40 (NA)	*	
Hoppe <i>et al.</i> 2020	19 (32%)	NA (M = 25)	*	
Kojić <i>et al.</i> 2018	36 (56%)	18–47 (M = 28.1)	*	
Liszio <i>et al.</i> 2017	75 (55%)	19–58 (M = 25)	*	
Sajjadi <i>et al.</i> 2019	41 (48%)	20–40 (M = 25.9)	*	
Seele <i>et al.</i> 2017	42 (40%)	NA	*	
Strojny <i>et al.</i> 2020	48 (0%)	NA (M = 22.5)	*	
Swidrak <i>et al.</i> 2020	113 (17%)	18–34 (M = 23)	*	
Thalmann <i>et al.</i> 2016	16 (25%)	NA (M = 28.5)	*	*
Zibrek <i>et al.</i> 2019	175 (53%)	18–76 (M = 27.8)	*	

categorization was not meant as discriminant, meaning that a single study could be included in different themes if it made use of different manipulations.

A categorization was derived from the literature and consisted of four high-level categories, which describe the broad points of interest in studying social affordances. These are *context*, describing physical or technological facets of the social experience; *agents*, referring to virtual agents, such as guides or non-player characters (NPCs); *co-players*, signifying the inclusion of other human players, either cooperating or competing; and *self*, the various (re-)presentations of self in VR. Additionally, *interaction factors* were identified as a tangential category found in agents and co-players but considered to be deserving of distinct emphasis due to the relevance of interaction in the domain of HCI. For the visual map of the categories, see Fig. 2.

Finally, distinct areas of interest for manipulating social experiences were described using five themes: physicality, interaction, co-existence, anthropomorphism and realism and individual differences. These themes are described shortly as they are further discussed in relation to their respective outcomes.

Theme I—Physicality

The first theme that emerged from the selected literature was that of physicality of the player and their surroundings. It assumes both 'real-world', or biological, and virtual physicality. For example, the question of the effects of users being co-located in the same playing space versus playing while physically separate (Andreasen *et al.*, 2018) is one such consideration in the domain of physical bodies. Virtual bodies and their relationship to the surroundings are presented, for example, in the investigation of the plausibility of spatial movements

of agents in the virtual environment, such as collision avoidance (Botella *et al.*, 2017).

Theme II—Interaction

The question of what kind of influence do different modes of social interaction, or even a complete lack of it, might have on the user was identified as the second theme. More specifically, it encompasses player–agent interactions (Braun & Clarke, 2006) as well as player–player interactions (Braun & Clarke, 2006, Coanda & Aupers, 2020, Freeman & Maloney, 2021), for example.

Theme III—Co-existence

What is the difference between solitary and social experiences, and what factors influence this difference, is the topic of the third theme. It encompasses both the inclusion of others as opposed to being alone in the environment (Bertrand *et al.*, 2018, Costa *et al.*, 2013, Högberg *et al.*, 2019), or the difference between others as agents or others as co-players (Costa *et al.*, 2013). The NPCs range from simplistic robot-like agents (Bertrand *et al.*, 2018) and fantastical animal agents (Costa *et al.*, 2013) to human-like bystanders designed to ‘act naturally’ in order to mimic human non-verbal behavior (Högberg *et al.*, 2019).

Theme IV—Anthropomorphism and realism

Different degrees of anthropomorphism and realism were investigated extensively by several studies (Biocca *et al.*, 2003, Högberg *et al.*, 2019, Hudson & Hurter, 2016). One of which (Biocca *et al.*, 2003) is surprisingly the only publication in this literature review that considered the presentation of self, or the player, with the representations including different levels of anthropomorphism of a robot avatar. On the other hand, Hudson & Hurter (2016) conducted a multi-step study including different levels of realism of a character.

Theme V—Individual differences

One of the more interesting themes from the point of view of social interactions was that of individual differences and personalization. In this literature it includes specifically gender (Houzangbe *et al.*, 2018), personality (Fairclough & Gilleade, 2012) and expressed mood (Hudson & Hurter, 2016). Additionally, one study (Banakou *et al.*, 2020) examined the effects of displaying biofeedback to co-players.

3.3. Outcomes

Overall, social presence, also termed co-presence, was the most studied outcome in the papers included in this review, with 9 out of 14 papers aiming to measure the phenomenon (Andreasen *et al.*, 2018, Botella *et al.*, 2017, Braun & Clarke, 2006, Coanda & Aupers, 2020, Costa *et al.*, 2013, Fairclough & Gilleade, 2012, Högberg *et al.*, 2019, Howard & Gutworth, 2020, ??). Immersion and flow (Bertrand *et al.*, 2018, Coanda & Aupers, 2020, Costa *et al.*, 2013, Fairclough & Gilleade, 2012), emotional response (Banakou *et al.*, 2020, Braun & Clarke, 2006, Costa *et al.*, 2013, Houzangbe *et al.*, 2018, Hudson & Hurter, 2016), realism and perceived agency (Braun & Clarke,

2006, Freeman & Maloney, 2021, Högberg *et al.*, 2019, Hudson & Hurter, 2016) and performance (Andreasen *et al.*, 2018, Bertrand *et al.*, 2018, Biocca *et al.*, 2003, Högberg *et al.*, 2019) were also commonly studied. Two papers (Andreasen *et al.*, 2018, Freeman & Maloney, 2021) measured quality or quantity of communication, while individual studies addressed place illusion (Hudson & Hurter, 2016), compliance (Houzangbe *et al.*, 2018) and avatar appearance and body ownership (Biocca *et al.*, 2003).

All the outcomes studied in the reviewed literature were coded and summarized. The summary of the outcome results were structured around seven themes: co-presence, realism and plausibility, place illusion, affect, embodiment, performance and gamefulness.

Theme I—Co-presence

Co-presence, also termed social presence, refers to the user’s sense of being together with another (Biocca *et al.*, 2003). In the reviewed literature, social presence was the most studied outcome (9 out of 14 papers) and was shown to be influenced by multiple factors including immersion, flow, realism and interactivity. Immersion and flow in particular were deemed necessary requirements for experiencing social presence in VR (Fairclough & Gilleade, 2012).

The perceived realism of the situation was also found to have a vital impact of the level of social presence experienced by users; realistic interactions and behaviours can improve the perceived social presence and blur the boundaries between human- and computer-controlled characters. The inclusion of aspects such as gazing, collision avoidance and ball passing in a VR volleyball game improved users’ social presence when playing with virtual agents (Botella *et al.*, 2017). Similarly, virtual agents’ touch (Braun & Clarke, 2006) and embodied conversational agents (Fairclough & Gilleade, 2012) evoked a higher sense of perceived social presence for users; as agents’ non-verbal behaviours became more pronounced and assertive, users experienced significantly higher levels of behavioural involvement.

A certain level of social realism, consisting of subjective co-presence and realism, is a vital part of successfully evoking the social facilitation effect in the presence of computer-generated agents. The simple fact that virtual agents were present in a simulation of an accident improved the performance of fire-fighting trainees. However, in order for this potential effect to be realized, trainees had to rate the co-presence and realism of the VR training simulation as being relatively high (Högberg *et al.*, 2019).

Interaction with the character appears more important in creating social presence than visual realism; render styling (realistic, simple or sketch) of virtual characters did not affect users’ sense of social presence (Hudson & Hurter, 2016). Interactivity can indeed improve the sense of co-presence when dealing with a virtual agent (e.g. Botella *et al.*, 2017, Braun & Clarke, 2006), albeit not to the same level as when dealing with human-controlled avatars. For example, the dimensions

of social presence, team involvement and team cohesion were found to have higher mean scores when users were engaging with a non-interactive, human co-player when compared to engaging with an interactive virtual agent (Costa *et al.*, 2013).

Enabling interaction between co-players can significantly improve social presence, influencing the dimensions of perceived emotional contagion, perceived comprehension and behavioural interdependence during gameplay (Coanda & Aupers, 2020). In addition, participants in a volleyball game using head mounted displays (HMD) perceived significantly higher levels of social presence, when compared to an immersive room, 3D TV or Alioscopy; HMDs provided participants with seamless, omnidirectional views and awareness of virtual players beside and behind them (Howard & Gutworth, 2020). Finally, remote gameplay during a multiplayer VR task increased perceived social presence when compared to players in a co-located gameplay condition (Andreasen *et al.*, 2018).

Theme II—Realism and plausibility

Realism in VR refers to plausibility, an illusion that the scenario being depicted is actually occurring (Slater, 2009); as previously discussed, perceived realism can serve to improve feelings of social presence in VR environments (Botella *et al.*, 2017, Braun & Clarke, 2006). Increased realism and perceived agency can be facilitated through the inclusion of social touch in VR environments, as it increases users' uncertainty regarding the differentiation of human- and computer-controlled characters (Braun & Clarke, 2006). As such, no significant differences on perceived realism were found when manipulating only avatar gaze during a co-located multiplayer VR task. (Freeman & Maloney, 2021).

Somewhat counter-intuitively, research found that realistic rendering style (compared to simple or sketch) did not increase users' emotional response in empathetic scenarios, instead results showed more appropriate emotional responses to stylized agents. Similarly, the movements of a sketched agent were perceived to be more realistic than those of the other render conditions; consequently, it is possible that the higher quality rendering could raise the expectations for animation fidelity (Hudson & Hurter, 2016).

Theme III—Place illusion

Place illusion, the sensation of being in an actual place, signifies an intense level of immersion into VR environment and can lead to user's realistic response to the content (Slater, 2009). Of the papers included in this review, only one examined this issue; it found a photorealistic render style to have a positive effect on users' feelings of being in a place, thus significantly increasing their place illusion (Hudson & Hurter, 2016).

Theme IV—Affect

The theme of affect here refers to the various emotional responses, positive or negative, that the virtual entities and environments can induce. In the reviewed literature, these included feelings of enjoyment, loneliness and awkwardness, among others.

Although the presence of a social entity did not increase user enjoyment in itself, playing with a human co-player significantly increased experiences of flow and positive affect. The lowest degree of positive affect was experienced when the users played alongside a non-interactive agent. (Costa *et al.*, 2013). In contrast, visually presenting co-player's heart-rate was found to have no influence on one's own emotional response (Banakou *et al.*, 2020).

Interactivity also influenced feelings of loneliness experienced by users; those with a non-interactive co-player or agent perceived the highest levels of loneliness, even when compared to the single player condition. The dissatisfaction of playing with a passive, non-responsive counterpart appears to engender higher levels of loneliness than the complete absence of social entities in the virtual game world. (Costa *et al.*, 2013).

Experiencing the touch of an agent can also create emotional responses in users, for example, a virtual agent's touch significantly increased users' feelings of embarrassment, comparable to that of being touched by a human-controlled avatar (Braun & Clarke, 2006). Furthermore, the touch of a female agent was perceived as being significantly more pleasant by both male and female participants than the touch of a male agent. Contrary to expectations, however, agents' touch did not have a significant effect on participant compliance during the VR task. (Houzangbe *et al.*, 2018).

Scenarios in which agents expressed emotions, e.g. friendly, unfriendly or sad, in VR environments affected user discomfort to a greater degree than render style, with users feeling more comfortable standing near a sad agent in comparison to a friendly or unfriendly one. As previously discussed, realistic rendering style did not increase the emotional response of participants in empathetic scenarios. In contrast, the more stylized agents received more appropriate emotional response from participants, indicating that as the degree of photorealism increases, it may also increase the possibility of recognizing more subtle expressions, while potentially obscuring others (Hudson & Hurter, 2016).

Theme V—Embodiment

The sense of embodiment in virtual environments is composed of self-location, agency and body ownership and refers to the combination of sensations that arise in conjunction with being inside, having and controlling a body (Kilteni *et al.*, 2013). In the reviewed literature, only one of these specific, embodied experiences afforded by VR was investigated, with results suggesting that the level of facial anthropomorphism of a robot-like avatar did not influence users' sense of body ownership (Biocca *et al.*, 2003). Additionally, no publications considered possible social effects on sense of embodiment.

Theme VI—Performance

The effects of the presence of social entities, avatar anthropomorphism and player location on communication, collaboration and task performance was investigated in five of the reviewed papers. As previously mentioned, the mere pres-

ence of virtual agents can have a positive effect on users' performance (Högberg *et al.*, 2019). However, in a separate study participants wearing HMDs in an immersive environment performed significantly worse when agents were present during a task than those participants using a 2D screen, thus indicating a social inhibition effect (Bertrand *et al.*, 2018).

Facial anthropomorphism was found to impact participants' performance in a multiplayer collaborative task; the more anthropomorphic avatars were used, the less time it took for the participants to complete the task. During the experiment a correlation between avatar attractiveness and performance was observed, with participants generally favouring those avatars with more anthropomorphic facial properties. The perceived attractiveness of avatars may have encouraged participants to look at, and focus on one another, thereby favouring non-verbal communication and improving their performance. (Biocca *et al.*, 2003)

Furthermore, higher mean scores for team involvement and team cohesion were observed even when users were dealing with a non-interactive human co-player when compared to an interactive virtual agent (Costa *et al.*, 2013). Remote participants of a multiplayer VR task also achieved better task performance, in general, than co-located participants (Andreasen *et al.*, 2018). No outcomes related to competition were identified in the reviewed literature.

Theme VII—Gamefulness

The theme Gamefulness is used here as an umbrella term for those outcomes often studied in games; in the reviewed papers immersion, flow, enjoyment and interactivity are examples of gameful qualities.

When compared to 2D screens, VR environments offer a significantly higher sense of immersion (Bertrand *et al.*, 2018), flow (Coanda & Aupers, 2020), perceived spatial presence (Coanda & Aupers, 2020, Howard & Gutworth, 2020) and both involvement and experienced realism of users (Coanda & Aupers, 2020). Furthermore, VR with enabled interactions between both users (Coanda & Aupers, 2020) and virtual agents (Botella *et al.*, 2017) increased their perception of general presence and quality of experience.

When comparing levels of immersion experienced while playing alongside human co-players or virtual agents, the former has been found to induce greater immersion than the latter, although single players scored highest for immersion when compared to co-player or agent conditions. Furthermore, a strong positive correlation was found between immersion, flow and positive affect, underlining the importance of immersion for a positive experience in VR games (Costa *et al.*, 2013).

As previously discussed, the existence of a social entity does not increase enjoyment in itself; playing with a human co-player, compared to playing with a virtual agent, significantly increased experiences of flow and positive affect. The lowest ratings of positive affect were provided by users who were given a non-interactive agent as their playing counterpart; overall, virtual agents as social entities are less impor-

tant in respect to their influence on enjoyment in comparison to human co-players. Furthermore, an interactive co-player condition was also found to be inferior to the single-player condition in respect to engendering positive player experience (Costa *et al.*, 2013).

Finally, realism was found to be particularly appealing in VR, and it was suggested that the higher quality rendering could be more fascinating and motivate a desire to explore surrounding environments (Hudson & Hurter, 2016).

4. DISCUSSION

This review mapped the current themes in the growing research domain of gameful social VR, with a specific focus on studies experimenting with social aspects. It should be noted that the findings of this review are generalizable only to the body of evidence that was examined. A total of 14 peer-reviewed publications were found to satisfy all inclusion criteria and, therefore, were included in the analysis. Two major aspects of interest in this study were the manipulations included in the design, or which different social aspects were compared, and what types of related outcomes were recorded.

Overall, the literature shows a very young but promising field with a distinct breadth of possibilities for researchers in the fields of games and gamification, psychology, communication and HCI. Figure 3 depicts the more commonly studied relationships between manipulation and outcome themes. The connecting lines typically reflect two studies; however, there were three studies investigating the relationship between *co-existence* and *co-presence*, as well as between *individual differences* and *affect* (for a graphical representation of connections between all manipulation and outcome themes, see Appendix). This fragmentation primarily testifies to the infancy of the existing literature and, in particular, of the tendency to overlook both the potential influence of the gamefulness of the used environments and the unique aspects of immersive VR experiences.

The manipulations, for the most part, focus on social interactions with agents, and their influence on various outcomes. This approach ensures congruence in agents' behaviour, securing higher validity and reliability of the results that could be assumed to be transferable to human–human interaction. However, it has also already been suggested even in this body of literature that these might not be completely comparable (Costa *et al.*, 2013). Therefore, it seems that more efforts could be directed towards co-players' interactions rather than that of a player with an agent.

Additionally, in the body of literature included in this review, surprisingly little attention overall has been dedicated to the effects of self-representations in gameful social VR, despite the breadth of potential effects of body ownership. The one study with this particular focus investigated the effects of different levels of facial anthropomorphism in robot-like avatars (Biocca *et al.*, 2003); none experimented with representations of, for

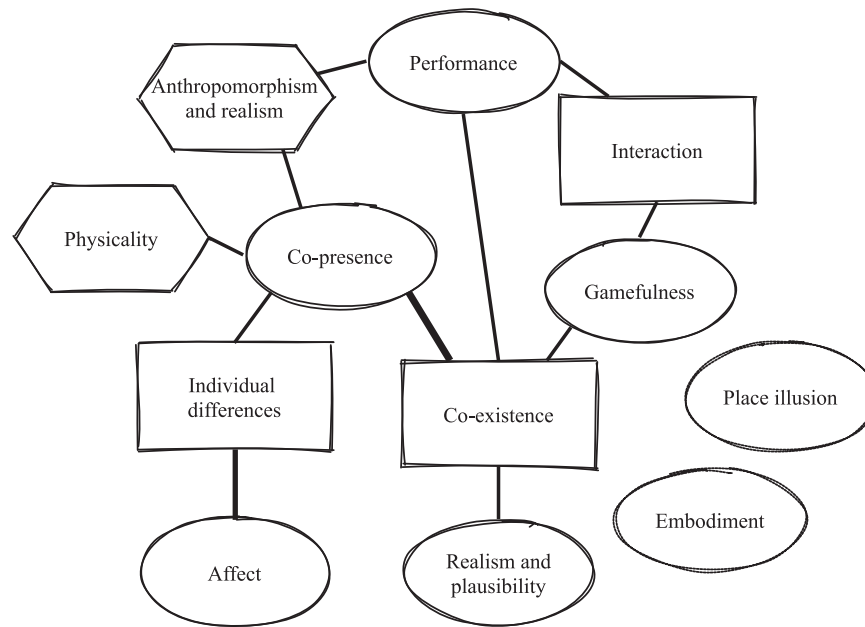


FIGURE 3. A network diagram of at least two studies investigating relations between manipulation and outcome themes. Rectangles signify manipulation and circles outcome themes.

example, non-congruent gender, ethnic or other identities. Several studies on these topics have been made in respect to non-gameful VR in recent years (e.g. (Kilteni *et al.*, 2013, Lopez *et al.*, 2019, Maister *et al.*, 2015)), yet the additional interactivity and other affordances of gamefulness and its effects remains under-represented in the current literature.

Most importantly, there is a distinct lack of investigation of the moderating effects of gameful stimuli, or of the experiences related to them, such as the perceived gamefulness (Högberg *et al.*, 2019) or game experience (IJsselsteijn *et al.*, 2013), for example. Some of the studies did consider immersion and flow (Bertrand *et al.*, 2018, Coanda & Aupers, 2020, Costa *et al.*, 2013, Fairclough & Gilleade, 2012), but only as outcome variables, not as mediators, bridging influences on the relevant final social outcomes. Of course, studying interaction or mediation effects require more statistical power and larger sample sizes than typically used in early-stage exploratory studies such as most of those in this review; this study clearly highlights the need for such work. Arguably, considering the effects of the realism of others in VR could be bundled under the gameful aspect as lower realism could be seen as more fantastical and ludic. However, the realism in presentations of others is not predetermined even in games, encompassing both ends of the spectrum from mundane to fantastical, and naturally includes many other aspects in rich interactive environments, in addition to the visual representation.

It was also challenging to find a common thread describing virtual environments or stimuli, with terms included *game*, *gameful* or *gamified*. Moreover, the detailed descriptions of

these environments and their affordances were often lacking, thereby preventing deeper analysis and reducing the possibility of conducting replication studies. This in itself is an important finding as it demonstrates the need for a more rigorous and critical view, both when designing the studies and when interpreting their results and implications. Although this research field draws on a wealth of previous multidisciplinary studies and is conducted in parallel with other social VR contexts, the gamefulness of the environments and experiences is the particularly novel factor in this case. As such, it should be dissected and its effects studied more transparently and systematically. The question of gameful aspects' effects will be highly relevant in the future when summarizing results on a specific research question, conducting meta-reviews or planning replications of previous findings. This is due to the fact that they can have significant influence on the experience as a whole and, consequently, on the final outcomes of social experiences.

The results of this review raised several points for consideration, noted above. Most notably, there appears to be an unexplored breadth of possibilities for future research that could be of value not only for immersive gaming experiences, but also a range of other, gameful serious applications such as: simulation training, education, emotional and social skill exercises and therapy. Finally, when investigating topics for research in this field, it may be useful to look forward five years and recognize the bleeding-edge technological developments. Higher immersion with tracking facial expressions and gaze in VR, tracking full body movements and transferring touch are steadily becoming parts of real-use scenarios in the

commercial sphere. Additionally, displaying biofeedback and using bioadaptation of the applications to primarily personalize and enhance the experience (e.g. Kivikangas *et al.*, 2011, Parandi & Gutierrez-Osuna, 2017, Zafar *et al.*, 2018) are increasingly being used for example for emotional skills training and have been permeating the games sphere alike (e.g. Nogueira *et al.*, 2016, ??). Including these technologies and meaningfully controlling the experiment conditions for producing valid and reliable insights is not without its hurdles. However, it is also a necessary and timely activity which should be considered in future works, both for the development of applications and understanding the potential pitfalls, such as arising ethical concerns specific to social VR (e.g. Maloney *et al.*, 2021).

4.1. Research gaps and avenues

Due to the immense complexity of each sole element, and even more so when exploring them and their interactions together, the full breadth of all the possible research avenues in the context of gameful social VR is virtually impossible to comprehend. However, based on a) the basic background information of the factors of gamefulness, social affordances and VR, b) the literature review and c) the short discussion on the results and emerging technologies, several major venues for research were identified.

Gameful environments

The majority of the reviewed studies involved simplistic environments, as opposed to fully fledged games and gameful experiences. Although this is understandable from the point of required resources and the ease of experimental control, it might be worthwhile to consider, for example, using already existing social VR spaces. These often deliver rich environments and wide avatar choices, while some also allow for alterations. There have already been notes on the feasibility of running experiments in such applications (Saffo *et al.*, 2020), showing promise for the future of gameful social VR research. The effects of the mere salience of such environments have already been suggested on embodiment in the single-player context (Lugrin *et al.*, 2018), which might then further influence social interactions. It would be relevant to consider, for example, the different effects of competitive and cooperative play, or genre-specific experiences of role-playing, puzzle, strategy or sports. Each of these requires that the players' attentional focus is specifically adjusted to the requirements of the game, shaping both the overall and the social experiences.

(Surreal) embodiment

Overall, different variations in the embodied representations of players in VR, and their effects on social outcomes, have been rarely studied (Freeman & Maloney, 2021, ??). The results of this scoping review also support this perspective. There is a wide and rich opportunity for research augments game contexts with aspects drawn from the flourishing literature in stripped-down, strictly controlled contexts on VR embodiment (see, for example, Bertrand *et al.*, 2018) and embodied cognition

(Costa *et al.*, 2013). Thereby allowing for an exploration of their interactions with more complex virtual environments.

A significant portion of studies on embodiment focus on different human representations and investigating the manipulations' effects on bias, such as gender (e.g. Schulze *et al.*, 2019) and ethnicity (e.g. Banakou *et al.*, 2020), with a smaller number studying the effects on bodily performance (e.g. Kilteni *et al.*, 2012) and learning (Slater *et al.*, 2010). It is not unimaginable, therefore, that different VR avatars might increase self-efficacy in players, followed by engrossment and enjoyment, and possibly even allow for the transfer of attitudes and behaviours outside of the game. Similarly, recent qualitative research of embodied social VR noted a range of effects of one's virtual appearance, or avatars, on social interactions or lack thereof (Freeman & Maloney, 2021).

Finally, to date, VR uniquely affords the possibility for body ownership illusion to be induced even in animal-shaped representations (Andreasen *et al.*, 2018, Krekhov *et al.*, 2019, Rativa *et al.*, 2020), already being explored for game contexts. These surreal experiences could also, for example, potentially be explored as a gameful social tool for raising environmental awareness and educating about nature, life and our relationship to it. Even for solely entertainment purposes, there seems to be a wealth of potential stemming from different surreal or even fantastical experiences of VR avatars.

Emotional and social skills

As with the potential influence of embodiment on social outcomes, there is a dearth of research addressing the possibilities afforded by the variation and manipulation of embodied representations in respect to the context of regulating and learning emotional and social skills. Currently, the use of VR to manage affective states is predominantly utilized in therapeutic contexts, e.g. exposing patients to scenarios, which induce phobic reactions (Botella *et al.*, 2017, Macey *et al.*, 2022, Powers & Emmelkamp, 2008), including those that result from social contexts such as public speaking (Kahlon *et al.*, 2019, Wallach *et al.*, 2009). However, a potentially fruitful avenue for further research would be to investigate the potential for immersive VR environments, and avatar manipulation, to be used to guide and regulate emotional responses in less extreme situations. Particularly, impactful areas for such research would be in the management of stress in workplaces or educational institutions, similar to that which has been studied with, for example VR meditation (Kosunen *et al.*, 2016, Lee & Kang, 2020, Salminen *et al.*, 2019), but which further leverages gamefulness and support from social dynamics. Furthermore, the study of emotional regulation and affective states benefit not only individuals but can also inform group interactions through understanding and managing the emotions of both self and others.

An especially productive approach would be for future studies to investigate the possibilities of utilizing gameful and game-like VR experiences to inform emotional and social skills. For example, the ways in which flow impacts upon skill

development, or whether an environment that promotes exploration and self-discovery compares to one in which actions are more guided. In this way, the value afforded by VR can move beyond established practices of simply replicating real-life events and scenarios and instead holds the potential to make use of a range of affective experiences and, again, transcend the limits of the ‘real’.

Biofeedback and bioadaptation

Of the reviewed literature, only one paper investigated the effect of added biofeedback in multiplayer collaborative gaming context, but the study was limited to a player-observer dyad (Banakou *et al.*, 2020). Indeed, the inclusion of biofeedback as part of VR scenarios has been utilized mainly in single-user contexts such as sports performance training (Lagos *et al.*, 2011) and stress management (Kosunen *et al.*, 2016, Soyka *et al.*, 2016), but its utilization in multi-user platforms and gaming contexts is particularly limited (Banakou *et al.*, 2020, Houzangbe *et al.*, 2018).

Research in which biofeedback is provided between players or users would offer a number of intriguing areas for investigation, for example how information such as heart rate may aid emotional regulation of self and others’ states, in comparison to more affective methods. Indeed, given that feelings of social presence have been found to be influenced more by interaction quality than by visual realism (Hudson & Hurter, 2016), it is possible that providing meaningful information through biofeedback could increase the perceived quality of interactions and, consequently, feelings of social presence. Once again, research into the effects of gameful VR experiences on processing biometric information could investigate how such environments compare to more traditional approaches to both providing and processing information. Only a single study utilizing biofeedback in gameful social VR was found (Banakou *et al.*, 2020), but a selection of studies utilizing biofeedback to support social interactions in more general contexts exist. The combination of shared VR environment and biofeedback open up the possibility to go even further and use physiological synchrony-based biofeedback to display users the joint changes in their physiological signals that are related to e.g. empathy (Salminen *et al.*, 2019). Considering the co-occurring fast developments in consumer grade biosignal measurement technology, VR devices and social neurosciences, it could be expected that these trends converge in novel uses of dyadic synchrony biofeedback to augment social interactions in VR and in gamifying the biocybernetic loop (Fairclough & Gilleade, 2012, Kosunen, 2018).

5. LIMITATIONS

This study has several limitations that are worth noting for better positioning and understanding of its outcomes.

First, although systematic attempts were made to scan and retrieve as many relevant publications as possible, it is likely

that some were omitted due to the broadness of the field and terminology employed. Furthermore, some studies may not have been indexed in the searched databases or might not have been even fully published by the time the searches were conducted. Despite this, it is reasonable to assume that the retrieved body of literature is comprehensive enough for building a thematic map of the topic, thereby achieving aims of this study.

Second, the scope was limited to state-of-the-art findings, or the period between year 2016 and year 2020. The time period was chosen purposefully as it is also when we had seen a proliferation of the commercial use of VR and the resultant academic research on the topic. However, it should not be forgotten that some of the landmark research in the field of VR has existed since long before 2016. Further review studies could potentially adopt a longitudinal approach and provide insights into how the field and its interests have changed with time, depending on the state and accessibility of the VR technology and applications.

Third, the focus of this scoping review was limited only to experimental data; however, the results are potentially applicable to more diverse types and aims of applications with far-reaching implications for serious and non-serious gameful social VR experiences alike. It should also be noted that the findings of this review are generalizable only to the body of literature that was examined, and that it should not be read as a meta-review.

This review provides a basis for future research in the form of an overview of themes in manipulations and outcomes, without going into implicit, in-depth analysis of all of the findings. However, considering the early state of the literature, it appears even prudent and more meaningful to delay in-depth analyses and meta-reviews until the field is somewhat more mature.

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A Appendix

This appendix contains the full graphical representation of the studies manipulations and outcomes. Darker connecting line signifies more studies investigating the relationship. The number of publications investigating each of the noted relationships is in the range from 1 to 3.

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