How do we perceive Characters? An Analysis of Human Perception in Still Images, Animations and VR Scenarios

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Abstract. *Virtual characters can elicit an uncomfortable sensation usually known as Uncanny Valley (UV). Evidence suggests that animation exacerbates the UV effect. This paper revisits the UV hypothesis to assess its effects on people's perception of virtual characters, to try to answer the questions "What happens to the perceptual comfort if, in addition to images and videos of characters, we include those characters in an interactive Virtual Reality (VR) environment?", and "Considering the VR environment, do people feel equally comfortable if we increase the number of characters?". The results indicate that there are differences in the perception of scenarios with low and high densities.*

Keywords: *Uncanny Valley, Perception, Perceived Comfort*

1. Introduction

The human perception is a subject that appears in many CG researchers [Zell et al. 2019], having high relevance when discussing the evolution of virtual humans for the public. UV theory [Mori et al. 2012] aims to assess perceptions of Human Likeness (HL) and comfort. The UV effect has become increasingly present in studies of virtual humans [Flach et al. 2012, Kätsyri et al. 2017, Kätsyri et al. 2015, Zibrek et al. 2018, Schwind et al. 2018]. According to [Schwind et al. 2018], the effect of UV is greater in VR. Observing a CG character in a VR environment, without having the virtual body for the user, does the feeling of discomfort change when we observe the same character in images, videos and in VR environments? Still on this point there work that [Musse et al. 2021, Pelechano and Allbecky 2016] the authors pointed out that people can feel good with crowds in a VR environment. So, if there is more than one of the same character, expectations tend to fall [Pelechano and Allbecky 2016], and strangeness tends to increase in a VR environment? In this paper, two questions were raised: *i)* "What happens to the perceptual comfort if, in addition to images and videos of characters, we include those characters in an interactive VR environment?; and *ii)* "Considering the VR environment, do people feel equally comfortable if we increase the number of characters?" To answer these questions, we performed some analyzes: First, we chose two characters a less realistic and a more realistic. In the second step, we chose images and videos of the characters. In addition, using low and high densities, we included the characters in an interactive VR environment. After that, we applied a questionnaire to obtain people's perceptions. We found evidence that people felt higher values of comfort in low densities. Furthermore, in most cases, the interaction with VR characters does not significantly change the comfort perceived by people.

2. Related Work

This section aims to present some related work on UV effects (caused by virtual humans and robots), and group perception. Regarding UV theory, we researched papers that explain how the theory can help us measure perceived realism and comfort. One of these studies is the work of [MacDorman and Chattopadhyay 2016], the authors' hypotheses are based on the theory of the inconsistency of realism, which predicts that the effect of the UV is caused by an entity with features that are not all perceived as belonging to a real living anthropomorphic being. The work of [Hodgins et al. 2010] reported how relevant realism is for characters created using CG. The authors performed perceptual experiments, which explored how different anomalies have relative importance. Regarding the interactivity of experiments with VR [Schwind et al. 2018, Pelechano and Allbecky 2016, Musse et al. 2021], in the work of [Seymour et al. 2017] the authors observed the effect of UV theory on user interaction with the photo-realistic human avatar without just looking at its appearance. The area of group perception has grown in recent years. Group perception is essential for learning about group patterns [McDonnell et al. 2008, Molina et al. 2021, Musse et al. 2021]. However, these results did not take into account the effect of UV and the use of VR in these scenarios, which is what we want to explore in our work.

3. Methodology

This section is divided into three sections: *i)* Section 3.1, which presents the characters that were used and why to use them; *ii)* Section 3.2 presents the applied questionnaire; and finally *iii)* Section 3.3, explains the perception stimuli and their application.

3.1. The Characters

The first stage of this work was to select the characters, which are illustrated in Figure 1. The character (a), being a less realistic, was taken from the Unity assets website[1] website, and (b), being a more realistic, was modeled using the Mixamo software[2], that is, "ready-made" characters to be used by the public [Mori et al. 2012, Flach et al. 2012, Araujo et al. 2021, Kätsyri et al. 2017]. In a possible order of HL, the character (a) is the first, and character (b) is the second. Only two characters were used so that the participants would not be exhausted. We were interested about testing characters outside the UV because those are comfortable in the human perception, and we want to test if VR and crowded spaces can change that. To select the characters, we chose one for the Unrealistic level ((a) Cartoon), and a character for the Very Realistic level ((b) Realistic). According to Katsyri et al. [Kätsyri et al. 2015] those kind of characters should convey more comfort.

3.2. The Questionnaire

We formulated a questionnaire in Google Forms to carry out the experiments, based on the work of [Flach et al. 2012]. For each question, we limited the number of responses to two options, i.e., categorical questions. As proposed by [Zell et al. 2019], this method is helpful to try to avoid subjectivity in the answers about the perception of virtual characters.

[1] Available at https://assetstore.unity.com/
[2] Available at https://www.mixamo.com

(a) Less Realistic (b) More Realistic

Figure 1. In (a) the less realistic character; (b) the most realistic character.

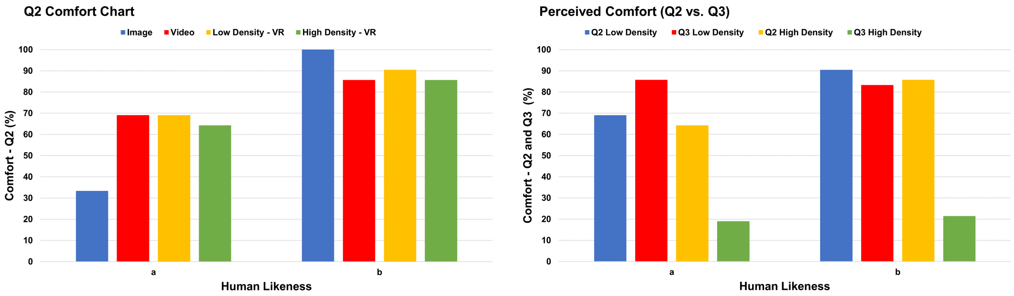
The Q1 question ("Do you think that the character in the picture/video above is:") aimed to assess the realism, and with the possible answers "A real person" and "Created using CG". Question Q2 ("Do you feel some discomfort (strangeness) looking to this character?", with the possible answers "Yes" and "No") was responsible for the perceived Comfort (in relation to the UV effect [Mori et al. 2012, Kätsyri et al. 2015, Kätsyri et al. 2017]). The perceived Comfort is given by the percentage of the answers "No".Question Q3 ("How do you feel about the number of people around you:", with the answers "Uncomfortable" and "Comfortable") aimed to analyze the impact of increasing the number of characters in the VR experiment.

3.3. Creation of Stimuli and Application of The Questionnaire

The questionnaire was applied in our research laboratories with voluntary participants. To avoid any influence, no explanation of the research's original intention was given. Participants responded to a consent form, which warned of possible problems with VR and the entire experiment. The questionnaire's application has four steps: *i)* An inspector with a laptop presented the two characters' images and asked the participants to observe each image for 30 seconds (chosen empirically). The images were exactly the same as shown in Figure 1, but cropped to show only the faces. Then, the participants answered Q1 and Q2. *ii)* Three videos were presented, one for each character and each containing 30 seconds with a resolution of 1920x1080. Then, the inspector asked the participants to observe the characters during the videos, and to answer the questions Q1 and Q2. To assess the movement effect, the characters moved randomly in the environment. *iii)* The third step involved the interaction of the participants in a VR environment, developed using the Unity3D[3]. We created a 9x13 meters virtual room (density was 0.26 characters/m^2 of the same type) with 10 characters. We did not add a virtual body to the participant, and the virtual humans did not react to the user. The "first-person" camera was used to observe the characters at the height of the face. The instructor asked the participant to use the VR equipment and visit the room for 30 seconds to learn how to move around. After that, the instructor asked the participant to observe virtual humans as close to them for one minute as possible. Then, the instructor asked the participant to answer all the questions of our questionnaire. The VR interaction was made using an HP mixed reality headset[4]. *iv)* The fourth stage was similar to the third, but increasing the density of characters (being 25

[3]Unity3D is available at https://unity3d.com/

[4]hp.com/us/en/campaigns/mixedrealityheadset/overview



(a) Comfort (all Q2 answers) (b) Comfort (Q2 vs. Q3)

Figure 2. The vertical axis in (a) represents the perceptual comfort (Q2). The blue, red, yellow, and green bars represent the answers of image, video, and VR experiments with low and high density. In (b), the chart represents the comfort data from low and high density VR experiments in questions Q2 and Q3. The blue and red bars representing the low density, and the green and yellow bars representing the high density. In both charts, the characters are distributed in the HL axis.

characters, 0.65 characters/m^2).

4. Results

This section presents the results obtained in this work. Section 4.1 presents the results of question Q1, while Section 4.2 attempts to answer the comfort research questions. 42 participants in our Research Labs answered the questionnaire. The age varies from 20 to 30 years old, 80% of the participants being male. We used the parametric *McNemar*[5] test for all statistical analyzes, considering 5% of significance level.

4.1. Assessing HL

As presented in Section 3.1, the order of the characters in relation to HL used in this work was distributed as follows: less realistic and more realistic characters. According to Katsyri et al. [Kätsyri et al. 2015], realism is related to HL, so we used question Q1 to test if our empirical order of HL is confirmed with subjects opinions. Analyzing individually, **character (a) had the highest percentage values of "Created using CG" responses in all stages** (for character (a) in image = 97.62%, video = 100%, low = 100% and high 97.62%, and for (b) image = 35.71%, video = 59.52%, low = 40.47% and high = 40.47%). We also can see that there was a trend that the most realistic character had the lower values, being in accordance with the literature [Kätsyri et al. 2015]. Statistically comparing the values between the two characters, all results were significant ($p < .001$). We also compared the responses between the stages (image, video, low and high densities) for each character. We only found significant differences in the comparisons between the video stage and all the other stages (image = .009, low = .04 and high = .04 densities) for the character (b). Indeed, more than 50% of the participants thought this character was a real person in most stages.

4.2. Assessing the Comfort

Analyzing the comfort values shown in the Figure 2(a), the character (b) had the highest comfort values. Character (a) was below 50% of perceived comfort in the image

[5]statistics.laerd.com/spss-tutorials/mcnemars-test-using-spss-statistics

analysis. Comparing the comfort values between characters, results were significant for almost all analysis (image = .001, both low and high densities = .03). The UV theory [Mori et al. 2012] states that the movement effect tends to amplify the effect of comfort when artificial beings are not in the valley region. However, the character (b) presents a higher comfort value in the image stage. There are significant differences between image stage and almost all other stages (video for (a) $< .001$ and (b) $= .04$, low density for (a) $< .001$, high density for (a) $= .003$ and (b) $= .04$). As far as we know, there is no literature report regarding perceived comfort concerning increasing the number of characters in VR scenarios. In our work, we firstly analyzed the difference between the perceived comfort of each character regarding answers of Q2 (asking about the character observation) and Q3 (asking about the population around the participant), both in VR environment. Comparing Q2 and Q3, we found a significant result only in the high scenario ($< .001$ for both (a) and (b)). It is easy to see in the Figure 2(b) that **subjects perceived more comfort when they answered about character observation (Q2) with a high density of characters than when they evaluated the group around the character (Q3).** When analyzing only Q3, all participants felt more comfortable in the low than in high densities VR scenarios ($< .001$ for both characters). In addition, the characters were considered similarly comfortable with each other.

5. Discussion and Final Considerations

This paper proposed a set of experiments to evaluate how people perceive characters in still images, animations, and interactive VR scenarios. Our results showed that the participants considered the character (b) to be more of a "real human being". Indeed, for the two characters, what was expected happened, i.e., following the literature [Mori et al. 2012, Kätsyri et al. 2015, Flach et al. 2012, Araujo et al. 2021]: the both characters evoke comfort in the human perception. People perceived that character (b) was the most similar to a healthy human being compared to the other character. In relation to the perceived comfort in VR environments the results showed that the effect of movement happened only in relation to the less realistic character. Movement effect happened to unrealistic characters with increased perceived comfort. In addition, people felt more comfortable when they had more space in the virtual environment, and this may be related to a proximity effect [Zibrek et al. 2018]. In terms of design, the results are interesting to help avoid UV in relation to VR environments, especially when we talk about proximity to groups of virtual humans in VR. We intend to do other specific experiments in the future, such as a group tasks, different genders and races of characters, among others.

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