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Designing diversity: ethical virtual agents for effective dermatological training

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This paper discusses the importance of diversity and inclusivity in designing virtual agent simulations for dermatology. As virtual reality (VR) technology become increasingly utilized in dermatological diagnosis, treatment, and training, there is a need to ensure the agent representations reflect diverse populations. Our paper explains that virtual agents should represent a wide range of ethnicities, genders, skin tones, and other physical characteristics relevant to dermatology. It criticizes current classification schemas like the Fitzpatrick scale as lacking diversity, and encourages alternative approaches. Technical considerations in modeling diverse agents are explored, with popular tools analyzed for customization options and usability. Ethical issues around cultural sensitivity and stereotyping are highlighted as crucial to agent design. Examples are provided of how skin conditions may manifest differently across diverse populations, emphasizing why inclusive agents are vital for virtual simulations. Overall, the paper argues that comprehensive agent diversity is indispensable for achieving acceptance of VR in dermatology and accurately connecting virtual representations to real-world patients.

KEYWORDS

virtual reality, diversity, virtual agents, medical simulations, inclusive design

1 Introduction

In dermatology, as in medicine in general, the integration of VR technology is becoming increasingly important (Wesley and Maibach, 2003), since they have the potential to fundamentally change future medical education and healthcare (Mergen et al., 2024a). Through their use in dermatology, skin diseases can be examined and treated in an innovative and immersive way. In this perspective paper, we argue that the successful implementation of VR in dermatology fundamentally depends on creating diverse and inclusive virtual agent representations that accurately reflect real-world patient populations. The conceivable applications of VR in dermatology are diverse: from the simulation of skin diseases for the creation of medical reports to the simulation of treatment of dermatological diseases - the range of possible applications is enormous and offers great potential for improving patient care (Satava and Jones, 1998). Particularly in the field of dermatology, special attention must be paid to designing agents that are as inclusive and diverse as possible (Harper et al., 2022; Kaur et al., 2023; Schneider et al., 2023). A successful presentation of these virtual characteristics of patients is of crucial importance to guarantee accurate real world conditions when training with VR simulations Gladstone et al. (2000); Harper et al. (2022). In order to ensure comprehensive and customized treatment, the challenge is to reflect the widest possible diversity of ethnicities, ages, genders and other physical characteristics in the virtual agents. The need for inclusive virtual agent design is highlighted by research showing racial disparities in dermatological diagnosis by Artificial Intelligence (AI), such as lower performance in classifying conditions like acne and atopic dermatitis in patients with darker skin tones (Kaur et al., 2023; Schneider et al., 2023) though new techniques are emerging to improve algorithmic diagnosis across diverse populations (Groh et al., 2024).

Although numerous applications, both commercial and non-commercial, already exist for creating virtual agents, there remains a lack of customization for the specific needs of dermatology. The tools used to create virtual agents must be able to adapt precisely to various physical characteristics like skin color, facial features, body hair, general sexual characteristics, as well as any physical limitations of patients. This is especially important for virtual agents used in medical VR training simulations, as accurate representation ensures healthcare professionals are better prepared to treat a diverse patient population Harper et al. (2022). Additionally, ensuring a low technical barrier for entry is particularly desirable, as customization should be accessible even to users without specific prior knowledge.

The authors of this paper are actively involved in the *medical tr.AI.ning* research project (Mergen et al., 2023) which aims at leveraging VR systems to support the education of medical doctors by providing immersive and realistic training environments. Concluding this paper we will summarize how the findings of this paper were applied to medical tr.AI.ning.

2 Cultural sensitivity and ethics in dermatology

Apart from technical aspects, a high degree of cultural sensitivity and ethical aspects must be taken into account when designing virtual agents (Gençoğlu, 2024). Taking this into account and thus preserving cultural identity are therefore of central importance in order to make VR applications appealing and inclusive for doctors and patients. Such ethical aspects should not be underestimated, as this will have a strong impact on long-term acceptance and thus the ultimate success of VR applications in the field of medicine. In the context of dermatology, skin color receives special attention. The Fitzpatrick scale (Fitzpatrick, 1975), named after the American dermatologist Thomas B. Fitzpatrick, is widely used to classify skin color. It is frequently used in dermatology, particularly in the assessment of skin type and the determination of the risk of sun damage. The scale uses the skin's reaction to sunlight and skin pigmentation as a criterion, based on genetic predisposition. It recognises six different skin types: from type I (very light skin, strongly prone to sunburn) to type VI (very dark skin, hardly prone to sunburn). Despite its continued widespread use in dermatological practice, the Fitzpatrick scale has recognised shortcomings and limitations: Since originally being developed solely to assess the skin reaction of people of European descent, it profoundly lacks ethnic diversity by not considering individual reactions to sun exposure of people with non-white skin (Goon et al., 2021). As a result, the use of this scale is limited to patients with white skin. Since no equivalent widely established tool is available for people of color, this leads to inaccurate assessments in diagnostics and thus potentially compromise appropriate treatment and prevention of skin conditions (Okoji et al., 2021). In order to overcome the problems mentioned above, alternative approaches and scales to the Fitzpatrick scale are now increasingly being used in dermatology. These include the ten-point Monk Skin Tone Scale (Monk, 2019) by Dr Ellis Monk, which is used by Google and others to train AI models (Google, 2024), and Taylor Hyperpigmentation Scale an inexpensive method based on representing progressive levels of hyperpigmentation to assess skin color and monitor the improvement of hyperpigmentation following therapy [(Taylor et al., 2005)]. Another example is the Lancer Ethnicity Scale (Lancer, 1998) by Dr Harold Lancer, which is based on the Fitzpatrick scale but includes the patient's ethnicity as an additional criterion for assessing skin type.

It is important to note that no scale is perfect and its application depends on the specific question or context. In dermatological practice, it is therefore advisable not to rely on a single scale, but to use a combination of clinical assessment and patient histories. Other cultural and social aspects have to be included as well: Due to different sun protection practices or aesthetic preferences, the effects of skin diseases can have different consequences depending on the cultural background and social context. Ideally, an individualized assessment of skin type should be carried out, tailored to each patient, with a more comprehensive analysis of individual skin characteristics.

3 Skin diseases and diversity

Although skin diseases are a universally occurring phenomenon, they are characterized by individual variations that can be influenced by genetic, environmental and social factors. This complex relationship requires a differentiated approach to the diagnosis and treatment of skin diseases (Daniel et al., 2009; Shao and Feng, 2022). In the world of VR, a wide range of virtual agents can be used to authentically represent the diversity of skin diseases. This enables an inclusive application that avoids discrimination and ensures that all patients are adequately represented. Some examples of skin diseases with possibly different manifestations depending on body colour (Henderson et al., 2012):

- Skin cancer: Skin cancer often occurs in unusual places in people with darker skin color and has a higher mortality rate (Wesley and Maibach, 2003).
- Pigmented lesions: Pigmented lesions such as nevi (moles) can look different in people with darker skin color than in white people (Halder and Nootheti, 2003).
- Keloid scars: People with darker skin have a higher risk of developing keloid scars (Berman et al., 2017).
- Vitiligo: Vitiligo is an autoimmune disease that leads to pigment loss. This can be particularly visible in people with darker skin and can lead to psychosocial effects (Picardo et al., 2015).
- Post-inflammatory hyperpigmentation: In people with darker skin, inflammation or injury can lead to post-inflammatory hyperpigmentation, for example, after acne treatment (Davis and Callender, 2010).

- Hypopigmentation: Hypopigmentation can be more noticeable in people with a darker skin colour (Kundu and Patterson, 2013).
- Post-inflammatory hypopigmentation: In addition to hyperpigmentation, people with darker skin can also experience post-inflammatory hypopigmentation following inflammation or injury (Dina et al., 2019).
- Psoriasis: It may be more difficult to recognise scaling in people with darker skin color, lesions may be less clearly defined (Alexis et al., 2007).
- Hair disorders: Hair disorders can have different symptoms and present differently in people with darker skin colour (Rodney et al., 2013).
- Hypertrophic scars: People with darker skin color have a higher risk of developing hypertrophic scars, which are characterized by excessive collagen production (Taylor and Koron, 2021).

4 Technical aspects of agent creation in dermatology

The creation and customisation of various agents in dermatological VR presents a technical challenge that entails specific requirements for skin representation and customisation. One of the biggest challenges is the variety of skin characteristics that need to be integrated into the agents. This includes not only different skin colors, but also different skin textures, tones and dermatological anomalies such as skin lesions, scars and pigment changes. Models available in 3D marketplaces and creation tools, which primarily cater to the gaming industry, often reflect the genre's preference for heroic and martial themes. As a result, both male and female models tend to embody a "heroic" aesthetic, which frequently translates into overly sexualized portrayals rooted in sexist ideologies, as well as promoting *whiteness* (Tompkins and Martins, 2022). This standard not only limits the diversity of character representations but also reinforces harmful stereotypes. Addressing this issue requires a deliberate shift towards creating more inclusive and varied character models that accurately represent the spectrum of human diversity. Another aspect that should not be neglected is accessibility. It is therefore crucial that the tools provided, as well as the interfaces for agent creation, are designed in such a way that they can also be easily used by dermatologists without specific knowledge in the areas of modeling, image generation and VR applications in general.

Below we list some popular tools for designing virtual agents, supplemented by information on any shortcomings in the areas of various design options and user-friendliness/usability:

- General 3D Design Software Suites (Blender, Maxon Cinema 4D, Autodesk 3ds Max and Maya): These tools enable the creation of virtual agents across an extensive spectrum of skin colors, reflecting the full diversity of human skin tones. However, crafting these individual designs requires a significant amount of time and a high level of expertise in 3D design. Consequently, it is essential to have an expert continuously available, dedicating their efforts to develop a vast array of virtual agents to fulfill the diverse needs and demands.
- Character Creator (Reallusion): The Character Creator comes from the US software developer Reallusion, currently available in version 4. The tool allows the creation of elaborate 3D characters with extensive options for customizing skin colors, facial features, body shapes and clothing. There is also criticism here due to the lack of individual customisation options, particularly with regard to skin colors, because the skin color and structure of the available models are based on the body scans of only a few human models.
- Daz 3D (Daz Productions Inc.): The Daz 3D tool also offers a variety of character models and customisation options for skin tones, facial features and clothing. Users particularly praise the wide range of options for modeling body shapes that deviate from the average.
- MakeHuman (The MakeHuman Team): MakeHuman is an open source middleware designed for the prototyping of photorealistic humanoids. It is developed by a community of programmers, artists, and academics developed to work primarily with Blender 3D. It allows users to create 3D human models through an interactive interface where various aspects of the model can be adjusted, such as age, gender, body proportions, and facial features. The software is equipped with a wide range of tools for detailing, including skin textures, hairstyles, clothing, and accessories. As an open source and community driven software MakeHuman can address many problems regarding diversity in proprietary software such as Daz3D and Character Creator, but it can only offer limited quality and realism and has less advanced features for skin textures, hair and clothing physics. MakeHuman has asset libraries, but in comparison to Daz3D and Character Creator, it has much less variety of clothing, accessories, hairstyles, and morphs. It also lacks an integrated workflow regarding 3D animation and modeling workflows in professional software other than Blender.
- MetaHuman Creator (Epic Games): MetaHuman Creator is offered by the creators of the Unreal Engine, which is widely used in the 3D graphics sector. In contrast to Character Creator, Daz3D and MakeHuman, where you start with one base model and customize it in further steps, in MetaHuman you start by mixing several characters with all their shapes and properties in a multidimensional scale. After mixing the base meshes you have then furthermore the option to customize certain body and face treats. While blending multiple base meshes is an effective method for creating diverse characters, MetaHuman's proprietary licensing restricts its broader utility and potential for generating greater diversity. MetaHuman is limited to the Unreal Engine and therefore cannot be used for end products outside of the Epic Games ecosystem. The enormous hardware requirements of Epic's tool should also be considered.

To summarize, each of these tools have certain advantages and disadvantages, with MetaHuman and Character Creator standing out for high-fidelity and realism or MakeHuman for open-source accessibility. Following discussions with our diverse consortium of medical doctors, software engineers, and designers, we opted for Character Creator. This decision was influenced by the software's seamless integration with Unity3D and the outstanding realism of its human models, despite its limited diversity options.

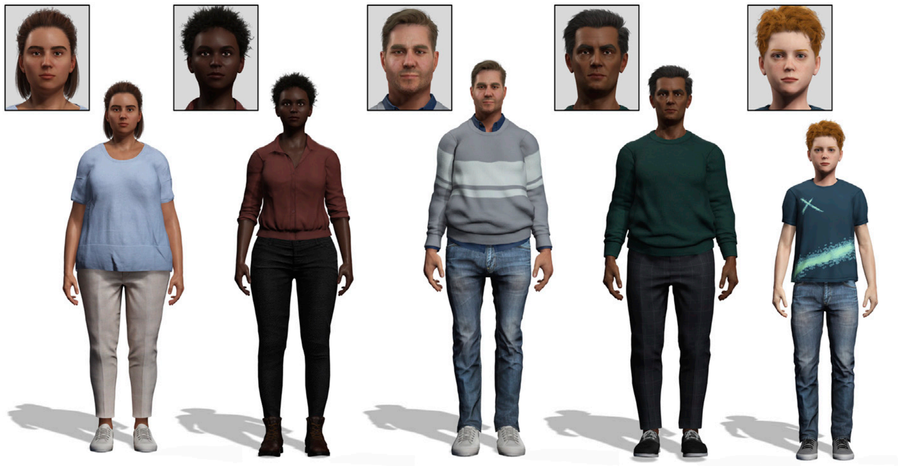

FIGURE 1
Overview of exemplary agents as created for the medical tr.AI.ning project.

5 Agent creation in the medical tr.AI.ning project

VR training has emerged as a powerful tool for developing clinical decision-making skills—a cornerstone of medical education; for an overview, see Mergen et al. (2023). VR simulations are increasingly being leveraged to bridge the gap between theoretical knowledge and practical clinical experience, see Mergen et al. (2024a). Recent findings from the *medical tr.AI.ning* project have demonstrated measurable improvements in medical students' self-reported competence levels following immersive VR training sessions, Mergen et al. (2024b). Incorporating a wide spectrum of patient profiles is essential for VR simulations to efficiently mirror the complexity and variability of real-world clinical scenarios. To develop our virtual agents, we prioritized inclusivity to ensure representation across demographics in Germany. Specifically, for the dermatological examination scenario, we incorporated a greater number of older agents. We then created detailed character sheets that outlined the agents' appearances, including age, gender, height, weight, skin, and hair color, based on precise statistics for accuracy. VR compatibility was crucial, focusing on balancing realism, performance, and engine compatibility to prevent motion sickness. Despite its limited diversity options for age, gender, and skin color, we utilized Reallusion Character Creator for its Unity3D integration and realistic models. Post-export, we manually enhanced textures, particularly adjusting skin textures and adding dermatological features, to ensure a broad and diverse range of virtual patients. This approach was pivotal in creating a sizable and varied patient group for the project. The creation of virtual agents for dermatological VR training involves a structured methodology that begins with conceptualizing the agent's identity and visualizing their characteristics. The selection of skin tones for agents utilized the Fitzpatrick scale, despite its controversies, due to the lack of detailed skin color statistics in Germany. This decision was informed by migration data from Destatis and aimed at a subjective yet random representation of skin tones. The project's conceptualization drew on the 2021 microcensus of Federal Statistical Office (Statistisches Bundesamt, 2024) and the 2020 NAKO Health Study (Peters et al., 2022) for physical metrics, integrating a wide ethnic range to mirror Germany's diversity amidst the absence of skin color data. This approach, coupled with the inclusion of older characters for dermatological scenarios, ensures a diverse and representative virtual patient group. For the concept design, two specific tools are utilized: Facial modeling is achieved through Generated Photos AI by Generated Media Inc., which employs AI-generated techniques, and body modeling is conducted with Body Visualiser from the Max Planck Society's Perceiving Systems Department, which involves manual processes. The concept of each agent is then realized in production of 3D figures. The process for creating virtual agents involves several steps: Familiarizing with the agent's concept and visualizing the character, selecting an appropriate base character from Character Creator, adjusting body and facial features to match desired proportions and unique characteristics, enhancing detail levels for realism, customizing skin and hair including adjustments for age-related features, selecting and modifying clothing, creating or acquiring additional assets not present in the content store, and making final adjustments based on feedback to ensure the agents accurately reflect the intended diversity and characteristics. In this phase of development, Character Creator 4 by Reallusion is used for the creation of the 3D agent, Blender by the Blender Foundation for custom agent assets and modifications (see examples in Figure 1, and Unity3D - HDRP by Unity Technologies serves as the target real-time engine for the project.

6 Discussion

As VR permeates dermatology, comprehensive agent diversity is indispensable for linking virtual and real worlds. Progress requires both technical precision and ethical mindfulness. Advancement on both fronts will realize VR's full potential to enhance dermatological education, research and patient care. Creating diverse virtual agents for dermatology is both a technical challenge and an ethical imperative. Comprehensive diversity is indispensable for gaining acceptance of VR technology and accurately linking virtual representations to real patients. On the technical side, comprehensively modeling the wide range of skin tones, textures, lesions, scars, and other variations requires advanced algorithms and AI, as well as thorough manual selection, creation, and design efforts to ensure accurate and inclusive representations. Accessibility is also crucial - interfaces must enable use by dermatologists regardless of 3D modeling expertise. The medical tr.AI.ning project, still in progress, aims to introduce an "authoring toolbox" for the training simulation. This toolbox will enable trainers to craft scenarios with virtual patients exhibiting not only various dermatological and other medical conditions, but also diverse physiological attributes, notably different skin types.

Open-source software development, like in MakeHuman (The MakeHuman Team), driven by community contributions, can enhance the diversity of virtual characters in terms of ethnicity, gender, and age. The technique of combining multiple base meshes to create unique characters, like in MetaHuman Creator (Epic Games), further aids in this diversity. Equally important are cultural sensitivity and ethics around agent design. Respectful, non-stereotypical representations of diverse populations avoids discrimination and builds trust. Preserving cultural identity ensures VR appeals to both patients and physicians. Considerations around tools like the Fitzpatrick skin typing scale demonstrate the complexities involved. A lack of comprehensive diversity can lead to misdiagnosis, inaccurate treatments, and poor medical outcomes. Capturing the nuances of how skin conditions manifest across populations through inclusive agents is vital for proper patient care. Further research should also explore incorporating age as a factor in virtual agent design, moving beyond just the representation of children. This should address the changes skin undergoes during the aging process, including atrophy, wrinkling, and other age-related variations.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: Destatis, https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bevoelkerung/Migration-Integration/Tabellen/migrationshintergrund-staatsangehoerigkeit-staaten.html and https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Gesundheit/Gesundheitszustand-Relevantes-Verhalten/Tabellen/liste-koerpermasse.html.

Author contributions

MK: Writing - original draft. MS: Conceptualization, Funding acquisition, Supervision, Writing – original draft, Writing - review and editing. MA: Methodology, Writing - review and editing. CS: Methodology, Writing - review and editing. MM: Writing - review and editing.

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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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