Avatars in Immersive Virtual Reality Education: Preliminary Insights and Recommendations from a Systematic Review

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Abstract. Immersive Virtual Reality (iVR) has gained popularity in education for its ability to engage students and enhance learning. With the growing use of avatars in collaborative iVR environments, there is a need for structured guidelines to optimize their effectiveness. This preliminary systematic literature review aims to synthesize key findings from relevant studies, investigates the potential of avatars in iVR education and proposes best practices to promote positive learning outcomes. Gathering data from various studies, the review provides initial insights that will aid future researchers and developers in effectively integrating iVR and avatars, optimizing them for the educational setting, and ensuring their effectiveness in enhancing learning outcomes.

Keywords: Immersive Virtual Reality, Avatars in Education, Collaborative Learning

1 Introduction

In recent years, Immersive Virtual Reality (iVR), often referred to as the interactive Virtual Reality, has witnessed substantial growth, particularly in the realms of learning and training. iVR simulators serve as potent tools, not only for replicating real-world scenarios but also for crafting engaging experiences that enhance learning and training outcomes. Advancements in hardware capabilities have facilitated collaborative environments where multiple users interact. A prevalent practice involves user identification through avatars, distinct from agents as clarified by [12]. Avatars represent players in collaborative settings, while agents depict non-player characters capable of interacting within the virtual environment. The term *Hybrid Agents-Avatars* introduced by [12] refers to

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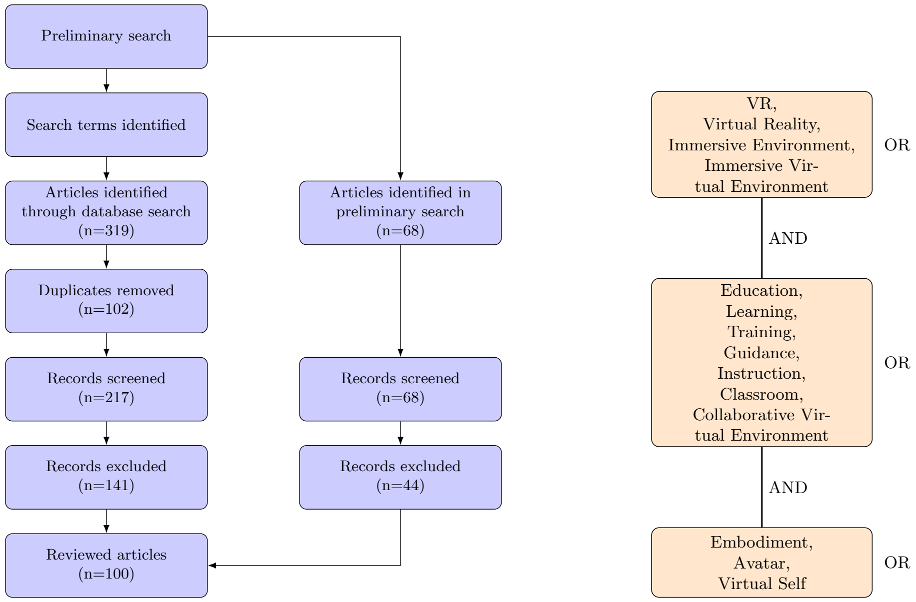

Fig. 1. Adapted PRISMA methodology (left) and structure of the constructed search term (right) used for the literature review.

avatars with additional computer-controlled features for improved communication. This preliminary review focuses on avatars within the context of learning, education, and training, with the primary goal of offering valuable insights to researchers and developers for the effective utilization and implementation of avatars in iVR environments, emphasizing their effectiveness in enhancing educational outcomes.

While avatars are widely used in both non-iVR and iVR video games, the existing literature varies in its approach. This preliminary review focuses on avatars within the context of learning, education, and training. The primary goal is to offer valuable insights to researchers and developers for the effective utilization and implementation of avatars in iVR environments.

2 Methodology

This literature review was conducted following an adapted version of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology, as outlined in [16] and illustrated in Figure 2. Initially, a broad search using *Google Scholar* was conducted to identify key terminology within the field. Complementary, *Research Rabbit*[4] was utilized to uncover related papers not captured by the initial search terms. This phase yielded 68 relevant articles.

[4] Research Rabbit: https://researchrabbitapp.com/

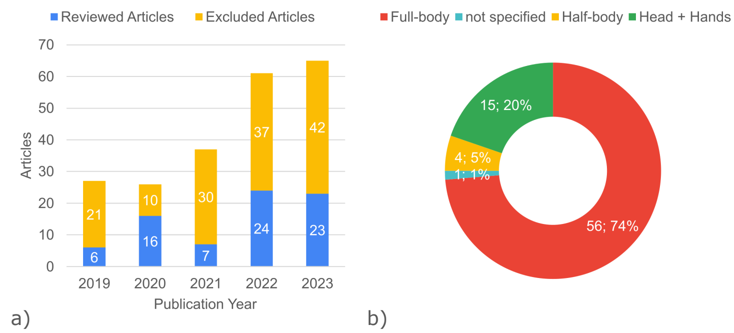

Fig. 2. a) Overview of found articles by the year of publication, b) identified avatar types in reviewed articles.

Transitioning to a more focused approach, the search terms were refined, adhering to the boolean expression scheme shown in Figure 2. Subsequently, a systematic search was conducted across selected digital libraries, including IEEE Xplore, ACM, ERIC, Web of Science, and Scopus. This phase, targeting open access and peer-reviewed articles, conference papers, and book chapters published in English from January 2019 to November 2023, resulted in the identification of an additional 319 articles.

After the removal of 102 duplicate records, a total of 285 articles ($n = 217$ from the structured search and $n = 68$ from the preliminary search) underwent screening. During the screening process, the following exclusion criteria were applied:

- Article is a review, meta-analysis, or survey.
- Application or experiment does not include user-controlled avatars.
- Technology utilized does not encompass iVR (VR, AR, MR).
- Field of application is outside learning, education, or training.
- Focus on machine learning and not on motion rehabilitation or training.

After the exclusion, 100 articles remained to be reviewed ($n = 76$ from the structured search and n=24 from the preliminary search). Figure 2 a) depicts the distribution of found, included and excluded articles by the year of publication.

3 Analysis

In this section the most relevant findings about avatar representation, collaborative environments, embodiment, presence and co-presence are summarized, providing guidelines and useful insights for the implementation of avatars in iVR for education.

3.1 Avatar Representation and Embodiment

In virtual environments, the representation of users significantly influences behaviour, shaping both how users are perceived by others and their own experiences as they control avatars. While the integration of full-body avatars is an evolving field, the majority of articles in this preliminary review (74%; $n = 56$) employ full-body avatars, with tracking for head and hands feasible through Head-Mounted-Display (HMD) systems. Approaches to lower body animation vary, including inverse kinematics (IK), motion tracking with additional sensors, or motion capture, as discussed by [2,15]. Some articles 5% ($n = 4$) use half-body avatars, and others 20% ($n = 15$) visualize only the head and hands, underscoring the diversity in avatar representation.

Despite their prevalence, the impact of avatars on learning outcomes is often unexplored in the reviewed articles. However, some studies investigate user representation through avatars. Notably, [5] found that minimal customization enhances learning, especially for users perceiving lower competence and higher similarity and presence. In a virtual classroom setting, [7] observed increased focus with realistic avatars, while [9] cautioned against task-irrelevant realism due to heightened cognitive workload. Facial animation's role is highlighted by [17], showing that realistic movements and lip-sync enhance presence, knowledge retention, and enjoyment. In contrast, [8] noted shifts in attention based on avatar styles, emphasizing the need for context-aware considerations.

Beyond avatar representation, the concepts of Embodiment and Sense of Embodiment (SoE) play crucial roles in shaping immersive virtual reality experiences. SoE involves feeling present in a virtual body, while Embodiment signifies user connection with a virtual body. The Sense of Agency (SoA) relates to controlling actions in the environment. Co-embodiment involves shared embodiment experiences among users. Studies, like [11], reveal co-embodiment's impact on learning, with increased Sense of Agency in co-embodied conditions. [4] explores the relationship between embodiment, empathy, and behaviour change, emphasizing the interconnectedness of these concepts. Additionally, [10] finds increased focus with realistic avatars in a virtual classroom.

3.2 Collaborative Environments

IVR Collaborative Environments (iVRCE) can be defined as a virtual environment shared among multiple users, irrespective of their physical locations or the involved time frame. IVRCE is not yet a ubiquitous phenomenon; in fact, the majority of articles analysed in this review do not involve any form of collaboration. However, given that this review encompasses topics related to learning/education and training, those articles that do incorporate collaboration in their applications can be classified within these fields.
Firstly, within the learning domain, [22] proposes an iVRCE shared by both AR and iVR users in a museum exploration. To successfully integrate these technologies in the same context, the researchers suggest using spatial anchors on the doors of the rooms to prevent tracking loss and provide feedback to the

user regarding the alignment precision. Additionally, they propose indicating the relative directions and paths of users. Even if users have different devices, they should be capable of performing the same actions in a human-like manner, including natural gestures. On the other hand, [13] found that incorporating an avatar to guide the users using facial expressions was not as successful as expected. Users did not pay attention to these expressions while performing tasks, resulting in no significant differences. [14] demonstrated that incorporating avatars related to the lesson improved the motivation, immersion, and students' comprehension, despite study limitation. Furthermore, [10] succeeded in showing that co-embodiment with weight adjustment prevented performance decline after assistance. [9]'s research indicated that realism in avatars and environment is not always necessary for learning; in fact, excessive realism could increase cognitive load. Emphasis should also be given to the interaction of roles and instructions, not just the tasks users perform. Other notable studies include [1,15], which present interesting applications in a shared learning environment. In the context of Social VR, experiences are implemented to enable users to socially interact and participate in learning activities together. This is evident in [6,19,25]. [25] emphasized the importance of avoiding distractions in the environment enhances learning, and the importance of the avatar of the teacher, which students rated higher than their own avatar.

3.3 Presence & Co-Presence

Presence refers to the profound sensation of being physically present within a given environment, particularly in the context of a virtual setting. Despite users physically inhabiting the real world, the immersive nature of iVR can make them feel as though they are truly situated within the virtual environment, blurring the lines between the two spaces. This seamless integration of the iVR environment into their perceived reality is a testament to the effectiveness of avatars in enhancing the sense of presence. Co-presence, on the other hand, delves into the ability to share the virtual environment with other users, transcending physical boundaries. Even when physically separated, users can experience a shared space, thanks to the capabilities of avatars. As evidenced by [25], avatars play a pivotal role in both presence and co-presence, particularly in scenarios where iVR is the sole condition for interaction. However, the work of [26] sheds light on a critical aspect — the visual quality of avatars. Not only does it impact the sense of presence, but if the avatars' expressions and gestures lack realism, the overall sense of presence can diminish. [17] reinforces this idea, emphasizing the importance of incorporating lip synchronization to further amplify the sense of presence. To bolster co-presence, [23] propose integrating gesture cues, making the interface more intuitive for users. Customization of avatars' appearances, as illuminated by [5]'s study, emerges as a significant factor influencing both presence and learning outcomes. Contrary to expectations, [20]'s research challenges the notion that embodied controls directly increase presence. Instead, it suggests

that presence, in itself, can be a facilitator for learning. [7]'s study further nuances this by revealing that the stylistic representation of avatars doesn't yield statistically significant differences in terms of presence. [3] take a pragmatic approach by opting for a single-item oral measure to gauge presence in iVR. This decision is rooted in the potential loss of VR-induced phenomena upon headset removal, making multiple surveys less accurate. Interestingly, [24] demonstrate that an assistance condition guiding users' movements in reality can paradoxically decrease presence, even without a proper avatar in the iVR environment. They stress the relevance of haptic feedback in enhancing presence during object manipulation tasks, emphasizing the need for coherence between haptic feedback and visual perception. [21]'s research unveils the impact of avatar collisions on co-presence, showcasing that removing collisions diminishes the sense of co-presence. However, providing feedback during avatar collisions in Social VR can counter-intuitively increase the sense of presence.
Additional studies by [14,8,18] contribute to the broader understanding of presence within the realm of iVR, enriching the discourse surrounding avatars and their implications for training and learning in virtual environments.

4 Conclusion and Outlook

This preliminary review of the literature provides essential insights into the use and implementation of avatars in immersive Virtual Reality (iVR) for educational purposes. The most popular form of user representation in iVR is the full-body avatar. Thereby, visual quality and realistic behaviour seem to improve the sense of presence, engagement and the learning outcome. Nevertheless, task-irrelevant realism should be avoided since it can add to the cognitive workload and distract users from the learning task. Collaborative environments are yet not well represented in educational iVR research, although they play a significant role in group work and virtual classrooms. In collaborative iVR avatars can enhance motivation, immersion and comprehension and thus are positively supporting educational group activities. The concepts of embodiment and presence are highlighted as central to the user experience in iVR, with a significant impact on learning outcomes. These findings are instrumental in guiding the development of effective educational iVR systems with avatar user representations. iVR is especially suitable to simulate dangerous environments and situations for training. When utilized for spatial guiding in real or virtual environments, the avatars' expressiveness seem not to play a significant role. An improved feeling of presence and co-presence plays a crucial role in iVR and affects learning outcomes. However, it is not clear whether the avatars visual appearance or its realistic behaviour and embodiment has a greater impact on presence. In any case, the coherence between different feedback mechanisms, like the visual and haptic feedback, is benefiting the sense of presence.

This review emphasizes on the importance of avatars for learning outcomes in iVR and summarizes important aspects which are instrumental in guiding the development of effective educational iVR systems with avatar user representations. An extended review will be published in the near future, encompassing all reviewed literature as well as detailed analysis results to provide a deeper understanding of these aspects.

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