Identifying Key Factors to Distinguish Artificial and Human Avatars in the Metaverse: Insights from Software Professionals

Osman Tahsin Berktaş[1], Murat Yılmaz[2], and Paul Clarke[3,4]

[1] Informatics Institute, Gazi University, Ankara, Turkey
osmantahsin.berktas@gazi.edu.tr
[1]Faculty of Engineering, Dept. of Computer Engineering, Gazi University, Ankara, Turkey
my@gazi.edu.tr
[3] School of Computing, Dublin City University, Dublin, Ireland
[4] Lero, the Science Foundation Ireland Research Center for Software
paul.m.clarke@dcu.ie

Abstract. The Metaverse comprises a network of interconnected 3D virtual worlds, poised to become the primary gateway for future online experiences. These experiences hinge upon the use of avatars, participants' virtual counterparts capable of exhibiting human-like non-verbal behaviors, such as gestures, walking, dancing, and social interaction. Discerning between human and artificial avatars becomes crucial as the concept gains prominence. Advances in artificial intelligence have facilitated the creation of virtual human-like entities, underscoring the importance of distinguishing between virtual agents and human characters. This paper investigates the factors differentiating human and virtual participants within the Metaverse environment. A semi-structured interview approach was employed, with data collected from software practitioners (N=10). Our preliminary findings indicate that response speed, adaptability to unforeseen events, and recurring scenarios play significant roles in determining whether an entity in the virtual world is a human or an intelligent agent.

Keywords: Metaverse, Avatars, Artificial Agents, Virtual Characters

1 Introduction

In recent years, the notion of the Metaverse has gained significant attention as an interconnected network of 3D virtual environments, which has the potential to serve as the primary gateway for most real-time experiences in the future. As a collective imaginary shared space, the Metaverse integrates virtual environments, augmented reality, and web-based internet, forging a new, inclusive social network that complements human communities [1].

The Metaverse holds immense potential to transform various aspects of society, revolutionizing how people experience the digital world by redefining the boundaries between physical and virtual realities. This unprecedented shift encompasses areas such as communication, education, entertainment, and work, attracting significant interest from both the software industry and academia [2]. As an immersive digital realm, the Metaverse presents unique opportunities for individuals, businesses, and organizations to interact, collaborate, and engage in a diverse range of activities within a virtual ecosystem. By seamlessly integrating elements from gaming, social media, e-commerce, and other digital platforms, the Metaverse provides a dynamic and interconnected virtual environment that facilitates innovation, creativity, and collaboration across various domains. As the development of the Metaverse accelerates, it becomes increasingly important to address emerging challenges and opportunities, such as maintaining privacy and security, ensuring equitable access, and tackling ethical concerns related to virtual interactions and artificial entities.

As the Metaverse gains prominence, the ability to discern between human and artificial avatars becomes increasingly crucial. Recent advances in artificial intelligence have enabled the creation of highly realistic virtual human-like entities, highlighting the importance of distinguishing between virtual agents and human characters in this evolving landscape. In this context, the growing need to differentiate human participants from virtual agents in the Metaverse is paramount, as it is essential to creating a safe, authentic, and engaging environment for all users. By understanding and addressing the factors that distinguish human users from artificial counterparts, researchers and practitioners can contribute to the responsible and sustainable development of the Metaverse, ultimately shaping its impact on society, culture, and the economy in the digital age.

This paper explores these factors and provides insights into the evolving landscape of the Metaverse, its implications, and its potential impact on society, culture, and the economy in the digital age. The primary research objectives of this paper can be summarized in three two aspects: (i) to identify and differentiate between virtual and human participants in the Metaverse environment to enhance the understanding of their distinct characteristics and behaviors within this immersive digital realm, (ii) to explore comparability and standardization of the assessment of virtual and human participants across various experimental contexts by developing a universally applicable, validated, and reliable questionnaire. The goal is to facilitate consistent and rigorous evaluations of the interactions and dynamics between virtual agents and human users in the Metaverse. Our approach will contribute to a robust and comprehensive understanding of the Metaverse environment and its implications for human and artificial entities, fostering the responsible and sustainable development of this transformative digital space.

The remaining part of the paper proceeds as follows: Section 2 reviews the literature, with Section 3 presenting the methodology employed for this study. Section 4 details the research findings. Ultimately, the final section concludes and suggests directions for further research.

2. Background

By harnessing a variety of advanced technologies, the Metaverse enables multifaceted applications across numerous domains, including technology, organization, individual participation, production, culture, social interaction, entertainment, and economy. In addition, it enables an inventive, inclusive social network that seamlessly interweaves with human communities, facilitating continuous sharing and collaboration. This shared, collective imaginary space melds virtual 3D environments, augmented reality, and blockchain technologies to create an immersive digital realm.

The Metaverse concept comprises five essential components [2]: Network Infrastructure, Cyber-Reality Interface, Data Management and Applications, Authentication System, and Content Generation. The first component, Network Infrastructure, employs high-speed end-to-end connections and IoT technology to facilitate rich content rendering and powerful interactive functionalities, with 5G networks being a core element. The second component, the Cyber-Reality Interface, enables seamless linking and transitioning between virtual and real worlds through reality, smart devices, and human-computer interaction. The third component, Data Management and Applications, leverages cloud technology, big data operations, and edge computing for large-scale data acquisition, analysis, storage, and transmission. The fourth component, the Authentication System, relies on blockchain technology to ensure transparency, stability, and reliability, addressing challenges such as data sovereignty, identity authentication, and value attribution and circulation through biometric solutions. The final component, Content Generation, maps the physical world to cyberspace using digital twins and integrates content with artificial intelligence-driven deep learning and cognitive learning methods for content editing and growth scenarios, fostering a rich, comprehensive, and self-contained digital world (ref. Figure 1).

Metaverse environments might not utilize the same methods employed by other applications, such as games, for content conditioning and preparation. While digital game developers can collaborate closely with content designers and process content through a conditioning pipeline to ensure real-time response speeds, virtual worlds must accommodate arbitrary user-generated content. Moreover, game content is typically delivered to players before the application runs, whereas Metaverse users expect to access and use new 3D models instantly by uploading them to cloud world servers. Imposing strict constraints on unoptimized data in the Metaverse could substantially reduce the availability of content and diminish the system's usability. Users should not be burdened with the complex, technical details of 3D content [3].

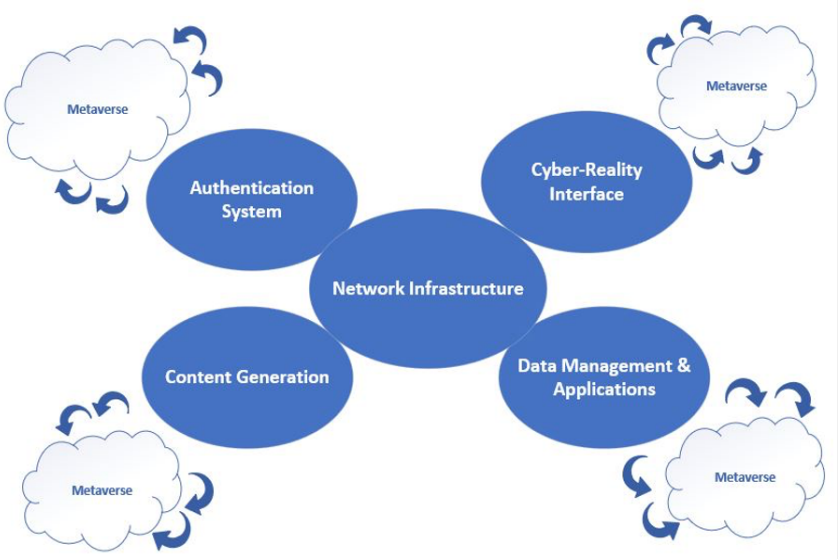

Figure 1: The proposed components of the Metaverse [2].

Mar Gonzales-Franco, a researcher at Microsoft, highlighted some challenges and deficiencies related to the Metaverse during her presentation at the ISMAR 2021 Symposium [4]. These concerns, some of which have been addressed, include:

- Locomotion: How can participants simultaneously navigate both real and virtual environments?
- Technological latency: How can latency or delay issues be resolved?
- Equipment affordability: How will users obtain costly devices?
- Characterization: Should this be achieved through animations or avatars?
- Sound direction: How can sound direction determination issues be addressed, as sound in virtual spaces does not behave like waves in real life?
- Cross-content interaction: How can problems, such as being unable to read emails while working in the virtual environment, be solved?
- Battery life: How can the battery challenges of auxiliary devices be overcome?
- Isolation: How can the potential for isolation from real life be mitigated? User adaptation: How can new technology adoption problems be resolved for users?

Gonzales-Franco [4] indicates that some challenges have been addressed. For instance, wearable devices and cost-effective products have become accessible to users, and adaptation issues are gradually being overcome thanks to investments in the sector. Moreover, the Metaverse has evolved into a social environment with its ecosystem.

As the concept garners increasing attention, it becomes crucial to differentiate between human and artificial avatars to ensure an authentic and immersive experience. This is particularly important because the Metaverse experience relies on avatars that can move freely in a virtual world, exhibiting human-like non-verbal behaviors such as walking, dancing, and interacting with others. Another problem mitigated is the characterization issue, where avatars are created using animated images of real people instead of generic animations.

Human or artificial avatars are defined as avatars that are co-located with the user's body and viewed from the user's perspective within an immersive virtual environment [5]. There is growing scientific evidence highlighting the significance of artificial humans in self-avatars. Apart from the apparent necessity of having a virtual representation to interact with others in social VR settings, artificial humans have been shown to enhance users' cognitive abilities [6] and improve self-recognition and identification in virtual meetings [7]. Nonetheless, the cognitive load impacts of avatars remain poorly understood and may influence outcomes [8,9]. Lush [10] has expressed concerns that the illusion of presence in a virtual environment could be a response to imaginative suggestion, suggesting that the power of suggestion itself may drive it.

A standardized measurement for differentiating characters is essential for comparing and replicating experiments across the field of character differentiation. Participants are unique and can have significantly different experiences and responses within the same virtual setup. For instance, avatars have been shown to affect distance prediction [11, 12] and object size estimation [13,14], which may further influence distance perception [15]. A standardized differentiation questionnaire sensitive enough to detect character differences could assist researchers in better understanding and interpreting the effects of artificial humans. In every experiment, research using questionnaires should measure differentiation to account for and comprehend intrinsic variables that might impact results. Differentiating characters presents challenges, given that virtual bodies can take any form. Recent advances in artificial intelligence have made it possible to create virtual human-like entities, further emphasizing the need to distinguish between virtual agents and human characters.

3 Methodology

The semi-structured interview is a widely used research method in qualitative data analysis. It combines elements of structured and unstructured interviews, offering advantages of each approach. While a structured interview features a strict set of questions without room for deviation, an unstructured interview is informal and free-flowing, resembling a casual conversation. A semi-structured interview falls between these two extremes, with loosely structured questions that give respondents more opportunity to express themselves fully.

In a semi-structured interview, the interviewer generally explores a particular theme but remains open to different perspectives and allows for the emergence of new ideas based on the respondent's input. This approach provides benefits for both interviewers

and respondents. For interviewers, the structured aspect offers a general overview of respondents, enabling objective comparisons that are valuable for qualitative research or job interviews. For respondents, the unstructured part affords more freedom to express thoughts, typically reducing stress during the interview.

By fostering a warm and friendly atmosphere, the interviewer can demonstrate better communication skills and establish a personal connection with the respondent. The data collected during the semi-structured interview undergo content and thematic analysis, with coding and categorization applied to the data. In this study, participants were chosen from individuals with a minimum of 5 years of experience in software development. These individuals were selected from those who presented as valuable contributors to our research, based on demonstrable experience and interest in the study domain. Table 1 below presents information on why these individuals were chosen.

Table 1. Participant Profiles.

ID	Role	Experience	Education
INT. 1	Software Team Leader	13 years	B.Sc.
INT. 2	Software Team Leader	20 years	B.Sc.
INT. 3	Software Developer	5 years	M.Sc.
INT. 4	Software Team Leader	10 years	Ph.D. Candidate
INT. 5	Scientific Researcher	10 years	Ph.D. Candidate
INT. 6	Software Developer	5 years	M.Sc.
INT. 7	Software Team Manager	12 years	Ph.D.
INT. 8	Assistant Professor	12 years	Ph.D.
INT. 9	Assistant Professor	12 years	Ph.D.
INT. 10	Software Team Leader	15 years	B.Sc.

The semi-structured interview process with participants comprises two stages. In the first stage, face-to-face interviews differentiate between virtual and real human characters in the Metaverse environment across five topics. In the second stage, participants are asked to evaluate the research study, separate from the study's subject matter. This approach allows for an examination of the study's method and content to identify potential areas for improvement.

To achieve the stated objectives, this study employed the grounded theory method [20], a frequently used approach across various disciplines for many years. The method offers flexible research and analysis capabilities, particularly in addressing people's problems. By collecting data from individuals and supplementing it with literature sources, the grounded theory method can contribute to solutions such as overcoming difficulties, managing risks, and improving working life in diverse research fields, ranging from manufacturing [21][22] to agriculture [23], from software development [24][25] to educational institutions [26]. The method's applicability in resolving problems in the research area is evident from the overview of recent studies in the literature. Grounded theory is also referred to as an embedded theory method in some sources. In summary,

this four-step method involves data collection, qualitative data analysis with coding, classification and grouping of coded or tagged information, and finally, developing a theoretical conclusion based on the research objectives.

Figure 2 provides a visual representation of the grounded theory steps. The diagram demonstrates the process, starting from data collection, followed by qualitative data analysis and coding. Next, the coded or tagged information is classified and grouped. Finally, the grouped data is organized under the research objectives, leading to a theoretical conclusion. This illustration serves as a guide to understanding the systematic approach taken in the grounded theory method.

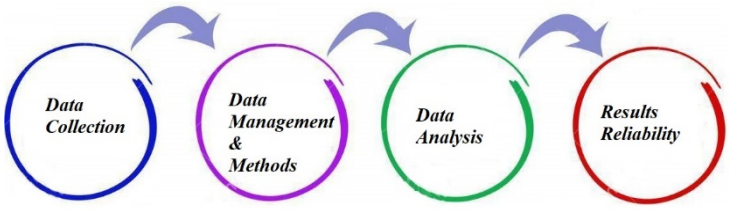

Figure 2: Grounded Theory Research Steps

To achieve these objectives, we administered 5-item questionnaires and collected data from software practitioners (N=10). Additionally, a semi-structured interview was conducted based on the answers obtained. In the following stage, the validity of the questionnaires was re-assessed by the software practitioners, providing a starting point for future correlation analyses and pilot studies, such as personality type analysis studies [17].

This paper analyzed the responses from ten software practitioners involved in software development projects. Our research study utilized a semi-structured interview and grounded theory method, incorporating semi-structured interview data as input. The first step involved conducting semi-structured interviews with ten software practitioners. The semi-structured interview is a data collection method that combines questionnaires and interviews. The 5-item questionnaire was structured around a predetermined thematic framework, with the questions presented in a non-linear order.

Figure 3 depicts the exploratory research process for differentiating artificial and natural human characters in the Metaverse. The first stage of this process was carried out in the current study

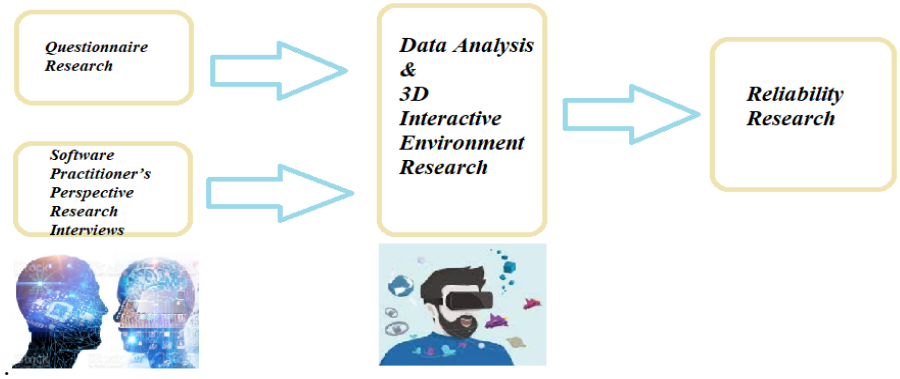

Figure 3: Research Steps for Differentiating Artificial and Human Characters in Metaverse

Our research questions were derived from the five evaluation criteria presented in Table 2. The first criterion focuses on human similarity questions, which aim to understand the parallels between a real person and an artificial intelligence character. The second evaluation criterion examines decision-making situations by preparing questions regarding the quality of responses from the characters. The third criterion is related to production and investigates the success of virtual characters when confronted with actions or verbal expressions directed towards them. Our fourth evaluation topic concerns operation, addressing questions about how characters are perceived in areas such as management, reproduction, and maintenance. Lastly, we asked questions about general evaluation scores and potential performance assessments. While formulating these questions, the criteria from Man-Je Kim's were also utilized [18].

Table 2. Questionnaire being gathered via software practitioners.

Evaluation Criteria	Criteria Description	# Of Questions
Human Likeness	Similarities	1
Decision Making	Quality of Response	1
Production	Unit Production per Response or Successfulness	1
Operation	Management, Creation, Maintenance	1
Performance	Overall Evaluation of Scores	1

This paper aims to validate and enhance the proposed questionnaire by incorporating a new one with additional analyses for three studies. We utilized the questions mentioned in Yiqian Han's publication [19]:

Q1: Would you recommend this work to others? A higher score indicates a greater willingness to recommend.

Q2: Do you believe the questionnaire requires improvement? A high score signifies that no improvement is needed.

Q3: Were you able to express your thoughts naturally? The higher the score, the more natural the expression.

Q4: Did any questions make you feel uncomfortable during the questionnaire? A high score implies discomfort.

Q5: Were you satisfied with the work? A high score denotes satisfaction.

Q6: Do you find this interactive technology comfortable to use? A high score suggests comfort.

4 Findings

In this publication, we studied five main headings to differentiate between artificial and real human characters in the Metaverse environment. The study was carried out in two stages using semi-structured interviews.

In stage 1, we gathered brief information on Human Likeness, Decision Making, Production, Operation, and Evaluation to inform the participants about the general framework of our research. We believed that prior knowledge of the Metaverse concept, a relatively new field, would benefit the participants.

In stage 2, we conducted face-to-face interviews with the participants. During these conversations, we revisited the questions from stage 1 and encouraged the participants to expand on their answers, facilitated by a card sort exercise. We had the audio recordings from stage 2 transcribed into text by expert individuals to capture the nuances of everyday speech. The collected data can be accessed from a shared source in the field, ensuring transparency and collaboration.

By conducting a systematic and consistent study of our data, we aimed to contribute valuable insights to the understanding and differentiating artificial and real human characters within the Metaverse environment.

Since the participants' identities are confidential, they will be referred to as ”participants”.

- In Interview 1, the participant mentioned that the most critical factor is the details in physical appearance. He thinks that differentiating factors can be obtained by examining demographic characteristics. The diversity of the avatar's reactions is important, and he stated that improvised words and behaviours might also be used. He evaluated that the richness of the reactions would also be the second distinguishing factor. According to the participant, **the algorithm pattern of the computer-aided machines is easy to understand**. He can distinguish that he is not a natural human by continuing on the same order. In addition, the pattern of responses in sick or disabled people changes dramatically. Another consideration is that continuity problems, which are very difficult for humans, can be easily solved by machines. Performance measurement systems have difficulty updating with time so a realistic measurement system will give different results after a while. Finally, it will be helpful to

examine the emotional state (EQ) as well as the intelligence-related (IQ) in human-human interaction.

- In Interview 2, the participant stated that artificial intelligence is at a prospering level regarding human similarity. It would not be a successful method to detect it with visual features. He also said that it would not be possible to differentiate artificial intelligence by following the logic sequence. He stated that he thought **a well-trained artificial character could imitate a natural person very well**. He emphasized that **smelling, one of human's five senses, is not in the digital environment**. In addition, he stated that **products belonging to the sense of touch are just beginning to appear in the market**. An artificial character can describe his recorded life. If he hasn't recorded it, he can't tell shared knowledge. Finally, he stated that computers would respond very quickly to some problems.
- According to the Interview 3 participant, gestures and facial expressions of the characters can be distinguishing factors. However, growing scientific studies will make it increasingly difficult to use those factors. He said virtual humans would have difficulty in edge and counter cases or when I asked him to tell a memory. He evaluated that differentiating can be done quickly in edge and corner cases. However, he mentioned that he had to spend time with the participant to use these factors. While distinguishing virtual and real human characters, we can divide our observation into passive and interactive methods. While performing interaction analysis, asking mathematical or logical questions increases the observation efficiency with a multi-dimensional perspective. In addition, in order not to give away the participant, the chosen balance points are invaluable. Using identified characters will solve the problems from a different perspective. But this method will reduce the reality somewhat. Inter-participant levelling or character classification may be beneficial instead of free-for-all environments. He recommends **using more than one method in the evaluation**.
- Observation can be made by calculating the mean and standard deviation of the natural human population and the mean and standard deviation of virtual human characters according to the Interview 4 participant. The life status of the observed character can be distinguished by using population references. Physical movements and reactions can be valuable distinguishing factors more than physical appearance. The interviewer suggests that physical movements and reactions can be used as distinguishing factors rather than the appearance of the characters. He suggested that **data per unit time can be used as a differentiating factor for successful responses or responses in decision-making processes**.
- According to the Interview 5 participant, a character's facial expressions and body movements create a perception in a Metaverse environment. Hand and arm motions, body movements or **laughing in response to a joke may be a useful indicator**. In addition, I think the principle of impartiality of measurement systems is essential. Finally, genuine responses, such as improvisation, would be used as distinguished data. She suggests that it would be logical to use body movements, mimics and facial expressions, which are called nonverbal communication, as differentiating factors. She suggests **that emotional observation, as well as logical evaluation, will be useful in decision-making processes**.

- Interview 6 participant stated that he does not consider it possible to use physical movements as a distinguishing factor. It is not possible to distinguish it from daily activities such as walking, running, sitting, and getting up. Monitoring of managerial decisions can result in a distinction. It would be helpful to introduce a systematic approach with regular time intervals to make the distinction. He stated that **the responses given as a result of the interaction could be used in differentiation**. He stated that responding in a short time could be done more easily by characters under computer control. He suggested that there can be a systematic measurement system with the resources used, the outputs produced, the decisions made, and the conclusions reached.
- According to the Interview 7 participant, patterns can be drawn from movement or other qualities. A real human appearance can be easily simulated by using recorded patterns. He stated that it would not be efficient to use visual factors as distinguishing factors since they are features that can be easily imitated today. In addition, a natural person will have daily needs. **Uninterrupted connection to the system for a long time can be the distinguishing factor**. Finally, different methods should be used according to the scenario. Purpose and scope are essential. **Applying more than one method at the same time will give more efficient results**. He also stated that repetitive actions on a specific task could be used as a differentiating factor.
- In response to the questions, Interview 8 participant said that personality analysis would yield effective results. He evaluated that **sentiment analysis could yield effective results**. In addition to quantitative data, more accurate results can be drawn with qualitative data.
- According to Interview 9 participant, **novel products or intellectual activities will be distinguished**. Computer-controlled characters will average scores better than natural human characters at computational tasks. He has evaluated that it is not easy to make concrete measurements but that observing interactive situations can yield successful results.
- Interview 10 participant evaluated the **character's reactions as distinguishing factors**. If the response time is too short, it can be defined as an artificial human. In addition, solutions using more than one method will be effective. Continuity can be a distinguishing feature. Non-interactive passive methods will be a problem because the word and movement analysis will not be enough. Finally, he evaluated that focusing on success in research would be misleading since people in the Metaverse environment will not have a goal of being successful. He suggested that machine management can be detected by observing cyclical movements and behaviors. **It has been stated that it is not easy for artificial intelligence to terminate the interaction**. It was stated that extending the observation over time would be useful.

The results from this study suggest that factors of response speed, improvised events, and loop scenarios have significant implications for understanding how we can differentiate humans from intelligent agents in a virtual setting. The participants provided supportive and positive answers in the questionnaire, expressing satisfaction, willingness, and answers in their unique way.

The contribution of our study is summarized as follows: As a result of our semi-structured interview study, three main factors emerged as the distinguishing factors between humans and intelligent agents in the Metaverse - response speed, improvised responses, and loop scenarios. These factors help in establishing a better understanding of how to differentiate between human and artificial characters in virtual environments, contributing to the ongoing research in this area. This knowledge can further improve user experience and interaction within the Metaverse and other virtual settings.

5 Conclusion and Future Work

In this study, we investigated the differentiation of virtual and human characters in a Metaverse environment. Our research utilized a semi-structured interview method with experienced software practitioners. The study identified three main factors that differentiate virtual and human characters: response speed, improvisation, and composite work in a loop scenario. These factors are crucial in determining the behavior of a character and differentiating it from an artificial intelligence algorithm. Our findings suggest that emotional and logical approaches are more effective than physical features in distinguishing between virtual and human characters. Additionally, distance and size measurement can be used as a differentiating factor.

Overall, this study contributes to the ongoing research on artificial and human characters in virtual environments. The findings provide valuable insights into the cognitive load impacts of avatars and suggest that a standardized measurement of differentiation is necessary for accurate and replicable results in future studies. Our study also highlights the importance of examining emotional and logical factors in addition to physical features to distinguish between virtual and human characters. With the pace of AI advance appearing to increase recently, for example with chatGPT [28], it may be the case that the challenge of identifying human and AI agents in the metaverse might become even more difficult in the near future. The need for further research in this space is therefore growing.

Further studies can build upon our findings by utilizing the data obtained from this research and repeating the same study with a larger sample size to increase the generalizability of the results. Ultimately, continued research in this field will contribute to the development of more advanced and realistic virtual environments with enhanced human-like interactions.

Acknowledgement. This research is supported in part by SFI, Science Foundation Ireland (https://www.sfi.ie/) grant No SFI 13/RC/2094 P2 to–Lero - the Science Foundation Ireland Research Centre for Software.

References

1. A. B. Raij et al., "Comparing Interpersonal Interactions with a Virtual Human to Those with a Real Human," in IEEE Transactions on Visualization and Computer Graphics, vol. 13, no. 3, pp. 443-457, May-June 2007, doi: 10.1109/TVCG.2007.1030
2. D. Wang, X. Yan and Y. Zhou, "Research on Metaverse: Concept, development and standard system," in 2021 2nd International Conference on Electronics, Communications and Information Technology (CECIT), Sanya, China, 2021 pp. 983-991.
3. J. Terrace, E. Cheslack-Postava, P. Levis ve MJ Freedman, "Unsupervised Conversion of 3D Models for Interactive Metaverses", 2012 IEEE International Conference on Multimedia and Expo, 2012, s. 902-907, doi: 10.1109/ICME.2012.186.
4. M. Gonzales-Franco, "Keynote Speaker: Metaverse from Fiction to Reality and the Research Behind It," 2021 IEEE International Symposium on Mixed and Augmented Reality (ISMAR), 2021, pp. 17-17, doi: 10.1109/ISMAR52148.2021.00011
5. Kilteni, K., Groten, R., and Slater, M. (2012). The sense of embodiment in virtual reality. Presence Teleoperators Virtual Environ. 21, 373–387. doi:10.1162/PRES_a_00124
6. Steed, A., Pan, Y., Zisch, F., and Steptoe, W. (2016). "The impact of a self-avatar on cognitive load in immersive virtual reality," in 2016 IEEE virtual reality (VR), Greenville, SC, March 19–23, 2016 (Piscataway, NJ: IEEE), 67–76.
7. Gonzalez-Franco, M., Steed, A., Hoogendyk, S., and Ofek, E. (2020b). Using facial animation to increase the enfacement illusion and avatar self-identification. IEEE Trans. Visual. Comput. Graph. 26, 2023–2029.
8. Peck, T. C., Doan, M., Bourne, K. A., and Good, J. J. (2018). The effect of gender body-swap illusions on working memory and stereotype threat. IEEE Trans. Visual. Comput. Graph 24, 1604–1612.
9. Peck, T. C., and Tutar, A. (2020). The impact of a self-avatar, hand collocation, and hand proximity on embodiment and stroop interference. IEEE Trans. Visual. Comput. Graph 26, 1964–1971.
10. Lush, P., Vazire, S., and Holcombe, A. (2020). Demand characteristics confound the rubber hand illusion. Collabra: Psychology 6, 83.
11. Ries, B., Interrante, V., Kaeding, M., and Anderson, L. (2008). "The effect of self-embodiment on distance perception in immersive virtual environments," in Proceedings of the 2008 ACM symposium on Virtual reality software and technology, New York; NY, United States, October 27, 2008 (New York; NY: Association for Computing Machinery), 167–170.
12. Ebrahimi, E., Hartman, L. S., Robb, A., Pagano, C. C., and Babu, S. V. (2018). "Investigating the effects of anthropomorphic fidelity of self-avatars on near field depth perception in immersive virtual environments," in 2018 IEEE Conference on Virtual Reality and 3D user interfaces (VR), Reutlingen, Germany, March 18, 2018 (Piscataway, NJ: IEEE), 1–8.
13. Jung, S., Bruder, G., Wisniewski, P. J., Sandor, C., and Hughes, C. E. (2018). "Over my hand: using a personalized hand in VR to improve object size estimation, body ownership, and presence," in Proceedings of the Symposium on spatial user interaction, Berlin, Germany, October 13–14, 2018 (New York; NY: Association for Computing Machinery), 60–68.
14. Ogawa, N., Narumi, T., and Hirose, M. (2019). "Virtual hand realism affects object size perception in body-based scaling," in 2019 IEEE Conference on Virtual Reality and 3D user interfaces (VR), Osaka, Japan, March 23–27, 2019 (Piscataway, NJ: IEEE), 519–528
15. Gonzalez-Franco, M., Abtahi, P., and Steed, A. (2019). "Individual differences in embodied distance estimation in virtual reality," in 2019 IEEE conference on virtual reality and 3D user interfaces (VR), Osaka, Japan, March 23–27, 2019 (Piscataway, NJ: IEEE), 941–943.

16. Yilmaz, Murat & O'Connor, Rory & Clarke, Paul. (2014). An Exploration of Individual Personality Types in Software Development. Communications in Computer and Information Science. 425. 10.1007/978-3-662-43896-1_10.
17. Yilmaz, Murat & O'Connor, Rory. (2013). Yazilim gelistiren organizasyonlar için düsünülmüs bir kisilik tipi ölçüm oyunu. CEUR Workshop Proceedings. 1072.
18. M. Kim, K. Kim, S. Kim, and A. K. Dey, "Performance Evaluation Gaps in a Real-Time Strategy Game Between Human and Artificial Intelligence Players," in IEEE Access, vol. 6, pp. 13575-13586, 2018, doi: 10.1109/ACCESS.2018.2800016.
19. Y. Han and S. Oh, "Investigation and Research on the Negotiation Space of Mental and Mental Illness Based on Metaverse," 2021 International Conference on Information and Communication Technology Convergence (ICTC), 2021, pp. 673-677, doi: 10.1109/ICTC52510.2021.9621118.
20. B. G. Glaser, A. L. Strauss, "The Discovery of Grounded Theory: Strategies for Qualitative Research", Chicago: Adline Publishing Company, 1967.
21. Y. Liu, S. Wu, "Quality Culture Management Model of Chinese Manufacturing Enterprises: A Grounded Theory Study," 2018 UKSim-AMSS 20th International Conference on Computer Modelling and Simulation (UKSim), 2018, pp. 102-107, doi: 10.1109/UKSim.2018.00030
22. J. Deng, S. Wu, Y. Liu, "Investigating the TQM Practice of Enterprises Winning China Quality Award: A Grounded Theory Perspective," 2017 European Modelling Symposium (EMS), 2017, pp. 115-120, doi: 10.1109/EMS.2017.30
23. X. Zhang, "A Framework of Value Connection Route for Fresh Agri-product E-commerce: A Grounded Theory Approach in the Context of China," 2021 2nd International Conference on Big Data Economy and Information Management (BDEIM), 2021, pp. 500-508, doi: 10.1109/BDEIM55082.2021.00109.
24. D. Ståhl, T. Mårtensson, "Won't Somebody Please Think of the Tests? A Grounded Theory Approach to Industry Challenges in Continuous Practices," 2021 47th Euromicro Conference on Software Engineering and Advanced Applications (SEAA), 2021, pp. 70-77, doi: 10.1109/SEAA53835.2021.00018.
25. Lili Yu, Xin Xu, Chao Liu, Bing Sheng, "Using grounded theory to understand testing engineers' soft skills of third-party software testing centers," 2012 IEEE International Conference on Computer Science and Automation Engineering, 2012, pp. 403-406, doi: 10.1109/ICSESS.2012.6269490.
26. C. Pang, A. Hindle, D. Barbosa, "Understanding DevOps Education with Grounded Theory," 2020 IEEE/ACM 42nd International Conference on Software Engineering: Software Engineering Education and Training (ICSE-SEET), 2020, pp. 107-118
27. Lee, L. H., Braud, T., Zhou, P., Wang, L., Xu, D., Lin, Z., Hui, P. 2021. "All one needs to know about metaverse: A complete survey on technological singularity, virtual ecosystem, and research agenda", arXiv preprint, arXiv:2110.05352
28. Zhai, X., 2023. ChatGPT for next generation science learning. XRDS: Crossroads, The ACM Magazine for Students, 29(3), pp.42-46.