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ORIGINAL ARTICLE

Leading presence-based strategies to manipulate user experience in virtual reality environments

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Abstract

Virtual reality (VR) has been widely used to simulate various real-like environments suitable to explore and interact, similar to being genuinely there (i.e., allowing presence). User experience in virtual environments (VE) is highly subjective, and presence-based self-reports have addressed its assessment; however, it is unclear how a diverse set of VR features relates to the subscales of the questionnaires (e.g., engagement, immersion, or Attention), which could be helpful to create and improve immersive VE. Consequently, most current studies have appealed to self-defined criteria to design their VE in response to a lack of accepted methodological frameworks. Therefore, we systematically reviewed the current publications to identify critical design elements to promote presence and realistic experiences in VR-games users. We extracted information from different databases (Scopus, Web of Science, PubMed, ACM, IEEE, Springer, and Scholar) and used inclusion and exclusion criteria to reduce the original set of 595 candidates to 53 final papers. The findings showed that better quality and quantity in resources allocation (software and hardware) and more accuracy in objects and characters, which all refer to higher immersion, provide Place Illusion (PI), i.e., the spatial dimension of presence. Furthermore, Scenario's Realism, external stimuli, and coherent match between virtual and real worlds (including body representation) are decisive to set Plausibility Illusion (PSI), i.e., the dimension associated with coherence. Finally, performance feedback, character customization, and multiplayer mechanics are crucial to assure motivation and agency, which are user-exclusive but crucial to defining presence's perception. Moreover, about 65% of the analyzed studies agreed that immersive media and social interaction could simultaneously influence PI and PSI.

Keywords Coherence · Immersion · Motivation · Presence · User experience · Virtual reality

1 Introduction

Recent years have witnessed a growing academic interest in enhanced Virtual Reality (VR) and immersive interfaces (Henderson et al. 2007; van der Kuil et al. 2018), since the years when it was considered as a mere medium to simulate real-life experiences until nowadays being a means to go beyond physical reality by transforming the perception of the Place and the self-body (Brooks 1999; Slater 2009). Researchers' main challenge during VR design is to provide an authentic and immersive experience capable of achieving such perception transformation and promoting active participation and engagement, whereas for entertaining or serious games. In fact, many authors highlight the need for immersive experiences by stating that the greater the immersion (commonly understood as the VR system quality), the better the sense of presence ("feeling there") (Kim et al. 2019; Zibrek et al. 2019; Slater 2009).

It is generally agreed that beyond immersion, it is having the sense of presence which allows users to move through the virtual environment (VE) while feeling like an integral part of the whole. Achieving presence could be considered as the most critical goal in VR despite approaching by different and non-standardized theoretical constructs (described and organized below) (Manivannan et al. 2019; Fox et al. 2020). Therefore, many strategies have been proposed to strengthen presence in the VE by focusing on technology, aesthetics, and realism to foster the Place Illusion (PI) and

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handling features related to motivation and engagement. Clear illustrations of the last point are the studies where the creation of challenges and the modulation of task difficulty promote user engagement and consequently achieve learning goals (Cuthbert et al. 2019; Vargas et al. 2020; van der Kuil et al. 2018; Caldas et al. 2020), or those VE that reproduce activities of daily living or include preferences-related features self-reported by study subjects (Manivannan et al. 2019; Birk et al. 2016; Cuthbert et al. 2019).

A further significant concept in VR is coherence, defined as the concrete logic experienced by the user via a well-presented set of reasonable circumstances, e.g., physical interactions and VR-objects' actions (Yu 2019; Skarbez et al. 2017a). Moreover, Skarbez et al. indicate that coherent VR experiences contribute to the Plausibility Illusion (PSI) and that having both PI and PSI are critical to improving presence Skarbez et al. (2017a). However, some authors suggest that the coherence in physical/virtual interactions might depend on the degree of user acceptance and willingness to play (Henderson et al. 2007; Yu 2019), which is different to the sense of presence, and there is little published regarding any possible correlation, as warned by Sagnier et al. (2020).

Given this situation of several factors working together but having an unclear individual degree of impact, it barely surprises the current lack of standard criteria to design immersive VR games regarding the available features to modify User Experience (UX). Thus, the following sections aim to address some open questions to answer *How do the current objective strategies modify user experience in VR-based games to increase the level of presence?*

This paper addresses that question via a systematic review by summarizing key theoretical definitions, highlighting similarities and differences between the most notable approaches, and finally classifying all the findings and suggesting guidelines for designing immersive VR applications. This paper was divided into three sections: the first section describes the survey methods; the second section presents the outcomes from the review, including standard and novel strategies and technologies in immersive VR design; and the final section contains a general discussion with the overall conclusions.

2 Methods

A systematic review was performed to survey recent empirical studies on strategies to design immersive VE, primarily but not limited to serious games (beyond entertaining). The screening was done in 2020 using the following academic databases: Scopus, Web of Science, PubMed, ACM, IEEEXplore, and Springer.

Search terms were: "virtual reality", "serious games", and "virtual environment". To better approach the variety of perspectives and applications, a bibliographic coupling network was organized using these terms in the software tool VOS Viewer to link journals, researchers, and publications to identify additional relevant terms before starting the articles' analysis. The resulting set of words was used to define the search equation and to perform further specific inspections in each database: "presence", "coherence", "immersion", "user experience", "emotion", and "agency". As can be seen in Fig. 1, the use of these terms and the following inclusion criteria in the first screening allowed to select 595 articles: (1) Papers published within the last five years; (2) English as the primary language (preferably); (3) Studies applying well-defined strategies for eliciting presence in VR games; (4) Manipulation of one or more features to modify UX in VR; (5) Use of at least one measuring method of UX (objective or subjective); and (6) A minimum sample of five individuals for hypotheses validation. Figure 2 displays the growing trend of related articles since 2015 in the considered databases.

Thereupon, articles with the following characteristics were excluded from the final set: (1) Not working on VR; (2) not mentioning validation tests; (3) Repeated among databases; (4) Not matching the selection criteria; and (5) having non-adult participants. Thus, fifty-three (53) articles were finally considered for this review, satisfying all selection criteria (see Fig. 1).

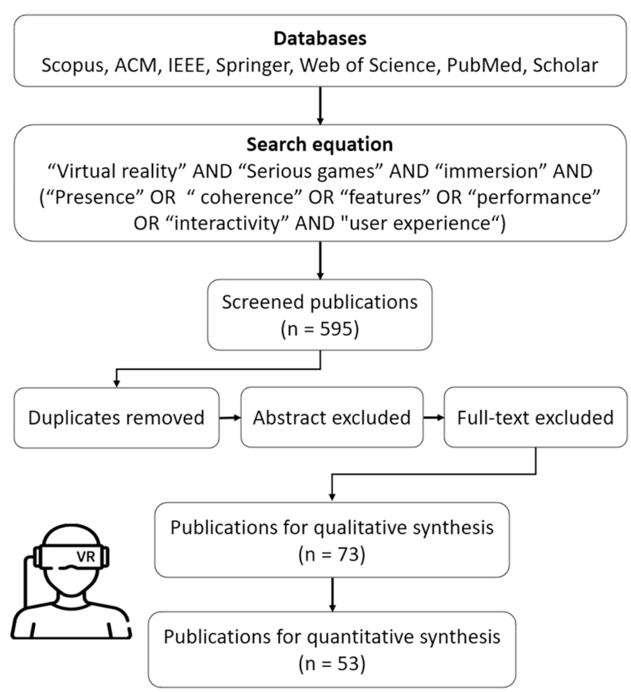


Fig. 1 Flowchart representing the selection process of literature to be reviewed, search equation and findings per database,

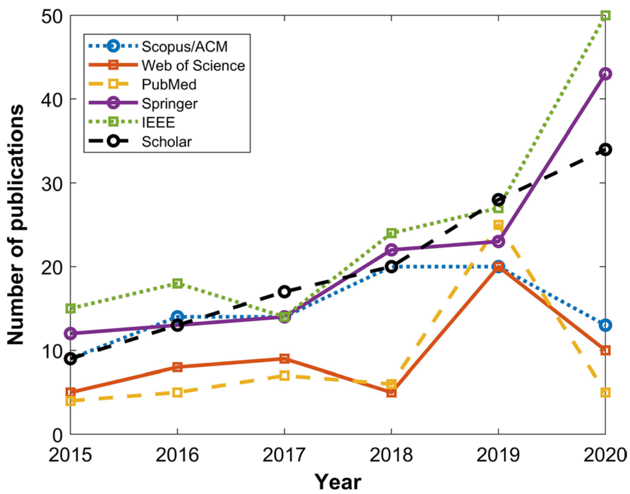


Fig. 2 Publications per year in selected databases (created on Matlab R2018b). Findings in 2020 refer to the studies published by the time that this review was performed (July)

3 Results

Figure 3 reveals that the strongest clusters in the bibliographic network were Virtual Reality, Serious Games (not included in the search) and Virtual Environments, which supports the inclusion and exclusion criteria mentioned above. Some of the additional terms that showed up after this analysis were the above-mentioned secondary terms included in the database search.

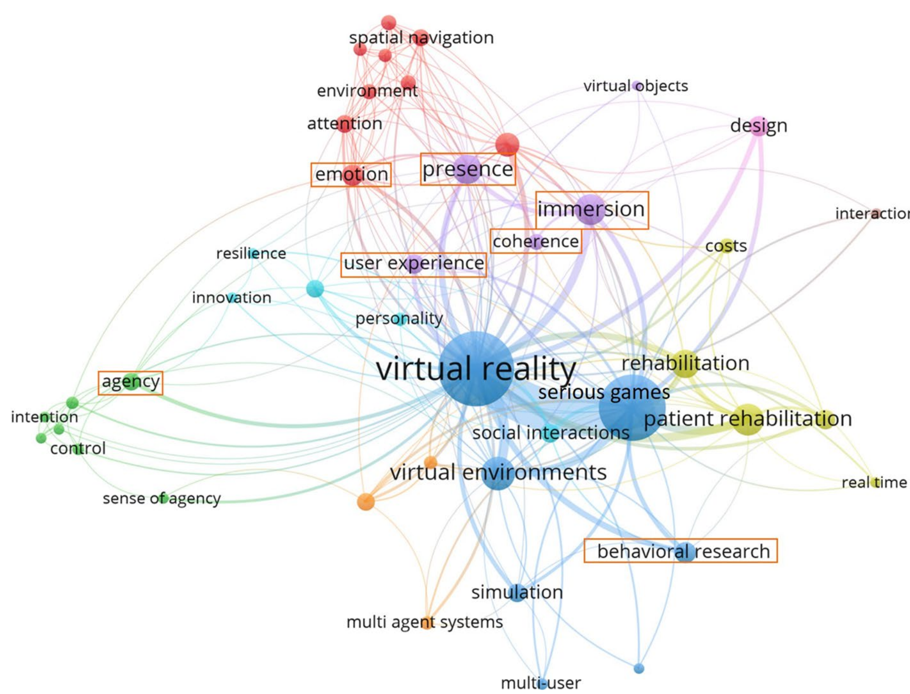
After a narrative synthesis, the findings regarding methods adopted to modify UX in VR for improving presence were classified into three groups: (1) immersion for spatial presence in VR, (2) Coherence in virtual environments and (3) motivation and agency. Consequently, this section starts with an overview of the importance of presence as an assessment of the quality of user experience in VR, followed by a comprehensive analysis of each of the three mentioned groups of strategies to modify UX, and finally, a brief focus on the accepted technological tools to address such strategies along with the most common methods to measure UX.

3.1 Relevance of presence in VR

A considerable number of publications in VR have taken advantage of evaluating presence to provide better and more vivid experiences, primarily for learning goals achievement (Eckstein et al. 2019; Çakirouglu and Gökouglu 2019; van't Riet et al. 2018). Despite the variety of definitions in the existing body of literature, authors agree in the understanding of presence as the sense of "being there" in a virtual place (Skarbez et al. 2017a; Yildirim et al. 2019). Some studies go further by claiming that it is the subjective experience of being in some place, despite the fact of being physically located elsewhere (Witmer and Singer 1998; Madier et al. 2019), in other words, when the VE makes the subject feel inside the virtual rather than in the physical world, it can evoke the sense of presence (Fox et al. 2020).

Given the relevance of presence in VR, it is critical to highlight the difference in opinion regarding presence and immersion. Witmer and Singer use both terms as equivalent,

Fig. 3 Bibliometric network to map the state of the art (created with VOS Viewer). The size of each circle represents the term activity, measured by publications and co-citations, whereas coincidences are shown as distance between clusters. Frames were placed to highlight the selected search terms.



but some other authors prefer to set the difference between feeling present and being in an immersive VE (Witmer and Singer 1998). For example, Slater refuses the indistinct use of both terms by saying that presence is a human reaction to immersion, being immersion the degree to which the technical attributes deliver the sense of spatial presence, i.e., they provide the PI and thus allow "being there in VR" Slater (2003). Moreover, Skarbez et al. (2020) introduces another term by arguing that both immersion and coherence are characteristics of the virtual environments from which, respectively, arise PI and PSI, being mental states of the user as a response to the VR experience and thus contributing orthogonally to presence. Moreover, Gilbert suggests a similar construct by describing presence as a measure of being engaged elsewhere, which is affected by a system-based factor: Immersion, as the measure of fidelity, and a human-based factor: Authenticity, as the measure of expectations matched (Gilbert 2016). Table 1 compiles these and other relevant terms and definitions for user experience in VR.

Similarly, it is necessary to highlight that presence is not exclusively individual but also conditioned by human interactions or by "being there" with someone else, i.e., the co-presence illusion that contributes to social presence (see Table 1). This additional mental state opens a broader spectrum of analysis, including the need to assess the perception of all the illusions related to presence (Yildirim et al. 2019; Collins et al. 2017).

Nevertheless, philosophical approaches in literature warn about the difficulty of measuring presence since it is a subjective and internal awareness introduced by the senses, as mentioned by Skarbez et al. (2017a). Consequently, a large number of published studies rely on measuring presence through standardized questionnaires instead of more objective measures, such as behavioral or physiological based. The most common of these self-report instruments are the Witmer and Singer's presence Questionnaire (PQ) and Slater-Usoh-Steed Questionnaire (SUS), mainly because they are reliable and widely used in VR studies, among other scales that typically use 7-points Likert-scale items. However, some authors prefer the use of Slater's Breaks in presence (BIP) rationale, which states that users might not be able to notice VR transitions, and it will be more efficient to remove evident presence-based cues to see significant changes in the reports (Slater and Steed 2000). Table 2 displays these and other presence scales, but also show that not all the studies have focused their attention on evaluating all the non-standardized components of presence but rather only involvement/engagement, Realism, or Immersion, as well as using objective corroborative measures related with behavioral and physiological responses.

3.2 Methods to manipulate UX in virtual environments

3.2.1 Immersion and somatosensory stimuli

Ferdani et al. agree with Slater and reject using immersion as a synonym of presence, but as the boundaries within spatial presence can occur (Ferdani et al. 2020). However, since immersion depends on the senses, those boundaries must be understood as the overall requirements that the system has to provide via well-defined somatosensory stimuli in terms of quality, frequency, and coherent Realism. According to Maneuvrier et al., immersion provided by realistic stimuli correlates with less simulation sickness and might better contribute to presence (Maneuvrier et al.

Table 1 Important concepts and definitions regarding subjective perception in VR

Concept	Definition
Agency	The perception of being the one who is causing an action (Gallagher 2000).
Authenticity	Whether the VE provides the experience expected by the user (both consciously and unconsciously (Gilbert 2016).
Coherence	"Aspects of VR that contributes to plausibility illusion" (Skarbez et al. 2017b).
Immersion	The set of valid actions and systems that define the boundaries within place illusion occurs in VR (Slater 2009).
Co-presence Illusion	The company of other beings in the virtual or mediated environment (Skarbez et al. 2017a)
Engagement	Consequent state of focusing energy and attention on a coherent set of stimuli or meaningful activities (Witmer and Singer 1998).
Fidelity	The extent to which the virtual environment emulates the real world" (Alexander et al. 2005).
Flow	When the individual is so involved in an activity that nothing else seems to matter (Csikszentmihalyi 1998)
Place Illusion	The illusion of being in a place despite the sure knowledge of the opposite (Slater 2009)
Plausibility Illusion	The illusion of something happening even with the sure knowledge of the opposite (Slater 2009)
Presence	"The cognitive feeling of being in a particular scenario" (Witmer and Singer 1998).
Self-presence	The effect of embodiment in by (1) self-location, (2) agency, and (3)body ownership (Skarbez et al. 2017a).
Social presence	The awareness of co-presence and engagement with the others (Biocca et al. 2001).

Table 2 Studies regarding the use of strategies to modify user experience in virtual reality

Study	*N*	Measurement method	Independent variable	Dependent variable
Immersion - Somatosensory stimuli				
Chittaro and Sioni (2015)	44	Custom (20 items) + GSES + ECG + EDA	Interactive vs Non-interactive simulation	Perception + Efficacy + Attention + Emotional response
Fröhner et al. (2018)	32	Custom (10 items) + Propioceptive drift	Haptic feedback (force vs vibro-tactile vs no feedback)	Embodiment
Grassini et al. (2020)	29	PQ	Training tool (2D vs VR)	Presence
Gorini et al. (2011)	84	SUS + ITC-SOPI + HR Variability	Narrative roles x Immersion (Screen vs HMD)	Presence + emotional responses
Kim et al. (2020)	37	NASA-TLX + TPI	Assistant (none vs voice vs embodied)	Task Load + Social Presence
Kim et al. (2014)	53	BAI + SAM + PQ + EDA + SSQ	Immersion (PC vs HMD vs CAVE) x Stress (high vs low)	Stress + Presence + Emotions + Simulation Sickness
Ma (2019)	216	Custom (13 items) + TPI	VR vs 360° video	Transportation + Identification + Willingness to help
Maffei et al. (2016)	32	Custom (8 items)	Real vs VR simulation	Coherence + Environment quality
Maneuvrier et al. (2020)	48	PQ + ITQ	Performance x Experience	Presence
Ramírez-Fernández et al. (2015)	30	Custom (3 items) + NASA-TLX	Haptic feedback vs control	Mental workload and Preference
Rodriguez-Guerrero et al. (2017)	11	Score + SAM + ECG + EDA + SKT + FlowIndex	Difficulty x haptic assistance	Satisfaction + Performance + Flow
van 't Riet et al. (2018)	295	Custom (6 items) + IS	Persuation medium (Game vs video vs text vs control)	Immersion + Willingness to help + Identification
Wu and Lin (2018)	115	Custom (21 items) + ARS	Immersion (Pc vs Tablet vs HMD)	Presence + Attitude + Enjoyment
Yildirim et al. (2019)	22	ITC-SOPI + MEC-SPQ	Immersion (360°-video vs 3D-animation vs 3D-game)	Cognitive involvement + Presence
Coherence				
Caldas et al. (2020)	87	SAM + ECG + EDA + RSP + Game Score	Coherence factors x Difficulty	Performance + Emotional and Psychophysiological responses
Choudhary et al. (2020)	23	Custom (7 items)	Scaling x Task x Distance	Comfort + Feeling of uncanniness
Eckstein et al. (2019)	79	IMI + SPES	Exteroceptive Stimuli x Level of Mismatch (LoM)	Intrinsic motivation + Spatial Presence
Hofer et al. (2020)	195	Custom (3 items) + SPES	Plausibility (high vs low) x Cognitive load (high vs low) x Immersion (HMD vs screen)	Spatial presence + Perceived plausibility
Martini et al. (2013)	30	Custom (1 item)	Thermal stimulation x VR skin color	Embodiment
Pals et al. (2014)	131	Custom (12 items) + PRCQ	Materials of VR objects	Coherence + Preference + Pleasure + Restoration
Skarbez et al. (2018)	32	ECG + EDA + SKT + PQ + SUS	Immersion x Coherence	Presence + Psychophysiological responses
Skarbez et al. (2017b)	21	Modified SUS	Coherence	Presence
Zibrek et al. (2018)	1106	Custom (10 items) + proximity	Render (Realistic vs Toon vs Creepy) x Avatar personality	Empathy + Low-level perception
Zibrek et al. (2019)	797	Custom (17 items)	Render (Realistic vs Simple vs Sketch) x Avatar (Friendly vs Unfriendly vs Sad)	Emotional response + Realism + Place illusion + Social presence
Motivation - Agency				
Baranes et al. (2014)	52	Score + repetit. rate	Size of group of choices	Preference for difficulty
Çakirouglu and Gökouglu (2019)	6	PQ	Skills training approach	Presence

Table 2 (continued)

Study	N	Measurement method	Independent variable	Dependent variable
Immersion - Somatosensory stimuli				
De Leo et al. (2014)	29	TPI + ITC-SOPI	Experience (PC vs videogames vs VR)	Presence
Goršič et al. (2017)	30	Custom (8 items) + IMI + IPIP + RCI	Single-play x cooperative x competitive	Subjective experience + Exercise intensity + Competitiveness
Hooi and Cho (2017)	209	Custom (12 items) + MH + SSS	Avatar customization options	Homophily and appearance + Self-awareness + Self-presence
Li and Fang (2020)	652	Custom (14 items)	Subjective experience between subjects	Challenge-reaction + Playfulness
Nierula et al. (2017)	24	Custom (7 items) + HPT	Drift from real/virtual body co-location	Perception illusion + Ownership
Novak et al. (2014)	38	Custom (8 items) + IMI + IPIP + RCI	Single-play vs cooperative vs competitive	Game experience + Personality + Competitiveness
Sailer et al. (2017)	419	Custom (13 items) + IMI	Game design elements	Motivation
Taub et al. (2020)	138	IMI + PQ	Levels of agency	Engagement + Gameplay duration
Turkay and Adinolf (2015)	66	Engagement Scale + IMI	Customization vs control	Engagement + Motivation + Control

ARS = Audience response scale, BAI = Beck anxiety inventory, ECG = Electrocargiogram, EDA = Electrodermal activity, GSES = Generalized self-efficacy scale, HMD = Head mounted display, HPT = Heat-pain threshold, IMI = Intrinsic motivation questionnaire, IPIP = International personality item pool, IS = Identification scale, ITC-SOPI = Independent television commission - Sense of presence inventory, ITQ = Immersive tendencies questionaire, MEC-SPQ = Project presence: measurement, effects, conditions - spatial presence questionnaire, MH = Measurement of homophily, PQ = Presence questionnaire, PRCQ = Perceived restorative characteristics questionnaire, RCI = Revised competitiveness index, SAM = Self-assessment manikin, RSP = Respiration, SKT = Skin temperature, SPES = Spatial presence experience scale, SSQ = Simulation sickness questionnaire ,SUS = Slater-usoh-steed presence score, SSS = Situational self-awareness Scale, TPI = Temple presence inventory

2020), however, this statement must be taken with caution because excessive stimuli could lead to the opposite reaction due to elicited stress (Kim et al. 2014). As reported by Cummings and Bailenson (2015), once the technology has defined the boundaries, several approaches come out to provide and manipulate immersion, mainly by system settings that ultimately promote presence better than mediating content (such as narrative, gameplay elements, or emotional tone) to achieve user engagement. Moreover, immersion provided by hardware and game settings usually begins with the minimum requirements to avoid the risk of simulation sickness and discomfort, such as proper tracking level (degrees of freedom), stereoscopic vision (screens or VR headsets), image quality (e.g., resolution, refreshments rate, and latency), the field of view (as wide of human sight), 3D sound quality, user perspective (first or third-person point of view), among others.

Some studies have tried to improve this minimum immersion by accurately simulating real-life events (Gilpin et al. 2014; Stanton et al. 2018), because technically, every event in physical reality can potentially be coded to happen in VR and be experienced realistically, and thus have the potential to evoke presence. For instance, these cited studies reported that participants showed the same autonomic response and motor cortex activation (at moving the hand away) as in real life when being at risk of virtual stab, which suggests an intense perceived presence as a response to high visual and auditory immersion.

Moreover, Simeone (2015) reported that variations in the VR appearance could be used to reshape the perceived environment and make it match with a variety of VR scenarios, i.e., realistic appearance also defines the sense of presence. For instance, the look of the virtual body and its perception (by either self-embodiment or body transfer) have a noticeable influence in physiological responses (Martini et al. 2013; Slater et al. 2010), as well as the capability to modulate behavioral responses (Nierula et al. 2017; Sanchez-Vives et al. 2010).

Sight and hearing have been historically prioritized over other senses. However, an increasing body of publications has included haptic stimuli to consider all the three primary senses in immersive VR technology: visual, tactile, and auditory (Rose et al. 2018). Eckstein et al. (2019) performed a randomized trial to measure spatial presence as an outcome for enhanced immersion on a Substitutional Reality (SR) application (i.e., integrating VR with the physical environment). They hypothesized that physical objects providing thermal and haptic stimuli could affect immersion, and the direct correlation with spatial presence was confirmed. Likewise, Kim et al. (2019) observed growth in presence when adding subtle environmental events, such as airflow, as a physical-virtual interaction that increases immersion and influences human behavior in social presence circumstances.

These findings suggest that immersion can be achieved through a collection of real-like VR objects and stimuli, provided in a manner that elicits a sense of spatial presence. Approaches have included explicit experiences by texture-detailed objects and thermal-based stimuli (touch), realistic appearance, and both visual and acoustic events (sight and hearing), plus features for virtual body accuracy.

3.2.2 Coherence in virtual environments

Coherence is also crucial to create links between the user and the immersive virtual environment for a further presence promotion. Coherence is widely understood as a series of rational contexts displayed to the user by employing still rational situations, in terms of being evident to themselves and with no need of any previous introduction or clarification (Yu 2019; Skarbez et al. 2017a).

This rationale suggests that even if the VR environment is already immersive, it must keep an internal logic throughout the VR experience so that the user can consciously and unconsciously perceive authentic and coherent behaviors (Skarbez et al. 2020; Gilbert 2016). Moreover, Maffei et al. (2016) argue that immersive experiences need mutual congruence between the visual and acoustic factors in both real-life and simulated worlds, which would allow the VR world to be plausible and therefore able to convey complex actions, emotions, and perceptions as desired.

Pals et al. (2014) reported that physical features of critical objects in VR influenced its perceived coherence. For example, they noticed that metal furniture was perceived as incoherent compared to wooden furniture and no furniture, which mediated subjective preferences, pleasure, and emotional restoration (from stress and mental fatigue). According to this work, accurate reproduction of remarkable features of some VR elements taken for granted in the real world, such as the material, is crucial to developing PSI and then the sense of presence. Ferdani et al. supported this view in a study where they demonstrated that immersion to a 3D reconstruction of the Forum of Augustus in Rome was mediated by the historical background of the study subjects and their demand for coherence on historically accurate aesthetic representations (Ferdani et al. 2020).

Oppositely, Eckstein et al. (2019) introduced the concept of Level of Mismatch (LoM), which defines the flexibility when designing virtual representation of physical objects in the interactive environment. They organized all the possible combinations into five categories: Replica (dimensions, textures, and affordances), Aesthetics (colors and shapes), Addition/Subtraction (of object's components), Function (usability), and Category (nonsense replacements, e.g., a tree instead of a standing lamp in a room).

Another recurrent approach for visual coherence is the use of virtual characters, aka avatars, which has been adopted to achieve environmental coherence by managing continuance intention via self-presence and self-conscience (Hooi and Cho 2017). Moreover, it has been shown that photorealistic characters could change the emotional response of VR participants (mainly as comfort) and therefore increase presence in the same way as realistic scenarios (Zibrek et al. 2019). For instance, Choudhary et al. found that VR users felt more social presence when the designers took good care of coherent proportions on virtual avatars, mainly by testing different head sizes and eyes position during social interaction (Choudhary et al. 2020). Furthermore, avatar customization has been recently included in many scales as one of the various aspects of game's interactivity, along with the standard features and game-controller configuration (Fox et al. 2020).

3.2.3 Motivation and agency

Human perception in VR is first mediated by the somatosensorial system, especially by visual cues promoting immersion. However, Zibrek et al. argued that perception is later modified by the awareness of the environmental context (requiring coherence) (Zibrek et al. 2019). Perception also depends on subjective cognitive states that might affect the dominating sensory organ to perceive selectively, such as focused attention, mood, personality, and motivation. Motivation is a core element in video games and VR design since it correlates with volition and therefore develops persistence and intention to remain to supply time and energy (indicators of engagement) (Cuthbert et al. 2019; Turkay and Adinolf 2015). Mediated by innovation and interaction, motivation has been considered by entertaining games developers as a fundamental attribute when seeking user acceptance and loyalty (Dawson and Goodwill 2013; Baranes et al. 2014).

The main challenge faced by serious games researchers and developers, on the other hand, is that the aim is reaching well-defined goals by measurable short-period exposure, with little room for complex motivating cues. Nonetheless, many authors suggest that given the learning-related objectives of most of those games, motivation is imperative to avoid the side effects of the inherent repetitive and tiresome tasks, e.g., VR has been increasingly used in rehabilitation therapies to allow positive motivational environments during task-oriented sessions for either cognitive, affective, or psychomotor learning (Radianti et al. 2020; Cuthbert et al. 2019). Furthermore, data from several studies suggest that motivated patients show better performance and increased cognitive engagement (Makransky and Petersen 2019; Eckstein et al. 2019). Likewise, Sailer et al. indicate that "gamification" can foster the initiation or continuation of goal-directed behavior" (Sailer et al. 2017).

Motivation could be either intrinsic (autonomous) or extrinsic (controlled). An individual inherent interest hinders intrinsic motivation in doing something and enjoying it, whereas extrinsically motivated people pursue a desirable outcome, e.g., a reward (Cuthbert et al. 2019; Makransky and Petersen 2019; Eckstein et al. 2019; Taub et al. 2020). For instance, on cognitive learning, there could be an intrinsically motivated subject interested in acquiring knowledge, whereas another participant is perhaps extrinsically motivated by its self-desire of getting good grades, degrees, or certificates of participation.

As highlighted by Swanson and Whittinghill (2015), two frameworks have been widely used in video games, making clear the contrast of intrinsic and extrinsic motivation. The most extended is Csikszentmihalyi's Flow theory (1990), which defines a state of intense concentration and involvement when the individual perceives a clear goal, feedback, proper challenge/skill ratio, and an environment for deep focus. Oppositely, Skinner's operant conditioning relies on extrinsic motivation to modify the subject's behavior via systematic reinforcement driven by previously defined rules ((Staddon and Cerutti 2003)).

Moreover, evidence from several experimental studies has established that intrinsic motivation could be correlated with players' need for satisfaction and based on theoretical frameworks, similar to Gilbert's idea of authenticity as expectations matched. For instance, the Self-Determination Theory (SDT) proposes three fundamental needs: competence (to perform effectively), Autonomy (to make own choices), and social relatedness (to connect with others) (Deci and Vansteenkiste 2004; Werbach, K., & Hunter 2012). Sailer et al. (2017) explored the effect of various specific game design elements and observed that badges, performance graphs, and leaderboards (performance feedback) affected the need for competence and Autonomy (they provide task meaningfulness). In contrast, teammates, avatars, and meaningful stories satisfied the need for relatedness by promoting a sense of relevance and shared goals.

Regarding the study reported by Choudary et al., they found that users preferred up-scaled head sizes when the avatars were at longer distances since it eased facial expression recognition, which is crucial to satisfy the need for social relatedness (Choudhary et al. 2020). However, the most relevant illustration of relatedness is the multiplayer mechanics, which many studies have proven to enhance engagement and motivation, measured via self-reports but delivered in at least two modalities: cooperation and competition. Some authors agree that the collaborative approach is necessary to develop motivation and involvement, whereas competitiveness might be more complex depending on the nature of the game but in any case would depend on the subjective need for competence (Peng and Hsieh 2012; Vorderer et al. 2003). In contrast, other studies have shown both approaches could raise benefits (such as enjoyment, exercise intensity, and intrinsic motivation) based on how user preferences define the amount of delivered effort: competition increases physiological intensity significantly more than cooperation, but each one can increase motivation if the subject dislikes the opposite option (Goršič et al. 2017; Novak et al. 2014).

Chiao et al. explored the effectiveness of VR in cultural education by providing decision freedom in a guide-tour platform, i.e., allowing the user to satisfy their need for autonomy Chiao et al. (2018). Furthermore, this need is strongly related to another concept: agency (see Fig. 3), which is known as the sense of being the one who is causing or generating a specific action (Taub et al. 2020).

According to Cuthbert et al. (2019), agency is one of the motivational consequences of customization of VR game-based activities, along with intrinsic motivation and engagement. Fox et al. (2020) agree by stating that characters customization is associated with a higher sense of control and identity (sympathy with the avatar) and intrinsic motivation, as well as higher levels of enjoyment when achieving goals and addressing challenges. Likewise, Gorini et al. (2011) included the role of meaningful narrative to boost agency and therefore contribute to presence enhancement through emotional responses mediated by the self-sense of control. Finally, Taub et al. (2020) performed a couple of studies to test the accepted understanding of better learning outcomes from increased agency. They observed that even low levels of agency led to high learning scores, whereas "no-agency" conditions provided less sense of presence in virtual environments.

Therefore, it seems that both motivation (mainly intrinsic) and agency work as practical approaches to assess presence. Notably, many elements can be included in VR environments to satisfy the need for competence (by performance feedback tools and competitive game mechanics), Autonomy (by decision freedom, customization, and sense of control/agency), and social relatedness (by narratives that promote a meaningful role, shared goals, and cooperation).

3.3 Measuring methods and technological approaches

Table 1 displays the results obtained from the literature search, except for review papers that were useful for the previous analysis but do not provide specific experimental data to be compared. As noted, the independent variables for the first group (Immersion) focused on interactive conditions and technological comparisons; the second group (Coherence) collects works on Realism, real-world mismatch, illusion breaks, and external stimuli; and the third group

(Motivation and Agency) considers Embodiment, customization (Autonomy), and social-relatedness satisfaction.

Most of the authors reported results directly in terms of presence (primarily spatial and social) or presence-based scales to evaluate the perception of Comfort, immersion, involvement, and focused attention. Other assessment variables were intrinsic motivation, body ownership (Embodiment), and perceived coherence. Many experiments had a between-subject design by assigning participants to either control or one or more experimental groups; however, others considered two or more independent variables and performed factorial experiments.

A considerable number of publications using between-group designs focused on comparing immersive approaches and real-world vs. simulation, but comparisons between interfaces were also common, e.g., screen vs. VR-device or 3D simulation vs. interactive VR, as well as headsets vs. Cave systems. Other setups included devices to provide external stimuli (acoustic and haptic), such as airflow, heat, or vibration.

Regarding the measuring method, the vast majority of the studies preferred subjective instruments, i.e., self-report questionnaires, mainly because of the lack of general agreement on alternative measures. Cummings and Bailenson (2015) argued about the meaning of many of these subjective measures and stated that their interpretation is still open to debate. On the other hand, behavioral cues (e.g., postures, speech, and gestures), performance-based measures, and cognitive tests are more objective and task-specific but still sensitive to external factors, which might hinder replication and extrapolation to unrelated experimental conditions. However, physiological signals, which are also objective, allow real-time acquisition and feature extraction, which helps with accurate statistical comparisons between experimental conditions. Moreover, most recent studies agree that heart rate variability, skin conductance, skin temperature, muscle activation, and respiration are reliable indicators of task-related psychological states, such as cognitive and physical workload, arousal, valence, stress, or anxiety (Rodriguez-Guerrero et al. 2017; Caldas et al. 2020; Knaepen et al. 2015).

4 General discussion

Regarding the question *How do the current objective strategies modify user experience in VR-based games to increase the level of presence?*, it is vital to clarify that we agree with Slater's and Gilbert's view of immersion being a different construct to presence. Then the first would be the objective degree of technological allocation (hardware and software) providing the necessary stimuli to elicit the Place Illusion (PI), a subjective mental state that corresponds to one dimension of presence. In fact, immersion was far from being the primary goal in the screened publications. Instead, many researchers pointed out the need for Plausibility Illusion (PSI), the emotional state needed as the second dimension of presence, elicited after coherent behaviors and appearances. Finally, other studies focused on user-oriented game dynamics to satisfy the human need for autonomy, social relatedness, and competence, which were generally provided by motivational cues.

Consequently, we could say that presence is reached when having the sense of "being there" in a virtual place, acknowledging its real-world consistency, and being "touched" by the user-oriented dynamics. Furthermore, since presence sets the foundation for user learning and adaptation in serious and entertaining games, the different UX-related strategies to reach presence in VR games must be analyzed. Therefore, we organized the analysis of the final publications sample by grouping the strategies by immersion-stimuli, coherence, and motivation-agency.

About 65% of the screened publications reported higher presence in VR after providing more intense immersive and coherent features and after introducing cues associated with motivation and agency (less effective though). Furthermore, and depending on the application, presence contributed to better performance, engagement, and skill learning.

Since immersion can be provided through system settings and technological allocation, most of the studies preferred using validated devices to provide the minimally required immersive features (and avoid motion sickness), such as 6-DOF, stereoscopic vision and sound, high resolution, 90 Hz of refresh rate, less than 10 ms of latency, position and orientation tracking and wide field of view. Therefore, they relied on identifying the influence of such immersive interfaces by testing significant differences in presence in between-group experiments, e.g., comparing Screen vs HMD, 3DOF vs 6DOF, HMD vs CAVE, and non-interactive vs interactive. They all agreed that most immersive setups contributed to higher spatial and social presence, enjoyment, and more robust emotional responses (in terms of arousal and skin conductance). Moreover, since most studies obtained favorable results by only providing visual and auditory stimuli, reasonably better data resulted from those involving haptic stimuli, provided as realistic vibrotactile/force feedback or thermal effects (heat or airflow-based), which reported higher Embodiment, Satisfaction, and Flow.

Regarding coherence, providing realism and authenticity is the central focus to provide Plausibility Illusion. Some studies compared the effects of realistic appearances (textures, sizes, and proportions) and accurate representations of objects, virtual characters, and oneself, which mainly affected the self-reported senses of presence and uncanniness, along with emotional responses in terms of arousal, heart rate variability and skin conductance.

Another typical strategy is presenting “Breaks in presence (BIP)” (i.e., Plausibility violations) to create a mismatch between real and virtual worlds, which usually introduce a lack of perceived coherence.

Sense of agency is well-known to promote engagement and sense of control. Thus, many publications relied on investigating the importance of body ownership (i.e., Embodiment) to define self-presence, self-awareness, continuance intention, and affect. Common studies were: introducing BIP in the form of drifts of body co-location (virtual body from the actual body) and manipulating self-avatar similarity or user’s perspective (i.e., switching between the game characters’ points of view).

Motivation has been commonly used in games due to the ease of providing rewards and penalties to promote extrinsic motivation. However, recent studies gave more attention to the need for satisfaction by fostering intrinsic motivation, primarily by following theoretical frameworks that recognize the need for autonomy, competence, and social relatedness, which have encouraged customization, performance feedback, and multiplayer mechanics, respectively. For instance, multiplayer games seem to increase enjoyment and intensive exercise; however, competition or cooperation might influence motivation differently, depending on self-reported subjective preferences.

Finally, it is essential to highlight that all the studies preferred self-reports to assess the desired outcome (i.e., promoting motivation, immersion, agency, or perceived coherence), either as custom-made or validated questionnaires. Most of the studies relied on the subjective nature of VR experiences to use scales, but others highlighted the ease to identify significant changes between a priori and a posteriori scores. presence questionnaires were the most common, especially the partial use of PQ and SUS to take advantage of the subscales to assess involvement, immersion, attention, and other suitable measures of experience. Moreover, the IMI questionnaire was familiar to evaluate motivation and the SAM test to do the same with emotional states. However, some psychophysiological signals, such as skin conductance and respiratory rate, are increasingly being used to corroborate self-reported emotional scales, mainly to exploit continuous real-time acquisition and data resolution and perform more accurate statistical analyzes. Many authors recommend including such measures in the upcoming research projects.

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Declarations

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