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From Robot to Virtual Doppelganger: Impact of Avatar Visual Fidelity and Self-esteem on Perceived Attractiveness

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ABSTRACT

This paper presents the first study of a series of experiments aiming to investigate the impact of avatar visual fidelity on user experience with emphasis on the sense of embodiment in immersive virtual environments (IVE). This first experiment requires participants to evaluate three characters with several levels of visual fidelity: a robot, a suit and a virtual doppelganger. Statistical analyses were performed to assess the impact of truthfulness (degree of similarity between users and avatars) and self-esteem on perceived avatars' attractiveness. Our results demonstrate the positive impact of truthfulness on the evaluation of attractiveness and suggest a correlation between self-esteem and avatar selection.

CCS CONCEPTS

• Human-centered computing → Virtual reality;

KEYWORDS

virtual reality, embodiment, avatar, doppelganger, self-esteem, attractiveness

1 INTRODUCTION AND RELATED WORK

User experience in immersive virtual environment (IVE) has been the subject of numerous investigations aiming to determine hardware and software properties of a virtual reality system allowing to immerse users [5]. In this context, we present herein the results



Figure 1: Illustration of three raw bust models (50K polygons) and their optimized versions (2.5K polygons) integrated in the virtual reality application

from the first study of a series of experiments addressing the impact of avatar visual fidelity [11] on the sense of embodiment [7, 10] and its behavioral implications induced by the Proteus effect [9, 19]. Previous work classifies visual fidelity according to the following three criteria:

- Anthropomorphism (*non-humanoid* ↔ *humanoid*): Morphological characteristics of the virtual character.
- Realism (*few detailed* ↔ *photorealistic*): level of detail of the mesh and textures of the 3D model.
- Truthfulness (*does not look like the user* ↔ *looks like the user*): degree of similarity between the user and the virtual character [2].

In this theoretical framework, the purpose of our study is to immerse the user in front of three virtual characters with several levels of truthfulness while keeping a constant level of anthropomorphism (humanoid body schema [3]) and realism. The degree of similarity with the user is therefore used as a variable in order to observe and evaluate the subjective impact of truthfulness on perceived avatars' attractiveness [6, 20]. At the end of our series of experiments, the first one being introduced here, we will be able to analyze the potential benefits of observing and controlling our 3D reconstructed virtual self-representation (Figure 1) [4, 8]. Previous work demonstrates that facing a virtual doppelganger (virtual

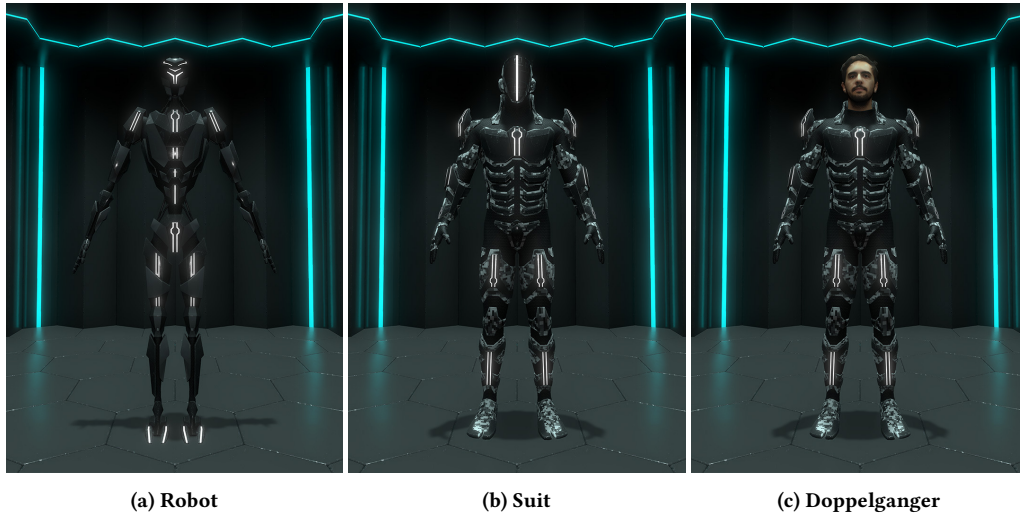


Figure 2: Screenshots of the three avatars presented to the participants in the virtual environment

version of the self) in immersive environments can impact users' behavior [1], but few studies have investigated the impact of real-time control (visuomotor synchrony) of one's own representation, especially in terms of embodiment.

In this context, realism and truthfulness levels induced by the 3D reconstruction of the users entails taking into account the Uncanny Valley phenomenon [14]. Indeed, the similarity and the high level of realism can potentially induce revulsion responses toward the 3D models if the participants observe inconsistencies on their virtual self-representation [13, 17].

Recent work highlights the effect of self-esteem on reactions and emotions aroused when facing 3D reconstructed doppelgangers [15]. Such additional psychological factors may affect user experience. Thus, particular effort was made in the present study to take into account subjects' self-esteem and its possible impact on the evaluation of avatars' attractiveness.

2 MATERIAL AND METHODS

In this experiment, users are immersed in front of three avatars with several levels of visual fidelity in a virtual environment. At the end of the session, the participants evaluate the attractiveness of each avatar and choose which one they would like to use for a subsequent experiment. These results are then compared with their self-esteem scores.

The visual fidelity of the avatars integrated in the application is categorized into three levels of truthfulness as follows (Figure 2):

- Robot (Figure 2a): the anthropomorphism level of the robot allows users to project their body schema to control it. However, its morphology does not allow them to imagine that they can be physically located "inside" the character as some parts of the robot (neck, abdomen, etc.) are designed not to match human size.

- Suit (Figure 2b): the suit is morphologically congruent with human size, potentially allowing users to imagine a projection of their body inside of it.
- Doppelganger (Figure 2c): the doppelganger is also scaled to human size, but unlike the suit it integrates the 3D reconstruction of the participant's head.

It should be noted that the size of the avatars is calibrated to match the size of the users when launching the application.

2.1 VR application

The application used for the experiment was developed using the real-time 3D engine Unity. The proposed environment draws its inspiration from the science fiction universe (Figure 2). This universe anchors the avatars, especially the robot, in a coherent whole providing some plausibility to the depicted scene. The avatars are located in transparent stasis boxes within the immersive virtual environment.

2.2 Apparatus

The participants' busts were scanned with a Structure Sensor. The HTC Vive virtual reality headset is used to display the virtual environment with a resolution of 2160 x 1200 pixels (1080 x 1200 pixels per eye), a field of view of 110° and a refresh rate of 90 Hz. The computer running the application is composed of an Intel Core i7-6700HQ @ 2.60 GHz processor and a Nvidia GeForce GTX 1070 graphics card.

2.3 Participants

34 male participants, aged from 21 to 42 ($M = 23.79$, $SD = 3.80$), were recruited for our experiment. Each subject has a correct or corrected vision thanks to vision glasses allowing them to use the VR headset. All the participants have used an immersive virtual reality system at least once and are experienced with video games involving the control of avatars (role playing games, first and third person shooter, platformer, etc.).

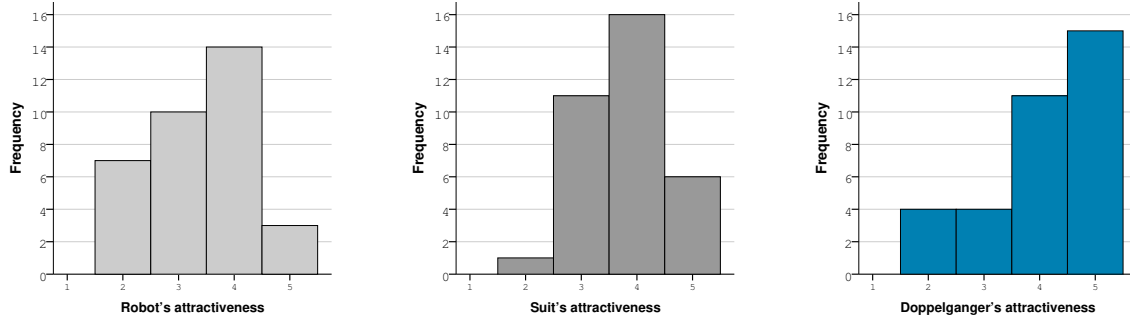


Figure 3: Distribution of the avatars' attractiveness scores

2.4 Procedure and Measures

Before the experiment, the subjects were invited to participate in a 3D scan session and to complete the Rosenberg self-esteem scale (cumulated score ranging from 10 to 40) [16, 18]. The participants' 3D models were then optimized to be integrated in the application dedicated to the experiment (Figure 1). Each subject was invited, a few days later, to participate in the experiment.

Once equipped with the virtual reality headset, the participants are immersed in the application for a period of time that is left to their discretion (between 3 and 10 minutes) to observe the three avatars freely. At the end of the experiment, participants complete a questionnaire to assess the attractiveness of each avatar using a five-point semantic scale based on the work of Zell et al. [20]. They also have to choose the avatar they would prefer to use for the next experiment, which will involve direct control of the character via a real-time motion capture system.

2.5 Hypotheses

H1: The truthfulness of the avatars' model has a positive impact on their attractiveness level.

H2: Participants with high self-esteem will mostly choose their virtual doppelganger, while participants with lower self-esteem will prefer a more abstract representation.

3 RESULTS

The Shapiro-Wilk Test was carried out to check the normality of the distributions of the answers to the post experiment questionnaire. As the variables did not follow a normal distribution ($p < 0.05$ for all tested variables), we chose non-parametric tests to compare avatars' attractiveness and self-esteem scores; results are considered significant when $p < 0.05$. Bonferroni's correction was used to adjust alpha value for post-hoc pairwise comparisons.

Self-esteem scores, measured prior to the experiment, range from 19 to 40 ($\bar{x} = 31.09$, $\sigma = 4.808$). The higher the score, the better the self-esteem. The table 1 presents a summary of descriptive statistics concerning the evaluation of avatars' attractiveness levels (Figure 3) and their selection frequency.

The results of the Friedman Test indicated that there was a statistically significant difference in attractiveness scores between the three truthfulness conditions (robot, suit and doppelganger),

$\chi^2(2, N = 34) = 11.372$, $p = 0.003$. The doppelganger condition recorded the same median score as the suit condition ($Md = 4$) and a higher one than the robot group ($Md = 3.5$). These results demonstrate that truthfulness can impact the evaluation of avatars' attractiveness, providing some evidence concerning the validity of our first hypothesis.

Post-hoc Wilcoxon Signed Ranks Tests revealed a significant difference in the avatars' attractiveness scores between the robot condition ($Md = 3.5$) and the doppelganger one ($Md = 4$), $Z = 2.453$, $p = 0.014$. Furthermore, a strong trend is observed between the groups who chose the robot and the suit $Z = 2.197$, $p = 0.028$. However, this result cannot be considered statistically significant due to the Bonferroni's correction applied to the alpha level for post-hoc tests.

A Kruskal-Wallis Test revealed a significant difference of the self-esteem scores between the groups of participants who chose a different avatar (Robot: $N = 3$, Suit: $N = 12$, Doppelganger: $N = 19$), $\chi^2(2, N = 34) = 6.734$, $p = 0.034$. The doppelganger group recorded the same median score as the suit group ($Md = 32$) and a higher one than the robot group ($Md = 25$). Therefore, the second hypothesis (H2) seems valid.

Post-hoc Mann-Whitney U Tests revealed a significant difference in the self-esteem levels between the participants who chose the robot ($Md = 25$) and those who chose the doppelganger ($Md = 32$), $U = 1.5$, $Z = 2.59$, $p = 0.01$. Furthermore, a trend is observed between

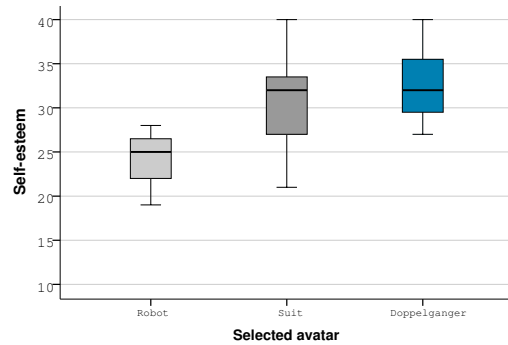


Figure 4: Boxplot of the participants' self-esteem scores regarding their selected avatar

Table 1: Statistical descriptive summary of the avatars’ attractiveness scores and of their selection frequency

| Avatar | Attractiveness | Frequency |
|--------------|---------------------------------------|-----------|
| Robot | $\bar{x} = 3.38$ ($\sigma = 0.922$) | 3 (9%) |
| Suit | $\bar{x} = 3.79$ ($\sigma = 0.770$) | 12 (35%) |
| Doppelganger | $\bar{x} = 4.09$ ($\sigma = 1.026$) | 19 (56%) |

the groups who chose the robot and the suit $U = 5$, $Z = 1.892$, $p = 0.59$. Further experiments involving a larger panel could probably confirm this trend.

4 DISCUSSION

Previous work addressing issues related to 3D reconstruction has demonstrated the impact of avatar stylization [20], or even behavioral implications induced by the observation of virtual doppelganger [1]. In this context, our research contributes to understanding the impact of avatar visual fidelity and self-esteem on perceived attractiveness. It is interesting to note that some participants noticed the progressive evolution of the truthfulness level of the avatars:

"I noticed that the three characters were becoming more and more similar to my physical appearance. Size for the first one, shape for the second and the exact 3D image of my head for the last."

The results of our experiment reveal the positive impact of truthfulness on the evaluation of avatars’ attractiveness. This demonstrates the validity of our first hypothesis. Indeed, the impact of visual fidelity is significant when there is an important truthfulness gap between the 3D models. Thus, the avatars resulting from the 3D reconstruction of the participants have recorded higher attractiveness scores compared to more abstract representations such as the robot one (Figure: 3). Furthermore, 56% of the participants report preferring their doppelganger for the next phase of the experiment involving real-time control of the avatar via a motion capture system:

"I would really feel like being in the game. Usually I take a lot of time to build a character that looks like me, so if I have one that looks exactly like me, I'll choose this one."

"It's pleasant to have your own avatar, to feel like a "hero"."

"I would choose my own representation because it is a unique avatar. The robot and the suit don't really have an identity, they are anonymous, everyone can play these characters."

However, some participants formulated interesting remarks in favor of the avatars with a lower level of truthfulness, underlining the necessity to further investigate the impact of self-representation in virtual environments:

"The robotic character seems interesting to me, because I'd like to see the different interactions one can have with a body which is not his/her own."

"I play to distract myself, to "cut myself off from the world", I don't necessarily want the character to look like me."

According to previous studies [15], self-esteem seems to affect users’ reactions when facing their doppelganger. Our statistical

analysis confirms these findings and suggests a relation between the avatar selected by the participants and their respective level of self-esteem. Participants with higher self-esteem prefer choosing their own representation, while those with lower self-esteem prefer an alternative one. This trend seems to be true for the three avatars, especially when comparing participants who selected the robot and those who chose their own representation (Figure 4). However, while a majority of the participants emphasize the quality and the realism of 3D reconstructions in open-ended questions, some of them ($N = 6$) seem to be disturbed by the presence of minor issues due to current hardware limitations. This side effect suggests the occurrence of the Uncanny Valley phenomenon [14, 17]. Indeed, the higher the level of realism of 3D models, the less the subjects seem to accept the observed flaws. It is therefore necessary to take into account the limitations of 3D reconstruction technologies before considering their use for the production of virtual reality applications.

5 CONCLUSION AND FUTURE WORK

The presented experiment investigates the impact of truthfulness of avatars (degree of similarity between users and avatars) and self-esteem on perceived attractiveness and character selection. Thanks to a virtual reality application developed in our lab, the participants were immersed in front of three characters with several levels of visual fidelity: a robot (Figure 2a), a suit (Figure 2b) and a virtual doppelganger (Figure 2c).

Our results demonstrate that attractiveness evaluations are significantly higher for the virtual doppelgangers (direct integration of the participants’ head enabled by 3D scanning technologies (Figure 2c)) and highlight the impact of self-esteem on character selection, especially between the extreme conditions (robot versus virtual doppelganger). Participants with the lower self-esteem scores are more prone to choose abstract representations, while participants with higher scores prefer to choose their own representation to enter the virtual world. These results demonstrate the interest of proposing personalized avatars, especially based on users’ appearance. However, depending on the context of each virtual reality experience and according to the willingness of some of our participants, it could be useful to propose more abstract characters to increase disconnection from reality.

In our next experiment, we will continue to investigate the impact of avatar fidelity, especially in terms of embodiment and behavior. Users will be able to control the different avatars introduced herein via a motion capture system. They will be involved in a series of tasks and situations that may potentially affect their avatars’ integrity. It will then be possible to check the occurrence of the Proteus effect [12, 19] induced by users’ representation in immersive virtual environments.

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