TYPE Review
PUBLISHED 13 June 2025
DOI 10.3389/frvir.2025.1496128

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OPEN ACCESS

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RECEIVED 13 September 2024
ACCEPTED 12 May 2025
PUBLISHED 13 June 2025

CITATION
Ouhnni H, Btissam A, Meryam B, El Bouchti K, Seghroucheni Yassine Z, Lagmiri SN, Rigalma B and Ziti S (2025) The evolution of virtual identity: a systematic review of avatar customization technologies and their behavioral effects in VR environments.
Front. Virtual Real. 6:1496128.
doi: 10.3389/frvir.2025.1496128

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The evolution of virtual identity: a systematic review of avatar customization technologies and their behavioral effects in VR environments

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Over the past 10 years, advancements in virtual reality (VR) technologies have been profound, yielding significant transformations within the digital milieu. This paper presents an extensive analysis of the cutting-edge research surrounding avatar customization in VR, concentrating on the technologies, methodologies, and challenges pertinent to the creation and management of digital representations. Through a meticulous examination of 45 curated studies, the research investigates three pivotal dimensions: the determinants affecting the aesthetic characteristics of avatars, the progression of avatar creation methodologies, and the practical applications of avatar customization. The investigation emphasizes the critical role of avatar customization in augmenting user identification, social presence, and interaction within virtual environments. Furthermore, it delves into nascent trends in avatar development, including artificial intelligence-driven customization tools and real-time rendering methodologies, which facilitate the production of increasingly realistic and individualized avatars. The concluding section articulates prospective trajectories for innovation within this domain, underscoring opportunities for further inquiry and the formulation of more diverse and adaptable strategies for avatar customization, thereby accommodating users across a spectrum of virtual environments.

KEYWORDS

avatar, digital body, virtual reality, augmented reality, AI-generated avatars, customization, personalization, embodiment

1 Introduction

In the preceding decade, advancements in virtual reality (VR) technologies have occurred at an extraordinary velocity, presenting novel opportunities for digital interaction, communication, and professional applications. Although still in the early stages of widespread adoption, VR has garnered significant attention within specialized sectors such as gaming, education, and remote collaboration (Li, 2024). The COVID-19 pandemic further intensified interest in immersive technologies, as various social, educational, and professional activities increasingly transitioned to digital platforms, thereby catalyzing the exploration of VR as a potential instrument for enhanced engagement (Wiederhold, 2020).

A fundamental component of VR's allure resides in avatar customization, which facilitates users in constructing digital manifestations of themselves within virtual environments. Progressions in this domain have fostered the development of more realistic and personalized avatars, aligning with the escalating consumer expectations for tailored digital experiences (Park and Ogle, 2021; Boon et al., 2022).

Avatars have transitioned from simplistic representations to intricate embodiments of user identity, preferences, and social roles (Jerry and Tavares-Jones, 2012).

Avatar customization assumes a pivotal role in shaping user experience and behavioral dynamics within VR. Empirical research indicates that avatars that closely resemble users' real-life appearances can modulate social dynamics, enhancing identifiability while potentially influencing intergroup perceptions (Peña et al., 2021). Furthermore, the provision of unrestricted customization options typically amplifies emotional engagement, particularly among individuals exhibiting high levels of extraversion and neuroticism (Bujić et al., 2023). Customized avatars also affect embodied perception, with users reporting an increased sense of immersion—and at times discomfort—when their virtual embodiments encounter constraints (Gonzalez-Franco et al., 2024; You and Sundar, 2013). In the realm of exergaming, avatar personalization has been demonstrated to enhance user identification, motivation, and physical performance (Koulouris et al., 2020).

Notwithstanding the burgeoning interest in avatar customization, there exists a conspicuous deficiency of systematic reviews that scrutinize the technologies, methodologies, and challenges associated with the creation and manipulation of virtual bodies. This paper seeks to address this lacuna by undertaking a literature review of 45 studies pertaining to VR avatar customization, concentrating on three pivotal research inquiries:

What factors exert influence over the visual representation of avatars in VR?

What are the preeminent innovations in the fields of avatar creation and customization?

In which social contexts is avatar customization employed, and what effects does it generate?

By addressing these inquiries, this review elucidates prevailing trends, challenges, and prospective directions for avatar customization research—highlighting the necessity for more adaptable and inclusive design methodologies to cater to the diverse requirements of users across virtual environments.

2 Methods

We conducted a structured systematic review based on the guidelines laid down in the Preferred Reporting Items for Systematic Reviews and MetaAnalysis (PRISMA -. prisma. io) statement (Sarkis-Onofre et al., 2021). The eligibility criteria, types of information used, the general search strategy, method of data collection, and selection criteria are presented in the subsequent sections. The exclusion criteria are indicated in a flow chart (Figure 1), with the items at each stage of the selective process and the total number of things in the review.

2.1 Eligibility criteria

A collaboratively formulated protocol was established and ratified by all contributing authors. This protocol functioned as a foundational framework for the inclusion of scientific articles that align with the fundamental objectives of the research—specifically, the representation of virtual entities (avatars), the determinants influencing their design, the technologies utilized for their manipulation, and their varied applications across multiple disciplines.

A principal eligibility criterion mandated that the articles directly engage with these thematic areas. In particular, studies were anticipated to incorporate key terminologies such as "avatar" or "digital body," as these terms are extensively acknowledged within the academic discourse. This linguistic stipulation further augmented the accuracy of indexing within academic repositories and facilitated the effective retrieval of pertinent literature.

Research that employed the term "avatar" in extraneous contexts—such as religious symbols (e.g., Hinduism), fictional portrayals (e.g., television series), or philosophical notions—was systematically excluded. This ensured that the review remained concentrated on VR applications and evaded peripheral subjects.

In instances where multiple studies addressed analogous themes, precedence was accorded to highly cited articles. This methodology guaranteed that the review encompassed influential and widely acknowledged research, thereby augmenting the credibility and impact of the findings.

For the section elucidating factors influencing the appearance of virtual characters, efforts were undertaken to incorporate studies that examined a comprehensive array of psychological, social, ethical, and legal dimensions. This expansive approach ensured a thorough comprehension of the multifaceted influences on avatar design.

In the section devoted to reviewing technologies, studies were included if they discussed tools—either in part or in full—utilized to control the appearance of virtual characters. The objective was to identify and showcase a set of tools that could be employed in forthcoming VR projects or as components of other associated endeavors.

The selection process was executed through several systematically organized stages:

Initial Screening: Titles and abstracts were initially scrutinized independently by Hamid Ouhnni and Acim Btissam predicated on their correspondence with the pre-established eligibility criteria.

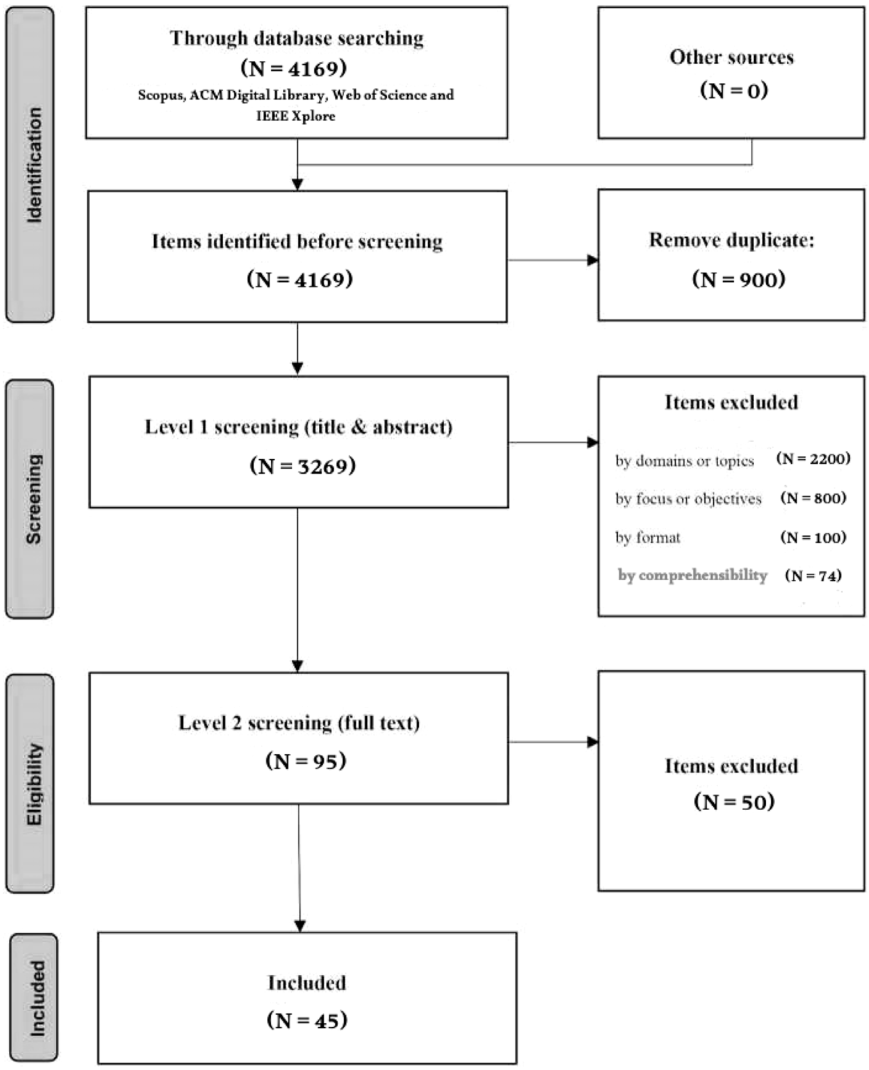

FIGURE 1
Flow diagram of the selection process, numbers of included and excluded items in each step.

Dispute Resolution: In cases of contention regarding the inclusion of a particular article, the matter was referred to an internal arbitration committee composed of Meryam Belhiah and Soumia Ziti, who evaluated the disputed articles and rendered the final decision concerning their inclusion or exclusion.

Thematic Categorization: Subsequent to the selection process, a qualitative categorization of the included studies was undertaken in two collaborative phases. The initial round was led by Hamid Ouhnni, who collaborated with Btissam Acim, Belhiah Meryam, and Benachir Rigal to allocate the studies to preliminary thematic categories.

Validation and Refinement: In the subsequent round, the categorization underwent review and refinement by a group led by Soumia Ziti, with contributions from the remaining co-authors. This phase sought to ensure thematic consistency, analytical clarity, and methodological coherence.

All procedures strictly adhered to the predetermined protocol, which was conceptualized and supervised by Hamid Ouhnni, who also coordinated the ultimate validation of the review process to ensure its quality and methodological rigor.

Ultimately, studies were included if they investigated the practical applications of VR, particularly those involving the utilization of avatars. It is noteworthy that certain papers addressed multiple dimensions of the research, providing a broader perspective on the subject matter.

2.2 Information sources and search strategy

The databases selected for this comprehensive review encompass Scopus, Web of Science, ACM Digital Library and IEEE Xplore, all of which are esteemed for their rigorous, peer-reviewed content and extensive interdisciplinary research coverage. Nonetheless, Scopus was designated as the principal source owing to its particular advantages in indexing literature pertinent to computer science, human-computer interaction, and virtual reality, which are integral to the focus of this research. For this source, we consistently utilized the search term queries outlined in (Table 1). The search terms were mandated to be incorporated within the title, abstract, or

TABLE 1 List of search terms utilized across Scopus database.

Combination 1			
1st keyword	And	2nd keyword	
Avatar	OR	Customization Personalization Embodiment Creation Generation	OR OR OR OR OR
Combination 2			
1st Keyword	AND	2nd Keyword	
"Virtual body"	OR	Customization Personalization Embodiment Creation Generation	OR OR OR OR OR

author keywords of the respective articles. We limited our selection to articles published between the conclusion of 2009 and January 2023.

The end of 2009 was strategically selected as the cutoff point, marking the start of a pivotal shift in the evolution of virtual reality (VR) technologies and avatar customization. This temporal milestone aligns with the advent of crucial technological innovations that propelled VR towards mainstream acceptance. For instance, in 2010, Palmer Luckey engineered the inaugural prototype of the Oculus Rift, which boasted a 90-degree field of vision and groundbreaking software solutions to mitigate lens distortion (Biju Kunnumpurath and Tribe, 2023). This prototype established the groundwork for contemporary VR headsets and rejuvenated interest in VR applications, including the aspect of avatar customization. Prior to this epoch, VR technologies were predominantly experimental and constrained in scope, with a scarcity of studies concentrating on user-centered dimensions such as avatar customization. By choosing the end of 2009 as the cutoff point, we ascertain that the literature under review accurately reflects the contemporary landscape of technological advancements and user anticipations, which are essential to the significance of this research.

We formulated the search term queries in two distinct sets of combinations: In the initial set of combinations, we utilized "avatar" as the primary keyword "AND" ("customization" OR "personalization" OR "embodiment" OR "creation" OR "generation") as the secondary keyword. Moreover, the second set of combinations was structured as follows: "virtual body" as the primary keyword AND ("customization" OR "personalization" OR "embodiment" OR "creation" OR "generation") as the secondary keyword. For those databases that allow for the specification of the language of the publications, we opted for "English." Additional articles identified through supplementary sources and citation indexing were also incorporated to guarantee a thorough review.

2.3 Data collection and organization

The Mendeley Reference Manager and its associated browser extension were employed to collect and organize the data. Information from each entry, such as titles, authors, abstracts, and the source of information, was compiled. This was done either by importing RIS files generated from the databases or by using the Mendeley Web Importer extension. In some cases, original work was manually searched through Scopus or captured using the Mendeley Web Importer. The authors express their gratitude to the library of their host institution for providing access to all the necessary data.

2.4 Selection process

The selection methodology is outlined in the flow diagram presented in (Figure 1) above. Initially, superfluous items were expunged. Subsequently, we undertook a screening process predicated on the title and abstract, executing level 1 evaluations, and perused a select few through comprehensive text analysis. During this phase, we eliminated manuscripts that were not pertinent to the avatar-related themes of "Customization, Personalization, Embodiment, Creation, Generation," as well as those lacking relevance to our research inquiries, non-English publications, and those with inaccessible abstracts and full texts. Subsequently, we scrutinized the remaining items to ascertain eligibility by performing meticulous readings as deemed necessary. Articles that were not accessible in full text were excluded, alongside those deemed irrelevant or diverging in focus, in addition to those lacking a robust foundation and empirical evidence to substantiate their conclusions. Ultimately, the items retained from the preceding processes were subjected to analysis within this systematic review. In summary, 45 scholarly articles were selected, as illustrated in Table 2, which we considered appropriate for subsequent examination.

3 Results

This table (Table 2) presents a brief synthesis of the selected studies examined in this literature review. The descriptions in the second column consist of summaries extracted directly from the Abstract section of each individual study. These summaries are designed to provide a rapid comprehension of the primary focus and contributions of each article without necessitating reference to the complete text. Through the provision of these descriptions, the table underscores the heterogeneity of research topics and methodologies incorporated in this review, thereby ensuring transparency and clarity in the selection process.

As shown in the (Figure 1) and (Table 2), the search keywords provided a total of 4,169 items. Thus, after excluding 900 records that were duplicates, 3,269 records were selected for the first round of screening. In the first stage of title and abstract filtering, 2,200 papers were removed because of irrelevant topics or domains, such as works that did not address avatars in virtual reality or were not related to customization and embodiment (e.g., religious avatars or other types of digital avatars). A further 800 items were excluded because they did not meet the criteria of our study aims, and 100 items were excluded due to the type of source (e.g., not peer reviewed). Another 74 items were excluded for other reasons, and 95 items were identified for full-text review. Full-

TABLE 2 Summary of the selected papers.

Reference	Definition
Cheok et al. (2009)	The article presents 'Petimo,' an interactive robotic toy enhancing children's safety in social networking by adding a physical authentication mode and connecting to virtual worlds like 'Petimo-World,' offering unique interactive features and secure social interactions
Kang and Gratch (2010)	The article talks about how avatar realism and anticipated future interaction (AFI) affect self-disclosure in emotionally engaged, synchronous computer-mediated interactions
Lin et al. (2012)	The article proposes a 3D model-based approach for face swapping that overcomes pose variations using personalized 3D head models and advanced blending techniques
Shang et al. (2012)	The article talks about how people buy symbolic virtual goods in the virtual world for emotional and social value
Song and Jung (2015)	The article explores how gender swapping in MMORPGs influences player behavior and social interactions, emphasizing strategic benefits and virtual goods purchases
Hu et al. (2015)	The article talks about a novel data-driven framework for digitizing complex 3D hairstyles from a single photograph
Ichim et al. (2015)	This paper introduces a method to create personalized 3D facial avatars from handheld video, capturing detailed expressions for realistic animation and online communication
Blažević et al. (2015)	We propose a de-identification pipeline that protects human privacy in videos by replacing them with rendered 3D models, using Kinect for joint detection and steganographic encoding to conceal original identities
Saito et al. (2016)	The paper introduces a technology that generates realistic 3D avatars from a single photograph, including hair modeling and real-time animation using deep learning techniques
Rehm et al. (2016)	The article reviews avatar use in e-mental health, emphasizing their roles in therapy, peer support, and treatment augmentation, highlighting benefits like anonymity and identity exploration
Serino et al. (2016a)	The study shows that virtual reality (VR) body swapping, particularly with a slim belly, can alter body perception and memory, offering potential therapeutic implications for eating and weight disorders
Serino et al. (2016b)	The article discusses the challenges in addressing body dissatisfaction and distortions among super-super obese patients (BMI >60 kg/m2) despite clinical guidelines recommending palliative multidisciplinary treatment; it explores VR body-swapping protocols as promising adjunctive therapies
Feng et al. (2017)	This document discusses the development of a system to generate realistic, interactive 3-D avatars from human scans for use in virtual reality, games, and communication, highlighting the importance of automation and accessibility
Achenbach et al. (2017)	This paper presents an efficient pipeline for creating realistic, ready-to-animate virtual humans from scanned data, optimized for quick processing and integration into standard VR engines
Alldieck et al. (2018a)	This paper details a method for creating accurate 3D body models from a single video, enabling fully animatable digital doubles with just a smartphone or webcam
Alldieck et al. (2018b)	This paper presents a method for creating highly detailed human avatars from a single video.
Alldieck et al. (2019)	This article presents a method to generate a personalized 3D model of a person from a single RGB video, incorporating body, hair, and clothing shapes, along with texture mapping and skeleton rigging for realistic animation
Roth et al. (2019)	The article talks about how avatars enable anonymous social interactions, perceived authentically and empathetically, fostering pro-social intentions and supporting mental wellbeing applications
Lazova et al. (2019)	The article presents a method to generate 360-degree textured 3D models of clothed humans from a single image using techniques like the SMPL model, DensePose, and conditional GANs for texture inpainting
Bigand et al. (2019)	The paper explores realistic virtual signer movement and the challenge of anonymizing identity-carrying parameters in motion capture applications
Zheng et al. (2019)	The article introduces DeepHuman, a framework for reconstructing detailed 3D human bodies from a single RGB image using technologies such as volume-to-volume translation CNNs, the SMPL model, multiscale volumetric feature transformation, and a volumetric normal projection layer
Serino et al. (2019)	The article discusses the integration of VR-based body swapping illusion in multidisciplinary treatment for anorexia nervosa, highlighting its role in monitoring and driving changes in multisensory bodily integration over treatment phases
Zhao et al. (2019)	The paper introduces a novel cartoon-style hybrid emotion embodiment model for VR storytelling, enhancing presenter engagement and emotional expression in live performances
Bragg et al. (2020)	Exploring privacy-enhancing distortions in sign language video datasets to balance algorithmic performance and contributors' privacy concerns
Beacco et al. (2020)	The article presents a method for creating an accurate, animatable 3D character from just two 2D RGB images, using SMPL models and various image processing techniques

(Continued on following page)

TABLE 2 (*Continued*) Summary of the selected papers.

Reference	Definition
ChengChiang Chen and Kent (2020)	The article investigates at-risk ESL learners' performance and attitudes towards using Second Life for improving English communication skills, finding that despite technical issues, the 3D environment enhanced engagement, confidence, and motivation
Mendels (2020)	The article shows how a digital role-playing game platform empowers marginalized Arab-Israeli teachers to express themselves freely and critically discuss social issues
Şenel and Slater (2020)	The article explores using VR body-swapping to facilitate dialogue between present and future selves of smokers, aiming to reduce nicotine dependence and promote long-term behavior change
Davidson (2021)	The article examines how virtual learning environments with avatars during the COVID-19 pandemic influence identity construction and digital literacy, balancing opportunities for expression with concerns about biases and inequalities
Trieu and Tu (2021)	The thesis explores engagement in online meetings using various modalities (audio, video, avatar), providing insights for future CMC tool design, including Metaverse platforms
Ishii et al. (2021)	This paper proposes an 'Avatar Twin' system that enhances communication in virtual spaces by using shadow avatars to synchronize user motions with auto-generated entrained movements
Malighetti et al. (2021)	The article explores a new VR paradigm using body-swapping and autobiographical recall techniques to address allocentric body memory in anorexia nervosa patients, showing promising results in improving body perception and emotional wellbeing
Nivière et al. (2021)	Virtual reality offers promising treatment for eating disorders by improving body image therapy and reducing binge episodes, but more research is needed to confirm its effectiveness
Oliva et al. (2022)	This document presents the development and introduction of QuickVR, a standard library for virtual embodiment in Unity, aiming to address the lack of user-friendly tools for embodying participants in virtual environments
Tze et al. (2022)	The article talks about a novel method for anonymizing sign language videos by reproducing the footage with animated cartoon characters, faithfully transferring the signer's motions and articulations using advanced deep learning techniques for body, hand, and face tracking
Sansoni et al. (2022)	The article proposes an innovative Virtual Reality (VR) training using embodiment techniques to bridge the gap with the bodily dimension of cancer, integrating psycho-educational procedures, exposure therapy, out-of-body experiences, and body swapping to enhance stress tolerance and patient empowerment
Sang et al. (2022)	The article presents a framework for avatar stylization using neural pose, expression, and illumination models, alongside a StyleGAN2-based imitator for generating high-quality avatar images from latent codes, facilitated by a mapper module trained on facial attribute datasets
Lin and Latoschik (2022)	The article 'Factors Affecting Avatar Customization Behavior in Virtual Environments' explores the psychology and behavior of avatar customization in various virtual environments
Zeng et al. (2023)	The article introduces a face-swapping framework for game characters using identity embedding, expression consistency, and domain adaptation techniques to enhance customization and realism
Ho et al. (2023)	The article introduces a novel hybrid representation combining neural fields and LBS-articulated mesh models for creating and customizing high-fidelity 3D avatars with local editing capabilities
Yu et al. (2023)	The article proposes NOFA, employing NeRF and 3D GAN for one-shot facial avatar reconstruction with dynamic 3DMM-guided modeling and compensation networks for fine detail enhancement
Garcia Estrada et al. (2023)	The article showcases using embodiment and 360° video to teach civilian protection at a military university, integrating 3D objects and avatars for a realistic XR experience with positive user feedback
Van Arsdale et al. (2023)	The article describes a VA-DoD initiative creating a 3D virtual space in the VA-Virtual Medical Center to educate Veterans and Active Duty Service Members on cardiovascular disease prevention
Wu et al. (2023)	This study examines how virtual environments influence avatar customization, showing that relaxed settings lead to less self-similarity and more self-disclosure, while serious settings increase self-similarity and self-presentation
Deighan et al. (2023)	The article talks about how people use social VR platforms like VRChat for mental health support, especially during the COVID-19 pandemic

text screening at the second level led to the exclusion of 50 items that did not meet the eligibility criteria, and 45 papers were included in the study. The following studies were chosen for the discussion and analysis presented in the subsequent section of this paper:

The findings of this research are articulated in four principal sections, each employing rigorous and complementary methodologies to facilitate a comprehensive examination of the subject matter. The following analysis (Sections 3.1–3.4) adopts a thematic analysis framework to probe into the content of the selected studies, categorizing results into four pivotal themes: The role does avatar customization in virtual reality (Section 3.1), The situations that may affect the appearance of the avatar in the virtual world (Section 3.2), The most important innovations used to customize the avatars (Section 3.3), Mention the most important social contexts in which avatar customization is used (Section 3.4). To ensure precision and uniformity, two independent reviewers meticulously analyzed the data, cross-referenced their outcomes, and reconciled any discrepancies through collaborative discussion. Collectively, these methodologies furnish a robust and insightful foundation for comprehending the contemporary landscape of avatar customization research and its broader implications.

3.1 The role avatar customization does in virtual reality

Customization of avatars is therefore an essential feature of user experience and interaction in VR, as the study results show. Avatar customization allows users to create digital representations of themselves or how they would like to be, either in real life or in their dreams (Lin and Latoschik, 2022; Wu et al., 2023; Ho et al., 2023). Such an approach not only helps to develop a better feeling of ownership of avatars in virtual reality but also contributes to the improvement of the quality of interactions in VR environments, as well as trust between the users (Lin and Latoschik, 2022; Wu et al., 2023). In addition, the link between online avatar representation and real-life identity also highlights the users' desire for consistency between the two worlds, the importance of avatar customization in the formation of online identities (Ho et al., 2023).

3.2 The situations that may affect the appearance of the avatar in the virtual world

Situational factors that determine the appearance of avatars in the virtual world are as follows: Firstly, the type of customization that is possible has a large part to play in the whole process. The studies show that people are more inclined to identify with their avatars when the options available for customization are realistic and can be changed in real life, for instance, hairdo or clothing. This identification is further supported by the use of real life factors such as friends or events in the customization process which makes users more attached to their avatars and encourages them to interact with others on the site (Wu et al., 2023).

Secondly, the type of virtual environment has a large influence on the level of customization of avatars. Since the level of public self-consciousness is low in casual and comfortable virtual social environments, users create a persona that is an imaginary one. On the other hand, in the more formal and serious virtual environments, where users feel higher public self-consciousness, they are willing to represent avatars that are closer to their real life. This implies that the level of self-similarity of avatars differs with the virtual environment and the level of public self-consciousness of the users (Alldieck et al., 2018a).

The need to construct a new self and to come out in cyberspace is another reason for this. People tend to design their avatars to have a new body which replaces the real one and enables them to express themselves more openly in the virtual environment (Roth et al., 2019). In addition, avatars in virtual spaces enable users to conceal their real-life identities and thus free themselves from social expectations, which results in more permissive behaviors and higher levels of self-actualization (Shang et al., 2012).

Also, the social context and the goals of interactions in virtual environments influence avatars' look. For instance, in social VR environments, the users can decide to have avatars that resemble their real-life physical appearance or have avatars that are enhanced in some way. This flexibility of customization improves the level of interest, identification with avatars, and the realism of interactions, which leads to trust and stronger social relations within the virtual environment (Lin and Latoschik, 2022).

TABLE 3 Key fields of avatar customization methods by number of articles covered.

Avatar Construction from Images	10
Avatar Construction from Videos	4
Avatar Construction from Scans	2
Technologies on real-time live input video	2
Add extra effect to avatars	1
Software libraries	1

3.3 The most important innovations used to customize the avatars

The innovations elucidated in this research were systematically derived from an exhaustive review of scholarly articles centered on the customization of avatars within virtual reality environments. The principal objective was to discern and classify technologies predicated on their methodologies for avatar construction, thereby ensuring a lucid and methodical presentation of the most consequential advancements within this domain.

The procedure commenced with a thorough examination of the selected studies, wherein pivotal technologies or methodologies employed in the creation and customization of avatars were identified. These innovations were subsequently categorized into six principal segments predicated on their construction techniques:

Images (Section 3.3.1): Technologies that utilize static imagery for the creation or modification of avatars. Videos (Section 3.3.2): Methods that exploit video data for the generation or enhancement of avatars. Scans (Section 3.3.3): Techniques that incorporate 3D scanning to produce detailed and lifelike avatars. Real-Time Video (Section 3.3.4): Innovations that facilitate avatar customization or interaction in real-time through the utilization of video input. Additional Effects (Section 3.3.5): Instruments or features that augment avatars with special effects, animations, or enhancements. Software Libraries (Section 3.3.6): Frameworks or libraries that furnish developers with the requisite tools for avatar creation and customization.

This classification was meticulously designed to encapsulate the heterogeneity of methodologies in avatar customization while accentuating the most significant advancements in each specific domain. By concentrating on innovations that exhibited discernible technical contributions and practical applications, we ensured that the selected technologies were both pertinent and impactful.

The final curation of 20 scholarly articles (Table 3) was predicated on their capacity to address critical challenges in avatar customization, such as enhancing realism, increasing user engagement, and facilitating greater personalization. Each innovation underwent thorough analysis, with its distinctive contributions and potential applications articulated in the pertinent sections of the research paper.

This methodical approach enabled us to furnish a comprehensive overview of the current state-of-the-art in avatar customization technologies, while simultaneously preserving a clear and logical arrangement of the findings.

3.3.1 Technologies and innovations in avatar construction from images

The research and development in avatar construction from images has resulted in a number of important technologies and innovations. Such enhancements have been helpful in enhancing the realism, precision, and versatility of 3D avatars. These are single-image 3D reconstruction, hybrid representation, face swapping, personalized 3D head model, and high-fidelity facial reconstruction.

Lazova et al. (2019) proposed a method to generate a full 3D model from a single image including texture, geometry, and segmentation map. This model enables the digital adjustment of pose, shape, garment change, and clothing alteration with a segmentation map, texture map, and displacement map for the realistic rendering of avatars.

In this work, Zheng et al. (2019) proposed DeepHuman which is a framework that can reconstruct 3D human models from a single RGB image. It employs dense semantic representation and volumetric feature transformation for better surface geometry and a normal refinement network for better surface details.

Beacco et al. (2020) introduced a method based on the Skinned Multi-Person Linear Model (SMPL) to reconstruct 3D characters from frontal and lateral RGB images with high accuracy of shape and texture in a few views.

Ho et al. (2023) described a technique that integrates neural fields with skinned meshes to build entirely modifiable and personalized neural avatars. This method enables local editing by transferring geometric and appearance details between 3D assets and is backed up by the high-quality CustomHumans dataset for training and testing.

Sang et al. (2022) proposed AgileAvatar, a system for stylized 3D avatar personalization. This system utilizes neural pose, expression, and illumination vectors for segmentation and utilizes a differentiable neural renderer with StyleGAN2 for rendering.

Zeng et al. (2023) proposed a face-replacement system for the gaming sector where the real face can be placed on the game's characters while retaining the original drawing style. This framework employs strong identity embeddings and fine-tuning methods to improve the image quality and the resemblance of the swapped and target faces.

In Lin et al. (2012), the authors developed a system for constructing a 3D head model that fits the user by matching the feature points on a frontal face image uploaded by the user. This system distorts a generic 3D head model by radial basis functions making avatar customization natural and fast.

Yu et al. (2023) presented a one-shot 3D facial avatar reconstruction system for VR, AR and teleconferencing. This framework synthesizes high-quality 3D facial avatars with precise control of facial behaviors and simultaneously produces new views, which makes it suitable for different industries that require realistic avatars.

Other authors Saito et al. (2016) underlined the necessity of using realistic and fully textured 3D avatars from the single image. The technology they employ is deep learning for hair segmentation and modeling, which is crucial for VR and AR applications.

Tex2Shape, a method for detailed full-body shape reconstruction from a single photograph was proposed by Alldieck et al. (2019). This innovation transforms shape reconstruction into an image-to-image translation problem, which enables the quick regression of full 3D clothes, hair, and facial features and, therefore, increases the level of realism and identification with avatars.

These developments emphasize the use of techniques such as advanced machine learning, computer vision and graphics to generate avatars from images in real life that are realistic and fully customizable for a wide range of uses, including gaming, entertainment, communication and social media.

3.3.2 Technologies and innovations in avatar construction from videos

The improvements in avatar construction from video inputs have brought revolutionary technologies in different fields, using new approaches and methods for realistic and interactive avatars. These technologies play a significant role in applications including VR, AR, fashion e-commerce, and human-avatar interfaces.

Hu et al. (2015) discuss the trend of realistic virtual characters and the emerging need for 3D avatar customization. Their work highlights the need to enhance the production capacity and also, the development of efficient and cheap ways of converting single-view images or videos of 3D hairstyles.

Alldieck et al. (2018a) present an approach to estimate accurate 3D body models from single video input for avatar creation in social VR and virtual fitting in online shopping. Their approach allows the generation of fully animatable digital avatars that can be aligned to input images to improve user engagement and customization.

Ichim et al. (2015) describe a pipeline that uses blendshape models and dynamic detail maps for building avatars from mobile phone camera video. It is their system that is aimed at enhancing the facial rig representation and the texture quality of avatars, providing the scalable solution for creating the high-quality avatars.

On such methodologies, Alldieck et al. (2018b) propose a new method of using SMPL body models and shape-from-shading techniques to enhance the avatar's facial features, hair, clothing, and body shape from monocular video. In their work, they show that other studies have found that users prefer their approach in preserving identity, realism, and general avatar quality.

3.3.3 Technologies and innovations in avatar construction from scans

Using scans, avatar construction has received major development, primarily in using superior and advanced technologies to develop a highly realistic, and, more interactive and versatile avatars for different disciplines.

Feng et al. (2017) present a system which creates photorealistic, interactive 3D avatars using human scans and has the ability to animate it. These avatars resemble specific manners that the user possesses like hair color, glasses, and even the outfit they wear. Stressing the automation, the system helps to generate avatars without much attention to technical background; thus, improving the usability of virtual environments.

Achenbach et al. (2017) describe a pipeline–by scanning, building, and rigging animatable virtual human avatars from scanned data. MVS reconstruction is used to fit a template character to scanned point sets by their approach. The avatars, as a result, come complete with skeletal rigging, rendered fingers, facial morph targets, and other realistic human features such as eyes and teeth. This method can cater for any need ranging from games all the way to medical simulations and virtual help which greatly highlights the realism of the method.

3.3.4 Technologies and innovations that depend on real-time live video input

One of the most important innovations is the de-identification pipeline that has been introduced by Blaževi´cblaževi´c et al. (2015). This system is rather aimed at preserving individual's identity in the surveillance videos through the use of avatars. It consists of tracking and partitioning humans in video sequences, estimating the body poses and synthesizing natural looking 3D avatars over the human detections. The technology applied in this system includes GrabCut segmentation algorithm, tracking and segmentation models, flexible mixture models, deep learning methods. Furthermore, body posture estimation of Microsoft Kinect has been used by depth maps. The system keeps the privacy of the individuals by blurring out features such as skin color, hair color, eye color, and the clothes that people wear while at the same time preserving the natural feel of the scene. The approach used in this paper enables privacy protection whilst not having a negative impact on the quality and usability of the surveillance videos.

Zhao et al. (2019) present a cartoonish hybrid emotion embodiment for live VR performance with simple animated characters having six basic emotions as well as additional supplementary peripheral devices. The model draws inspiration from comic animation techniques and adheres to three key design principles: The discrete categorization of emotions, the mapping of emotional meanings through iconic abstraction, and the integration of multiple channels in the representation of emotions. One of the technologies employed in this system is the face tracking module that relates the feelings of the presenter to the avatar in real time. Further, there is a visual programming tool that allows the users to adjust the emotional impact which further increases the interactivity of live VR storytelling. This model greatly enhances the richness and the ease of use of avatars in the VR setting and enhances the storytelling experience.

3.3.5 Add extra effect to avatars

According to Ishii et al. (2021), avatar customization is a key feature in the virtual communication systems. It says that in 'virtual space' avatars can easily alter appearance characteristics and there are many scenarios where communication is done through the character. However, the document also recognizes that appearance characteristics might be a limitation to role play. To this end, the document calls for the use of shadow avatars to alter the appearance of the avatar as perceived without having to alter the avatar, which is useful in communication environments.

3.3.6 Software libraries to simplify avatar appearance control

The focus of this document is the creation and implementation of a standard library named QuickVR for VR embodiment in Unity, which is a popular game engine for VR. The document also underlines the importance of VR in different areas of studies and uses and stresses on the fact that VR offers the possibility of designing virtual environments that may not correspond to the real world. Nevertheless, the document also notes the absence of a clear and easily accessible technique for 'imprinting' participants into human avatars that can react to the participants' movements in real time. To this end, QuickVR is designed to deliver the library based on Unity that has the virtual embodiment together with the high-level features required for VR applications that can save time for production. It is intended for use by people who are new to coding as well as being flexible and expandable for those who know coding. In the given document, the author focuses on the possibility of presence illusion, body ownership illusion, and agency that can be provided by virtual embodiment and the role of VR in different experiments and researches. It also lists out the available tools and packages for VR in Unity but states that only a few are concerned with embodiment (Oliva et al., 2022).

3.3.7 Summary of technologies for controlling virtual characters (per table)

Table 4 delineates a comprehensive array of technologies employed in the customization of avatars, elucidating their respective functions and the scholarly investigations that incorporate each technology. The technologies are systematically classified into various categories, which encompass 3D Effects and Reconstruction, Segmentation and Mapping, Animation and Motion Capture, Quality Enhancement, and Sensors and Capture Technologies. These technologies were either partially or wholly integrated into the innovations examined in the selected research articles, which exhibit significant potential for future capital investment and practical application in forthcoming scholarly endeavors. By methodically categorizing these technologies, the table offers a coherent overview of the instruments and methodologies propelling progress in avatar customization, thereby providing critical insights for researchers and developers who aspire to investigate or expand upon these advancements.

3.3.7.1 Overview of the five main technology categories

The presented table delineates five fundamental categories of technologies employed in the customization of avatars:

3D Effects and Reconstruction: This category emphasizes the generation of realistic representations of human anatomical features and facial structures, thereby enhancing the overall believability of avatars.

Segmentation and Mapping: This process involves the translation of two-dimensional images into three-dimensional spatial configurations, guaranteeing that avatars correspond accurately to the physical forms of actual humans.

Animation and Motion Capture: This technology facilitates the production of dynamic and expressive movements in avatars through the application of sophisticated animation methodologies.

TABLE 4 Technologies for avatar customization used in selected papers.

Categories	Technologies	Definition	Citations
Effects And Reconstruction 3D	SMPL Model	Generates realistic human body shapes	Lazova et al. (2019) Zheng et al. (2019) Beacco et al. (2020) Alldieck et al. (2018a)
	3DMM (3D Morphable Model)	Creates and manipulates 3D facial shapes	Yu et al. (2023)
	Implicit Surface Rendering	Renders surfaces not explicitly defined	Ho et al. (2023)
	Generative Adversarial Networks (GANs)	Produces synthetic data through adversarial training	Lazova et al. (2019) Ho et al. (2023)
	3D GAN	Generates three-dimensional object models	Yu et al. (2023)
	GAN Inversion (e4e Encoder)	Converts images back into GAN's inputs	Sang et al. (2022) Yu et al. (2023)
	Image-to-Image Translation	Converts images between different visual domains	Lazova et al. (2019)
	NeRF (Neural Radiance Fields)	Renders 3D scenes from 2D images	Yu et al. (2023)
	Poisson Blending	Seamlessly merges image regions together	Beacco et al. (2020)
	Multi-Resolution Spline Technique	Smoothly transforms images across resolutions	Lin et al. (2012)
Segmentation and Mapping	DensePose	Maps 2D images to 3D body surfaces	Lazova et al. (2019) Beacco et al. (2020)
	Human Semantic Segmentation	Divides images into human-relevant segments	Beacco et al. (2020)
	BiSeNet Module	Enables real-time image segmentation	Sang et al. (2022)
	CNN-based video segmentation	Segments video frames using neural networks	Alldieck et al. (2018a)
	GrabCut segmentation algorithm	Extracts foreground objects interactively	Blaževi´cblaževi´c et al. (2015)
	Facial expression recognition	Identifies emotions from facial expressions	Sang et al. (2022)
	Face tracking	Tracks facial movements in real-time	Zhao et al. (2019)
	ArcFace	Recognizes faces with deep learning	Sang et al. (2022)
	Azure Face API	Provides facial recognition as a service	Sang et al. (2022)
	Facial tracking software	Tracks facial movements using software	Ichim et al. (2015)
	RGB-based facial performance capture	Captures facial expressions with RGB cameras	Saito et al. (2016)
	Azure Face API	Provides facial recognition as a service	Sang et al. (2022)
Animation and Motion Capture	PhotoWakeUp Method	Animates characters from 2D photos	Beacco et al. (2020)
	Neural Pose	Estimates human poses with neural networks	Sang et al. (2022)
	Expression Model	Represents facial expressions mathematically	Sang et al. (2022)
	Blendshape models	Creates expressions by blending shapes	Saito et al. (2016)
	Dynamic blendshape rig building	Builds facial animation rigs dynamically	Ichim et al. (2015)
	3D pose reconstruction	Builds facial animation rigs dynamically	Alldieck et al. (2018a)
	SMPL body model adaptation	Adjusts SMPL model for diverse shapes	Alldieck et al. (2018a)
	Illumination Models (Be sure)	Simulates light interactions on surfaces	Sang et al. (2022)
	Hand rigging process	Creates skeletal structures for animating hands	Feng et al. (2017)
	Linear Blend Skinning (LBS)	Smoothly deforms mesh for animations	Beacco et al. (2020)
	Iterative Closest Points (ICP)	Aligns and matches 3D shapes iteratively	Beacco et al. (2020)
	Skeletal Animation Technology	Animates characters using skeletons	Ishii et al. (2021)

(Continued on following page)

TABLE 4 (*Continued*) Technologies for avatar customization used in selected papers.

Categories	Technologies	Definition	Citations
Quality Enhancement	LPIPS (Perceptual Similarity)	Measures perceptual similarity between images	Sang et al. (2022)
	Frame refinement	Enhances quality of individual video frames	Alldieck et al. (2018a)
	Symmetry Constraints for Mesh Regularization	Ensures symmetrical properties in 3D meshes	Alldieck et al. (2018a)
	Laplacian Mesh Regularizer	Smooths and regularizes 3D meshes	Alldieck et al. (2018a)
	Principal Component Analysis (PCA)	Reduces data dimensionality effectively	Ho et al. (2023)
	3D Mesh Processing	Manipulates and edits 3D mesh structures	Ho et al. (2023)
	Rasterization	Converts 3D objects into 2D pixels	Ho et al. (2023)
Sensors and Capture Technologies	Monocular RGB video capture (capturer la vidéo RGB monoculaire)	Records video using a single RGB camera	Alldieck et al. (2018a)
	RGB-D sensors for scanning facial expressions	Captures depth and color for facial scans	Feng et al. (2017)
	Depth sensing technology	Measures distances using sensor data	Ichim et al. (2015)
	Magnetic Sensors (Polhemus FASTRAK)	Tracks positions using magnetic fields	Ishii et al. (2021)
	Microsoft Kinect's depth maps	Provides depth sensing for motion capture	Blaževi´cblaževi´c et al. (2015)
	Cell phone camera	Captures images and videos on phones	Ichim et al. (2015)
	Commodity or off-the-shelf hardware	Easily available commercial hardware products	Feng et al. (2017)
	Photogrammetric reconstruction for capturing the 3-D body model	Creates 3D models from multiple photos	Feng et al. (2017)

Quality Enhancement: This aspect focuses on the augmentation of the visual fidelity of avatars by refining intricate details and optimizing the smoothness of three-dimensional constructs.

Sensors and Capture Technologies: This category encompasses the acquisition of facial expressions and bodily movements, thereby supplying precise data essential for the development of avatars.

The technologies mentioned above frequently operate in tandem to forge cohesive and fully developed virtual characters, thereby propelling advancements within the domain of avatar customization.

3.3.7.2 Interdependencies between some of these avatar customization technologies and major tech companies

3.3.7.2.1 Microsoft. Azure Face API: Microsoft offers this service as an integral component of the Azure cloud platform, which is utilized for the purposes of facial recognition and analysis. This technology is inherently connected to the facial recognition methodologies delineated in the accompanying table.

Microsoft Kinect: Kinect represents a sensor apparatus conceived by Microsoft, employed for the purposes of motion and depth tracking. It bears relevance to technologies such as RGB-D sensors and depth-sensing methodologies referenced in the table.

Mixed Reality: Microsoft is actively engaged in the advancement of augmented reality (AR) and virtual reality (VR) technologies, necessitating techniques such as 3D reconstruction and NeRF to facilitate the creation of interactive environments.

3.3.7.2.2 Nvidia. GPU Acceleration: Nvidia is prominently recognized for the development of graphics processing units (GPUs) that are leveraged to enhance the performance of artificial intelligence (AI) and deep learning technologies, including GANs and 3D GANs specified in the table.

Omniverse: The Nvidia Omniverse platform serves as a medium for the creation of 3D simulations and virtual environments, relying on technologies such as NeRF and 3D mesh processing.

AI Research: Nvidia is significantly invested in the domain of AI research, encompassing neural networks that underpin technologies such as CNN-based video segmentation and facial expression recognition.

3.3.7.2.3 Meta (formerly facebook). Meta Avatars: Meta is engaged in the development of realistic avatars for virtual and augmented reality, which depend on technologies including the SMPL model and blendshape models to generate authentic human forms.

VR/AR Headsets: Devices such as the Oculus Quest implement face and motion tracking technologies, including face tracking and RGB-based facial performance capture.

AI Research: Meta allocates substantial resources to AI research, incorporating technologies such as GANs and neural pose estimation.

3.3.7.2.4 Google. DeepMind: A subsidiary of Google dedicated to advancing AI research, including technologies such as GANs and NeRF.

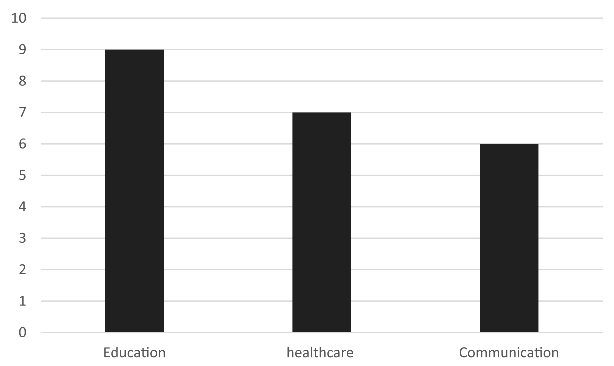

FIGURE 2
Key social contexts for avatar customization usage.

Google ARCore: Google's framework for the development of augmented reality applications, which is grounded in technologies such as 3D reconstruction and image-to-image translation.

Cloud AI: Google offers cloud-based AI services, which are capable of supporting technologies such as facial recognition and CNN-based segmentation.

3.3.7.2.5 Apple. ARKit: Apple's framework for the development of augmented reality applications, which relies on technologies such as 3D reconstruction and face tracking.

Face ID: The facial recognition system integrated into iPhones employs technologies akin to ArcFace and facial expression recognition.

LiDAR Scanner: Devices such as the iPhone Pro incorporate LiDAR sensors to produce depth maps, which are associated with technologies such as RGB-D sensors and depth-sensing methodologies.

3.4 The most important social contexts in which avatar customization is used

As illustrated in (Figure 2), our review and analysis of the collected scientific research revealed that the majority of applications for avatar customization are concentrated in three primary social contexts: education (9 works), mental health (7 works), and communication (6 works).

In the course of the first analysis of the research, these three spheres were distinguished as the most extensive areas where avatar customization is employed. Although, we did not set out to specifically target these contexts in our analysis, the findings from the reviewed studies pointed towards their relevance. Those that did not help in the advancement of virtual reality or were not insightful about these key social contexts were omitted; those with little room for future investment. This process helped in the elimination of any study that was not considered to be very relevant and important. After this, a full-text screening was done in order to make a more selective choice of the articles. This led to the elimination of articles that were related to non-central or non-social uses of avatar customization to minimize the study on areas that are less relevant. In this way, 23 works were selected for the final analysis, which were grouped according to their relevance to education, mental health, and communication.

3.4.1 Education

Avatar customization is employed in different manners and in different situations. In the context of VR education, and online learning platforms, including VRChat and Alt-Space, avatars refer to the representations of the users in virtual classes and forums (Davidson, 2021). Such customization assists in portraying the inner self of a person without any regard to the outer appearance of the person. However, it also raises issues of digital literacy and semiotics of avatars into the discussion which should make us keep on looking for the best ways to build identity in the context of online learning.

The customization of avatars is regarded as an instrumental mechanism for facilitating language acquisition within virtual reality contexts, notably on platforms such as Second Life (Kang and Gratch, 2010). This approach aids learners—especially those encountering difficulties in mastering new languages like English—by fostering an environment that enhances comfort and motivation for engagement in educational activities. Through the utilization of avatars, participants can obscure their actual identities, thereby promoting a sense of security and a greater willingness to engage authentically with peers. In a similar vein, additional scholars (ChengChiang Chen and Kent, 2020; Trieu and Tu, 2021) assert that empowering students to design and manage their own avatars significantly elevates their interest, self-efficacy, and motivation. Given that avatars provide a degree of anonymity, learners experience diminished anxiety concerning errors or embarrassment, as their interactions are not conducted in a direct, face-to-face manner.

Furthermore, avatar customization plays a role in the generation of new strategies in the military training and education (Garcia Estrada et al., 2023). In the military, military officers use applications of Extended Reality (XR) including virtual embodiment and 360° video applications to provide the officers with better learning of the different scenarios. The use of avatars and realistic simulations is an effective and cheap way of providing an emotionally engaging training.

In the training programs of child protection services and law enforcement, avatar customization is helpful in developing the scenarios and simulation (Bigand et al., 2019). The realistic child avatars allow training programs to offer the practitioners with the best experience that enhances their interviewing and communication with the vulnerable children. In these contexts, the employment of avatars guarantees the participants' anonymity and privacy, although the effectiveness of the training interventions does not suffer.

Avatar customization was used in the context of the Virtual Medical Center (VMC) project which was described in the document. The VMC is an educational game that is based on the creation of avatars. The avatars can be used to move from one learning environment to another, attend conferences and meetings as well as interact with other avatars in the virtual environment. The conclusion that can be made from the integration of avatar-based technology is that the technology is useful in enhancing knowledge of chronic diseases as well as self-care practices (Van Arsdale et al., 2023).

3.4.2 Mental health

Avatar customization is used in body swap experiments meant to change people's attitude towards their bodies (Serino et al., 2016a; Serino et al., 2016b). In virtual reality arrangements, participants physically act as different avatars, which in turn results in changes to their body image memories. It has the potential of altering memory of the body and thus holds some potential for individuals with eating and weight disorders.

Furthermore, avatar customization is a significant component of the interventions for health behavior change, including smoking cessation (Şenel and Slater, 2020). To increase the future self-continuity, which in turn can have a positive effect on long-term health behavior, researchers develop avatars that represent participants' current and future selves. These avatars help to discuss smoking risks and benefits and, therefore, promote better behavioral patterns.

Moreover, avatar customization is part of the strategies of the interventions for people who are dealing with challenges in the context of cancer (Sansoni et al., 2022). In the VR settings, patients become the strong characters which help them to learn how to cope with the situations and acquire the necessary skills. In the same way, in Anorexia Nervosa (AN), avatar customization helps in evaluating and intervening on body representation alterations (Malighetti et al., 2021; Nivière et al., 2021; Serino et al., 2019). They change clothes and body shapes of avatars to reflect their desired and perceived body sizes and this determines the degree of control and identification with the virtual body. These interventions may therefore help to enhance body image dysfunctions and the treatment of AN.

In addition, avatar customization is not limited to gaming platforms but also applies to social virtual reality environments such as VRChat (Deighan et al., 2023). Personalized avatars allow the users to have a psychological detachment from their actual selves and thereby help them to overcome stress and gain confidence in interpersonal communication. In the same way, avatars help in expression and critical engagement in Digital Role-Playing Games (DRPGs) enhancing the gaming experience (Mendels, 2020).

Besides, avatar customization enhances the creation of new strategies in the treatment of mental health disorders (Rehm et al., 2016). Through avatars in psychotherapy, therapists can help clients communicate and reflect on aspects of the self in cyberspace. Avatars are a way of involving clients in the therapy while at the same time giving the clients some measure of control over the treatment stimuli.

Last but not least, avatar customization is also useful in treating body image disorders and ensuring positive body experiences (Malighetti et al., 2021; Nivière et al., 2021; Serino et al., 2019; Serino et al., 2016a; Serino et al., 2016b). Using body swapping illusions in virtual reality, people with body image distortion or eating disorders or obesity can change the size and shape of their body and, therefore, enhance the body representation. Real or preferred body image replicas are used to embody virtual bodies and thus have an impact on memory, perception and motivation towards behavioral change.

3.4.3 Communication

Customization of avatars is one of the most critical aspects of improving the level of involvement and social presence in the context of communication in social spaces such as Gather-Town (Trieu and Tu, 2021). As the users are allowed to choose the appearance of avatars, these platforms make individuals feel that they belong to a community. This is because users need more options in terms of customization of avatars–something as simple as hair style–which shows that avatar personalization is essential to user satisfaction and, by extension, the extent of immersion possible in an online environment.

Moreover, avatar customization is used in social virtual reality environments such as VRChat for social interaction and psychological wellbeing (Deighan et al., 2023). These platforms provide individuals the chance to discuss identity, build emotions, and share information without restrictions based on appearance due to the creation of avatars. Avatar customization in VRChat enables the user to get a break from the physical self, hence helping in managing anxiety and boosting confidence in social related tasks.

With regards to privacy-preserving filters for sign language datasets, avatar personalization provides solutions to blind the signers' identity while maintaining the dataset's quality (Bragg et al., 2020). The ideas given by participants regarding the change of videos through avatar filters improve the contribution to sign language datasets.

In this article, avatar customization was used to mask or anonymize sign language video. The method employed an animated cartoon character in order to mask the identity of the original signer and translate their motions and articulations to the cartoon figure. The outcome derived from this strategy was that it enhanced the readiness of the deaf and people with hearing difficulty to contribute to sign language corpora (Tze et al., 2022).

In this article, avatar customization was used while addressing issues of gender swapping in virtual gaming environments. The research questions of the study were: What are the reasons for gender swapping and what does gender swapping mean to the players? It examined antecedent of gender swapping which include gender schema, perceived anonymity, and perceived benefits. This research showed that gender swapping is not exceptional and players change their gender in games for purposes of gaining from other players while still being anonymous, not for the purpose of gender identity. Male players who played as female characters were more friendly as is expected of women and the players were willing to spend money to beautify their gender swapped characters because of the perceived closeness to the characters (Song and Jung, 2015).

The process of avatar personalization was employed in the three-dimensional virtual environment known as "Petimo-World," which incorporates elements of social networking that facilitate interactions among children through their robotic representations. A fundamental component of Petimo-World is the implementation of avatars, which permits children to develop virtual counterparts that embody their identities in the digital realm. As noted by Cheok et al. (2009), this method of avatar personalization significantly augments social connections among children, both in physical and virtual contexts, by enabling them to share distinctive gifts and emoticons.

4 Discussion

This scholarly endeavor sought to deliver a comprehensive examination of the contemporary landscape of avatar customization within virtual reality (VR), investigating its ramifications for user engagement, identity representation, and social interactions. Through an analysis of 45 scholarly works, we discerned three principal themes: 1) Situations Affecting Avatar Appearance in Virtual Worlds, 2) advancements in avatar development, and 3) The Most Important Social Contexts in Which Avatar Customization is Used. Our results indicate that avatar aesthetics are influenced by social dynamics and customization alternatives, with users frequently opting to create realistic avatars for formal contexts and whimsical ones for informal environments. This adaptability profoundly influences user identification and immersion within VR settings (Zhang K. et al., 2022; Hart et al., 2021). Technological innovations, such as single-image 3D reconstruction and tailored content recommendation systems, have further augmented avatar realism and user engagement, with applications encompassing gaming, social VR, and professional domains (Gisbergen et al., 2020). Furthermore, avatar customization has demonstrated efficacy in educational settings, mental health interventions, and social interactions, promoting enhanced student involvement, facilitating therapeutic role-playing, and enriching emotional expression in virtual social contexts (Alblehai, 2021; Pakanen et al., 2021).

The involvement of technology corporations in propelling avatar customization is also of considerable significance. Entities such as Microsoft, Nvidia, and Meta have played a pivotal role in the advancement of technologies pertinent to avatar personalization. Microsoft, frequently cited in academic discourse, has pioneered platforms for avatar creation, while Nvidia's graphics processing capabilities have facilitated immersive experiences in VR. Meta and Google have harnessed artificial intelligence and social media to influence the trajectory of avatar customization. Historical platforms such as Second Life, which debuted in 2003 (Jarmon, 2009), established the foundational framework for virtual environments, while contemporary platforms like VRChat and Roblox are spearheading innovation within the discipline. These findings underscore the dynamic progression of avatar customization, deeply rooted in technological history yet perpetually evolving through the contributions of both established enterprises and emerging platforms.

4.1 Situations affecting avatar appearance in virtual worlds

This work establishes that the determinants of avatars' appearance in virtual worlds are customizability, types of virtual environments, social relations and user requirements for representation and anonymity. All these factors define the level of realism of avatars and real or imaginary selves of the users, interaction and reality of virtual environments. The analysis in this paper reveals that the options that are present in virtual environments play a role in the manner in which users perceive and interact with avatars. For instance, the look of avatars influences physical outcome and perceived effort, muscular avatars reduce perceived effort and improve strength in tasks (Kocur et al., 2020). The personalized avatars are also better in increasing the body ownership, presence, and emotions than the general ones, and hence, the need to establish high fidelity and personalized avatar creation processes (Waltemate et al., 2018). Another critical aspect is the kind of virtual environment that is being used. In social VR environments, motion-controlled avatars with full body representation improves presence and co-presence, it shows that avatar completeness is significant for social presence (Heidicker et al., 2017). One of the emerging trends was the role of social relationships and the nature of the interaction in the appearance of avatars. The avatars chosen by users in social VR environments are similar to the real life appearance of the users or an even better version of the users and thus, the user is more immersed, trusting, and building better relationships with other users in the virtual environment (Radiah et al., 2023).

However, the study has the following limitations: The degree of customization offered by the various virtual platforms may also be a limitation because users' experiences may be influenced by the platform being used. Moreover, the research is mainly conducted in social contexts of VR; more investigations are required to examine avatar customization in professional or educational environments of VR (Buck et al., 2023). Future research should focus on the effect of various virtual environments on avatar customization in professional and educational contexts. Longitudinal studies should also be conducted to examine the impact of avatar customization on the usage and relationships within virtual environments. One of the other research directions is the examination of cultural differences in preferences regarding avatars and their influence on virtual communication (Thomas et al., 2017). In the research, the authors demonstrate the significance of avatar customization on the level of interest and actuality of users and interactions. Choices and preferences, virtual environment, social interactions, and the need for uniqueness affect avatar look. These considerations indicate the necessity of providing a wide range of diverse and flexible options for customization of virtual platforms to support better user experiences and interactions in virtual worlds (Reinhard et al., 2019). Therefore, avatars in virtual worlds are determined by the choice of the appearance, characteristics of the virtual environment, interaction with other avatars, and the need for self-identification and anonymity. Knowledge of these factors is highly essential in developing virtual environments that will increase user participation and promote real-life interactions.

4.2 Key innovations in avatar customization

The advancement in technology has seen many improvements in the area of research and development of avatars and their customization. All these innovations have contributed significantly to improving the precision, realism, and individuality of 3D avatars. Some of them are single image 3D reconstruction, hybrid representation techniques, face swapping techniques, personalized 3D head model, high fidelity facial reconstruction and building avatars from videos and scans. Furthermore, the current trend in creating avatars is the AI-generated avatars and not the standard options where one is limited to choices or has to select the features manually. Some of the recent developments that have been made in single-image 3D reconstruction include the models that were made by Zollhöfer et al. (2011). Hu et al. (2017) and from the work of other authors as well.

emphasize the combination of the dense semantic representation and volumetric feature transformation to increase the surface details and geometry from a small set of input data. Also, there are more complex representation methods that are half way between the previous types, such as those described by Ichim et al. (2015) and Pan et al. (2023) which combine neural fields with skinned meshes, thus enabling fine-grained local editing and cartoon-like avatars' customization. One of the emergent positive effects is the improvement of the techniques of high-fidelity facial reconstruction from minimal data inputs, for instance, the one-shot 3D facial avatar reconstruction by Yu et al. (2023). This innovation gives practical use in the fields of VR and AR, which greatly expands the use of realistic avatars in different fields. These are some of the most important technologies, and as such, they have their drawbacks as well. For instance, the use of input data of high quality and computational power can be a limitation as highlighted by Garrido et al. (Yu et al., 2023) and Liao et al. (2023).

These studies stress the importance of developing strong data acquisition and processing methodologies to achieve realistic and accurate avatars in the reconstructed scenes. Using AI for avatars' generation has become more frequent than the methods that involve using presets or certain settings for customization. This change can be attributed to the use of AI and speed that is offered by the same as well as the shift towards more realistic avatars. GANs stand out as the most used technology in avatar customization due to their versatility, ability to generate realistic data, and the continuous improvements in their architecture, all of which contribute to creating more dynamic and lifelike avatars.

The future work should be dedicated to the improvement of the algorithms that would allow creating high-quality avatars based on low-quality or even partial input data. Also, the further development of more convenient and affordable scanning technologies may open the possibility to create personalized avatars for everyone, as Bai et al. pointed out Bai et al. (2022) and Zhang L. et al. (2022) pointed out. These innovations in avatar customization have greatly enhanced the general possibilities of constructing avatars in 3D in terms of realism and individuality. The use of AI instead of conventional techniques is a sign of the growing demand for more effectiveness and realism of avatars. These technologies are versatile and can be applied in many fields including but not limited to gaming, entertainment, business meetings, and virtual shopping. Future studies should build upon current gaps and extend the research findings to new directions to improve avatar customization to the user convenience.

4.3 The most important social contexts in which avatar customization is used

Avatar customization plays a critical role in improving the communication, education and healthcare delivery. In communication, avatars facilitate better interaction since the user is able to show nonverbal signs and has a higher social presence. Research indicates that avatars with actual human features and realistic emotions enhance interaction and communication quality in virtual environments (Hart et al., 2021). In education, avatars enhance interaction and learning in virtual classrooms and language learning platforms where students are more active and engaged (Woodworth et al., 2019). In the context of healthcare, avatars enhance patient involvement and change in behavior through the use of personalized and interactive health management (Kim, 2014). In communication, avatars are not only the visual appearance but also self-sufficient communicative actions that improve the interaction experience. In education, avatars are important enablers of learning personalization, which has been discussed in the context of fashion education where avatars improve creative self-confidence and interest (Jang and Kim, 2023). In the healthcare context, avatars assist in the delivery of behaviour change interventions; for instance, the medical avatars for lifestyle changes and management of chronic illnesses (Anam et al., 2016).

A surprising result is the large effect of avatar customization on user attachment and communication in telehealth. The more avatars physically resemble users, the more attached they become, and the better they communicate with friends and family, which is the psychological value of custom avatars, (Rice et al., 2018). Research on avatar customization to date tends to be limited in scope, with few longitudinal studies of psychological impact, or consideration of the effects across diverse populations. Further, there is a dearth of research on the ethics of avatar use in particularly vulnerable settings like healthcare and education (Hart et al., 2021). Further work needs to address the long-term psychology of avatar customization and its role in increasing user engagement and behavior change for health and education. Further research is required to understand the ethical concerns and possible biases that may arise from avatar customization in different social settings (Kang and Kim, 2020) Avatar customization is an effective strategy in communication, education, and healthcare, to increase user motivation, interaction quality, and behavioral change. Further work may wish to pursue these applications to refine avatar utilization and mitigate possible ethical issues.

5 Limitations

While this review provides valuable insights into the current methods and benefits of avatar customization in virtual reality (VR), it is important to acknowledge its limitations. One notable limitation is the potential geographic and economic bias in the literature reviewed. The majority of the studies included may originate from specific regions of the world, particularly high-income countries, which could limit the generalizability of the findings to other contexts. This raises questions about whether the results and recommendations are equally applicable to low- and middle-income countries, where cultural, technological, and economic factors may differ significantly.

Additionally, the review may not fully capture the diversity of user needs and preferences across different demographics, such as age, gender, and cultural backgrounds. The reliance on studies from certain regions or populations could result in a skewed understanding of avatar customization practices and their effectiveness in broader, more diverse settings.

Despite these limitations, this review has strong implications for education, practice, research, and representation in healthcare. The results, discussion, and tables offer key insights into current trends and benefits of avatar customization in VR. By addressing these limitations in future research—such as incorporating studies from a wider range of geographic and economic contexts—this review can serve as a robust foundation for further innovation and development in the field. With these clarifications, it will be an even more valuable resource for advancing VR applications across various domains.

6 Future direction

The results of this research reveal a major research gap in the literature and methods related to avatar customization in virtual environments. As it has been established that the kind of avatars that are personalized is greatly determined by the operating environment, whether it is the kind of people or the events in question, this study shows that this is a significant limitation when the operating environments are multiple and diverse. For example, the fact that people from different backgrounds, age, or social circles (friends and strangers) are in the same virtual space creates a different set of issues. Most of the current approaches to avatar customization are based on the one-size-fits-all solution, which is insufficient to provide a representation that is satisfactory in such cases as it does not take into account the variety of the users' needs in these scenarios.

This limitation therefore points to the fact that there is a need for more research and innovation in this field. The scientific community needs to study new ways of avatar customization that can provide more freedom and variety in the choice of a virtual image, so that the virtual environment can be adapted to a wider range of situations and needs of users. These approaches should go beyond the current fashion of equal percentage adjustments and offer solutions that would be effective in the context of the conflicting and diverse needs of the users within the same virtual environment.

Therefore, we are pleased to inform you that a new original research paper is under preparation, where we will present a new approach to this problem. To this end, this paper seeks to fill the gaps that have been observed in the current research by proposing new approaches and models for avatar customization that are capable of dealing with the multiple context issues. This upcoming work will help enhance the field by providing a possible direction towards more diverse and flexible virtual environments. We expect that this research will create new directions for investigation and utilization and will contribute to the development of further innovations in the exciting and constantly developing area of virtual reality.

7 Conclusion

In view of the fact that social virtual reality technologies and applications have evolved rapidly and are being used extensively, new problems associated with user privacy and identity have appeared. This paper provides a systematic review of avatar customization technologies in virtual reality and identifies the main innovations and the main issues that determine the appearance of avatars in virtual environments. From 45 reviewed and chosen studies, we divided these innovations into several main groups, including image-based, video-based, and live sensor technologies. Furthermore, we looked at the social uses of these avatars, in education, mental health, and social interaction. Based on the analysis of the technologies used in avatar customization in virtual reality, we have identified the following areas of future research. Of these gaps, one of the most important is the lack of understanding of how customization influences social behaviors and self-identity in virtual environments, especially in the sphere of work and study. However, there is a lack of tools and techniques that will enable the users to have a more precise and interactive control over the avatars in order to have a better experience of the virtual reality. We suggest that future research should investigate the effects of advanced customization on social interaction, more precisely, the positive and negative effects of these technologies on trust and engagement of users in virtual environments. Moreover, we think that the future research should investigate the cultural differences in customization and the impact of these differences on the communication in the virtual reality, which will help to create more diverse and inclusive virtual environment.

Author contributions

HO: Writing – original draft, Writing – review and editing. AB: Writing – review and editing. BM: Methodology, Resources, Writing – review and editing. KE: Resources, Writing – review and editing. ZS: Methodology, Writing – review and editing. SL: Writing – review and editing. BR: Writing – review and editing. SZ: Conceptualization, Methodology, Validation, Writing – review and editing.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

Acknowledgments

The authors would like to express their deepest gratitude to the Computer Science Department and the Intelligent Processing and Security of Systems (IPSS) Laboratory, Faculty of Sciences, Mohammed V University, Rabat, Morocco, for their invaluable support and resources that made this research possible.

Conflict of interest

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

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