

Consistency of Virtual Human Faces: Effect of Stylization and Expressiveness Intensity on Character Perception

Charlotte Dubosc¹ , Geoffrey Gorisse¹ , Olivier Christmann¹  and Simon Richir¹ 

¹Arts et Métiers Institute of Technology, France



Figure 1: Stylized, semi-realistic and realistic female characters used in the online experiment.

Abstract

The perception of virtual human faces is impacted by several interrelated factors, such as shapes, materials, textures, shading or animation. Previous research demonstrated that animation flaws and inconsistencies tend to be less accepted on realistic characters compared to stylized ones. To further investigate the relationship between stylization and facial expressions, we designed an online investigation to assess participants' perception of virtual human faces with regards to perceived realism, attractiveness and eeriness. We modeled a female and a male character with three levels of stylization (stylized, semi-realistic, realistic) and four expressiveness intensities (idle, low, moderate and exaggerated). 135 participants took part in the experiment which consisted of watching a set of 24 videos lasting 30 seconds each. Interaction effects were observed between the independent variables. Overall, results indicated that perceived realism was mainly driven by the stylization level. Visually realistic characters were perceived as more realistic even with exaggerated facial expressions. In terms of attractiveness, scores tended to decrease as the intensity of facial expressions increased. At the highest expressiveness intensity, the semi-realistic female character was preferred over the stylized and the realistic ones, while the realistic male character scored higher than the others. In line with previous studies, results indicated that perceived eeriness rises with the intensities of facial expressions. Taken as a whole, this study provides valuable guidelines for 3D artists and developers to design avatars and autonomous agents.

CCS Concepts

• Applied computing → Psychology; • Computing methodologies → Perception;

1. Introduction

In recent years, we tend to be increasingly confronted with virtual humans, such as digital representations of other users (avatars) or with autonomous characters (agents) [BB04]. Modern tools and software, such as Character Creator[†] or MetaHuman[‡] allow for the creation of realistic characters with simplified pipelines compared to 3D modeling and sculpting. However, some productions from the video game industry demonstrated that realistic virtual humans tend to be less convincing when their animation does not align with their visual realism (i.e. *Mass effect: Andromeda*[§]). Indeed, the now well-known *Uncanny Valley* [Mor70, MMK12] phenomenon, which describes the drop in affinity towards a virtual character when its appearance tends to get closer to reality, seems to be even more pronounced with animated faces. To bypass this effect, several companies rely on stylized characters for their virtual environments [DIG13]. Stylized characters can be seen as caricatured or simplified versions that retain and emphasize some essential morphological properties to convey emotions. Previous investigations compared stylized and realistic virtual characters [ZAJ*15, TCM*19, YDR*19], and contrasted results were reported. Some participants preferred stylized characters over realistic ones [TCM*19], while the opposite effect was observed in another study conducted the same year [YDR*19]. The reasons behind a preference for stylized or realistic characters were not clearly identified, but it might be argued that people may be influenced by the content they watch are exposed to (e.g. cartoons, which often feature characters with exaggerated expressions) [CRNL10]. However, as demonstrated by Mäkäräinen *et al.* [MKT14], stylized characters must rely on exaggerated expressions to achieve a similar level of perceived emotional intensity. It should be noted that this study focused on motionless faces. In this context, we were interested in investigating how virtual human perception could be impacted by both their level of stylization and the intensity of their facial expressions.

The following section introduces related work on virtual character perception. Section 3 presents the design of our experiment and its protocol. Results are reported in Section 4 and are discussed in Section 5. Section 7 concludes the study. Limitations and potential future work are presented in Section 6.

2. Related work

Considering that even minor flaws can induce negative responses [SN07], designing virtual characters is challenging. While numerous studies explored this phenomenon under the frame of the *Uncanny Valley* phenomenon [MMK12, SO18, HPDW21, DFH*12a, DFH*12b], some factors influencing the perception of virtual faces, and especially their interrelation, remain unexplored. This theory is depicted by a function linking visual realism and affinity toward a virtual character. It states that as realism increases, so does

affinity. However, an affinity drop can be induced by its "eerie" aspect when the virtual model reaches an almost human-like appearance. These effects were empirically demonstrated by MacDorman and Ishiguro [MI06]. Moreover, the theory suggests that this effect on affinity is further pronounced when observing an animated character. Animation flaws, which can be induced by motion capture devices, are better accepted with stylized characters [MBB12, TCM*19]. Previous work also demonstrated that perceived eeriness of virtual faces increases when emotional expressivity is reduced [TGNW11], especially on realistic faces. In most circumstances, using less realistic characters suppresses the *Uncanny Valley* effect [MGHK09].

According to the observations of Mäkäräinen *et al.* [MKT14], *Uncanny Valley* effect tends to appear in two different situations. Firstly, when characters appear "distorted", that is to say when facial properties deviate from human proportions. For instance, enlarged eyes on realistic faces increase the perceived eeriness [MGHK09, SN07, FM18]. It seems that eyes, eyelashes and mouth are the most impactful physical properties [MC16]. Secondly, when virtual characters look "lifeless", in other words, when animation is not convincing and when characters lack expressiveness. It may also occur without any abnormal physical characteristics. Indeed, eeriness can arise when subconscious expectations in human interaction are not met [MI06]. A third aspect inducing this *uncanny valley* effect was identified by Zell *et al.* [ZAJ*15]. They demonstrated that a mismatch between 3D shapes and materials (textures and shading) decreased the affinity toward the virtual characters. More specifically, they compared a set of different textures ranging from simple flat colors to highly detailed skins on 3D characters presenting stylized to realistic shapes. Results indicated that characters with cartoon-like shapes and realistic skin textures were perceived as more eerie. The more realistic the skin texture, the more consistent it is expected to be with its shape.

Besides eeriness, several aspects of virtual human perception need to be considered, such as perceived realism and attractiveness. According to McDonnell *et al.* [McD12], a significant portion of the data used to evaluate virtual characters with regards to the aforementioned criteria can be retrieved from a single image, while the impact of animation is mainly reflected in familiarity and attractiveness. Zell *et al.* [ZAJ*15] demonstrated that perceived realism was impacted by 3D shapes, while attractiveness was mainly determined by materials. A smooth and homogeneous skin is a good indicator of a healthy young subject and is perceived as more attractive [FBMD12]. This observation also applies to virtual characters [ZAJ*15, SWHK15, MGHK09]. As for the effect of shapes, we mentioned previously that facial properties of virtual characters (e.g. eye size) can increase perceived eeriness [MGHK09, SN07, FM18]. However, it was also demonstrated that human faces with larger eyes can be perceived as more honest [ZVC96] and less dominant [Kea85, FPM21]. Nevertheless, a mismatch between abnormal shapes and more realistic textures can negatively affect virtual characters perceived attractiveness [SO18]. Therefore, shapes and materials must be carefully adjusted to fit the purpose of the virtual character being designed. For instance, Gollum from *the Lord of the Ring* has large eyes and a small mouth with a highly detailed skin that enhances, by design, the eeriness of the character. However, increasing the size of the eyes on a stylized

[†] Soft to create 3D virtual humans for 3D realtime

[‡] Framework to create highly realistic human characters developed by Epic Games.

[§] Action role-playing video game developed by BioWare and published by Electronic Arts in 2017.

face with smooth skin is a common practice to make a character more attractive [ZM92].

It should be noted that some studies demonstrated that people are prone to find realistic characters more attractive than their stylized versions [McD12, SRK17]. Schwind *et al.* [SWHK15] conducted an experiment where participants had to create an avatar to assess their preferences toward parametrized faces. Although given the choice, participants rarely created virtual faces with obvious cartoon-like attributes. In addition, the work of Seymour *et al.* [YDR*19] revealed that people were more likely to trust and feel greater affinity toward realistic virtual characters. However, a study published in the same year, which also compared a realistic and a stylized virtual agent, demonstrated that participants preferred to interact with a stylized character [TCM*19]. This inconsistency in results may be due to different character design choices. Indeed, realistic characters were based on real humans, while a wide range of stylization could have been considered (e.g. occidental versus Japanese animation). All stylizations may not be equal depending on how frequently people are confronted with these different types of content [CRNL10].

To the best of our knowledge, the study of Mäkäräinen *et al.* [MKT14] is the only experimental investigation considering both the impact of stylization (from schematic to photorealistic) and the magnitude of facial expressions (from neutral to extremely exaggerated) on the perceived intensity of emotions. Using both real pictures and 2D post-processed pictures, this experiment demonstrated that stylized faces required more exaggeration to reach the same perceived emotional intensity compared to real faces. Furthermore, stimuli in this study focused on a type of stylization that goes as far as drawing strokes and was not based on well-known styles. To summarize, our literature review pointed to different studies comparing stylized and realistic characters, but none of them considered expressiveness intensity on animated virtual characters. Inspired by experimental design of the work of Zell *et al.* [ZAJ*15], we designed an experiment to assess the impact of combining three levels of stylization and four facial expression intensities on the perception of 3D animated faces.

3. Materials and Methods

3.1. Stimuli

The study reported here aims at investigating the impact of stylization and facial expression intensity on perceived realism, attractiveness and eeriness. Using *Character Creator 3*, we modeled a female and a male character with three stylization levels: stylized, semi-realistic and realistic. Corrected ratios from Chen *et al.* [CZ14] were considered to design the characters (figure 2). The stylized characters were derived from the realistic ones using stylization techniques as enlarging eyes, caricaturing shapes, and reducing skin details, which are the main indicators of character realism [ZAJ*15]. As there are a multitude of potential stylizations, we focused on a style close to Western animated film studios (e.g., *Disney*, *Pixar*). Our panel of participants were more likely to be familiar with this type of stylization. Finally, the semi-realistic condition was a blend between stylized and realistic conditions (figures 3a and 3b). Four expressiveness intensities were considered:

- Idle: the character performs no action. It stares straight ahead, with a blinking animation.
- Low intensity: animation (head movement and eyes direction with expression shift) with head movement and expression shift with a low expressiveness magnitude.
- Moderate intensity: animation (head movement and eyes direction with expression shift) with a moderate expressiveness magnitude.
- Exaggerated intensity: animation (head movement and eyes direction with expression shift) with exaggerated, yet plausible, facial expressions.

We created a set of facial expressions (basic emotions: anger, sadness, disgust, surprise, happiness and fear) referring to Ekman's guidelines [EF72] with head and gaze movements allowing participants to observe the characters' faces from different angles. Varying the emotions helped the participants to perceive more finely the differences in expressiveness intensity [ZAJ*15, MKT14]. The stimuli consisted of 12 conditions for both the male and the female characters (see figure 4), for a total of 24 conditions presented to participants in short videos. Each 30-second video featured the same sequence of emotions, with the exception of the idle condition. Stimuli were presented in a counterbalanced order. The video sequences were recorded directly from the Unity LTS 2020.3.32f1 game engine. Each character was placed in front of a gray background to avoid any distracting elements. A three-point lighting was used to ensure a proper lighting of the characters' faces.

3.2. Participants

We designed an online questionnaire for distribution in computer science schools and on mailing lists in extended realities and human-computer interaction communities. 165 participants took part in this study. As it was not possible to guarantee similar exposure conditions due to the online nature of the experiment, a series of exclusion rules were considered. We excluded participants who answered in less than 10 seconds per block (video and questions). Participants who exceeded 300 seconds per block were also excluded. These rules made it possible to exclude participants who responded without watching the videos and those who may have been interrupted. We also excluded participants who consistently chose extreme values on Likert items, indicating they were not pay-



Figure 2: Corrected ratios of Chen *et al.* [CZ14] on realistic conditions.

ing attention to the questions. Our final panel was composed of 135 participants, 94 males and 41 females, aged from 19 to 72 ($M = 32.84$, $SD = 11.50$).

3.3. Procedure and Measures

Participants received a message through mailing lists with an introductory statement and a link to the survey. They were also invited to complete the experiment on a computer or tablet with large screens to ensure good visibility of the videos. The first page informed participants and asked for their consent to start the experiment. Then, they completed a demographic questionnaire and they self-reported their gaming experience as well as their familiarity with 3D animations.

Following a within-subjects design, participants observed the 24-video set. After each video, they were asked to rate the observed virtual character using a Likert scale ranging from 1 (*= not at all*) to 7 (*= very much*): realism, attractiveness and eeriness (as measured by the inverted reassurance scale).

- *Extremely abstract–Extremely realistic*: Indicates if you find the character’s appearance to be highly stylized like in cartoons, or close to photo-realistic as in real pictures.
- *Extremely unattractive–Extremely attractive*: Indicates whether you find the character unattractive and ugly or beautiful and attractive.
- *Extremely eerie–Extremely re-assuring*: Indicate if you find the character eerie, which means that they are gloomy and leaves you with a sense of fear. Re-assuring means that the character restores a sense of security, confidence, calm in you.

The metrics were based on previous relevant works [TCM*19, ZAJ*15, MBB12]. To ensure that participants had a clear understanding, items definitions were provided based on the work of Zell *et al.* [ZAJ*15]. Following the 24 stimuli, participants had to select

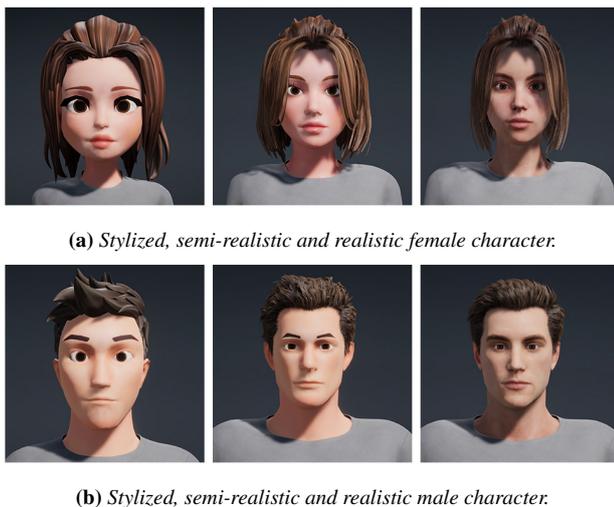


Figure 3: Screenshots of the three male and female virtual characters



Figure 4: Visual realism conditions of the female character (from stylized (left) to realistic (right)) and intensity of the sadness expression (from low (top) to exaggerated (bottom)).

their favorite male and female characters among the three stylization levels (one out of three for each gender). A text field allowed them to comment on their choices.

3.4. Hypotheses

Based on our literature review and given the proposed experimental protocol, we expected participants to evaluate characters differently depending on their level of stylization and intensity of facial expressions. We formulated two hypotheses:

- H1: Perceived realism is impacted by the intensity of facial expressions depending on the level of stylization of the characters. Thus, realistic characters with exaggerated expressions will have a lower level of realism than stylized characters.
- H2: Stylized characters with exaggerated animations will be perceived as more attractive (*H2.1*) and less eerie (*H2.2*) than realistic characters with a similar level of animation.

4. Results

4.1. Realism

Maulchly’s test of sphericity indicated that the assumption of sphericity was violated for the three-way interaction $\chi^2(20) = 52.593$, $p < .001$. Greenhouse-Geisser correction was considered when interpreting the data. A three-way repeated measures ANOVA was conducted to determine the effects of characters’ sex,

intensity and stylization on perceived realism. There was a statistically significant three-way interaction between character sex, intensity and stylization, $F(5.423, 726.688) = 2.310, p = .038$. For the simple two-way interactions, simple main effects and pairwise comparisons, a Bonferroni adjustment was applied. There was a statistically significant simple two-way interaction between stylization and intensity for male characters $F(5.275, 706.890) = 4.395, p < .001$ and for female characters $F(5.461, 731.800) = 3.496, p = .003$.

All simple pairwise comparisons were run between the different stylization levels for each intensity level. At exaggerated intensity level, there was a statistically significant mean difference for the perceived realism between: realistic ($m = 4.96, SD = 1.263$) and semi-realistic ($m = 3.61, SD = 1.246$) 95% CI [1.001, 1.488], $p < .001$; realistic ($m = 4.96, SD = 1.263$) and stylized ($m = 2.65, SD = 1.254$) 95% CI [2.060, 2.666], $p < .001$; semi-realistic ($m = 3.61, SD = 1.246$) and stylized ($m = 2.65, SD = 1.254$) 95% CI [1.837, 1.400], $p < .001$ (figures 5a and 5b).

There was a statistically significant simple main effect of stylization at the highest intensity level for both male and female characters. Perceived realism was higher for realistic characters than semi-realistic and stylized characters, and higher for semi-realistic characters than stylized characters. $H1$ is therefore not supported. A post-hoc analysis revealed that perceived realism tends to decrease as the intensity of emotions increases for the realistic female and male characters.

4.2. Attractiveness

Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the three-way interaction $\chi^2(20) = 41.369, p < .001$. Greenhouse-Geisser correction was considered when interpreting the data. A three-way repeated measures ANOVA was conducted to determine the effects of character sex, intensity and stylization on attractiveness. There was a statistically significant three-way interaction between character sex, intensity and stylization, $F(6, 804) = 5.388, p < .001$. For the simple two-way interactions, simple main effects and pairwise comparisons, a Bonferroni adjustment was applied. There was a statistically significant simple two-way interaction between stylization and intensity for male characters $F(5.4845, 734.815) = 5.759, p < .001$ and for female characters $F(6, 804) = 8.329, p < .001$.

All simple pairwise comparisons were run between the different stylization levels for each intensity level. At exaggerated intensity level, there was a statistically significant mean difference for attractiveness between: realistic ($m = 3.89, SD = 1.444$) and semi-realistic ($m = 3.50, SD = 1.221$) 95% CI [.094, .691], $p = .005$.

There was a statistically significant simple main effect of stylization at the highest intensity level for both male and female characters. For male characters, attractiveness was higher for the realistic character than the semi-realistic one. For the female characters, attractiveness was higher for the semi-realistic character than both the realistic and stylized characters, and higher for the realistic character than the stylized character. $H2.1$ is therefore not supported. Post-hoc analysis shows that male characters

are perceived as less attractive at every stylization level with exaggerated facial expressions compared to the idle animation. For the realistic character, the higher the emotion intensity, the lower the perceived attractiveness between the first and the second intensity levels. Concerning female characters, for most expression intensities, the higher the intensity, the lower the perceived attractiveness for the semi-realistic and realistic female characters.

4.3. Eeriness

Mauchly's test of sphericity indicated that the assumption of sphericity was met for the three-way interaction, $\chi^2(20) = 29.734, p = .074$. A three-way repeated measures ANOVA was conducted to determine the effects of characters' sex, intensity and stylization on the potential uncanny effect induced by the virtual characters. There was a statistically significant three-way interaction between character sex, intensity and stylization, $F(6, 804) = 5.824, p < .001$. For the simple two-way interactions, simple main effects and pairwise comparisons, a Bonferroni adjustment was applied. There was a statistically significant simple two-way interaction between stylization and intensity for male characters $F(6, 804) = 5.587, p < .001$ and for female characters $F(5.335, 714.904) = 9.152, p < .001$.

All simple pairwise comparisons were run between the different stylization levels for each intensity. At exaggerated intensity level, there was a statistically significant mean difference for reassuring between: stylized ($m = 3.73, SD = 1.328$) and semi-realistic ($m = 3.36, SD = 1.250$) 95% CI [.076, .665], $p = .008$; stylized ($m = 3.73, SD = 1.328$) and realistic ($m = 3.35, SD = 1.323$) 95% CI [.045, .725], $p = .021$ (figures 5e and 5f).

There was a statistically significant simple main effect of stylization at the highest intensity level for both male and female characters. For male characters, the stylized character was perceived as more reassuring than semi-realistic and realistic characters. For female characters, stylized and semi-realistic characters were perceived as more reassuring than the realistic character. $H2.2$ is therefore supported. Post-hoc tests revealed that for most intensity levels, the higher the intensity, the lower the potential uncanny valley effect for all characters, except for the stylized female character.

5. Discussion

We analyzed the perceptual effects of different stylizations and expressiveness intensities of 3D animated virtual characters. Specifically, we compared three levels of stylization (stylized, semi-realistic and realistic) and four expressiveness intensities (idle animation, low intensity, moderate intensity, and exaggerated intensity) on a female and a male character. Several perceptual measures were considered: perceived realism, attractiveness and eeriness.

5.1. Perceived Realism

Realistic characters scored higher on the perceived realism scale compared to stylized and semi-realistic ones, even with exaggerated facial expressions. Therefore, $H1$ was not supported. Zell *et*

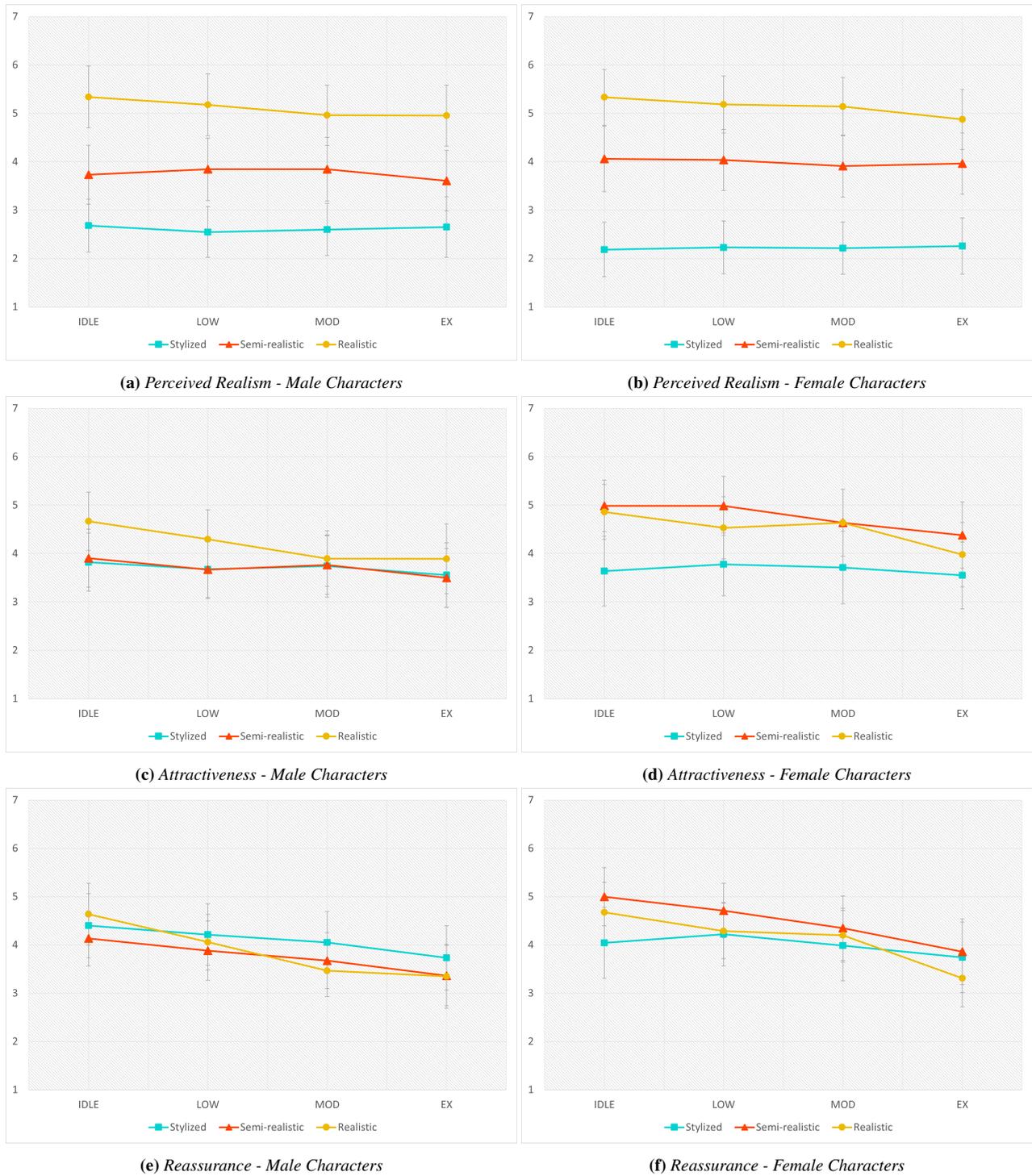


Figure 5: Scores for perceived realism, attractiveness and reassurance for male (left) and female (right) characters, depending on their expressiveness intensity: idle, low intensity (LOW), moderate intensity (MOD) and exaggerated intensity (EX).

al. [ZAJ*15] also observed that 3D shape realism was a good predictor of perceived realism without considering the expressiveness intensity. In our context, we hypothesized that using exaggerated facial expressions on realistic faces would have induced a mismatch potentially decreasing the perceived realism of the characters in return. However, it is possible that the magnitude between the proposed facial expressions was too narrow and that visual fidelity took precedence over perceived realism.

5.2. Perceived Attractiveness

Results on perceived attractiveness highlight that the realistic male character was perceived as significantly more attractive than the semi-realistic one at the highest level of expressiveness. Once again, this result does not align with our second hypothesis *H2.1*. We expected to observe lower attractiveness scores with realistic characters presenting exaggerated facial expressions. However, McDonnell *et al.* [MBB12] compared different render styles on an animated virtual male character and they observed that the more realistic render style was perceived as more attractive too. Similarly, Seymour *et al.* [YDR*19] conducted an experiment in which participants were confronted with both a stylized and a realistic male character. The realistic character was also perceived as more attractive. When it comes to the female character, results indicated that the semi-realistic model was significantly more attractive than the realistic and stylized versions at the highest expressiveness intensity. This difference observed between the male and the female characters could be partly explained by the fact that large eyes are often considered attractive, especially in females [FM18]. The semi-realistic female character being a blend of the two other conditions, it preserves most of human proportions, but with slightly larger eyes and a smoother skin [MGHK09, FPM21, ZAJ*15]. In line with the attractiveness scores, 50 % of the participants chose the realistic male as their favorite male character and 67 % the semi-realistic female as their favorite female character. Regarding qualitative data, some participants stated that the realistic female character looked more tired than the male one:

"The semi-realistic character is the one I feel most comfortable with. The realistic one seems tired and have dark circles under her eyes."

"The semi-realistic female character has beautiful eyes and lips. The realistic one has dark circles under her eyes [...]."

Overall, smooth and flawless skin and color variation are highly valued, particularly among women [SFM10]. As for the virtual characters, a subtle stylization of a realistic material, such as blurring the albedo, can increase appeal without drastically reducing realism [ZAJ*15]. In addition, Schwind *et al.* [SWHK15] conducted an experiment in which participants were asked to design virtual characters. They found that participants tended to create male faces with more detailed skin than females.

5.3. Eeriness

Eeriness results, as measured by the inverted reassurance scale, indicated that in most cases the higher the expressiveness intensity,

the higher the perceived eeriness for both male and female characters. The shape of stylized characters can make faces more reassuring and prevent the Uncanny Valley effect to arise [MGHK09]. Regarding stylization, the stylized version of the male character was perceived as more reassuring than the other versions, while it was the semi-realistic female version that was perceived as more reassuring at the highest intensity level. Therefore, these results partly support our hypothesis *H2.2*.

Interestingly, this result highlights that a character could be considered attractive, while being perceived as more eerie at the same time. It could be argued that this difference between perceived attractiveness and eeriness scores may be due to the fact that a more human-like character could be perceived as more appealing [McD12, SRK17]. Indeed, Schwind *et al.* [SWHK15] demonstrated that when users are asked to design a virtual character, they tend to create realistic ones. Nevertheless, animation flaws are more accepted on stylized characters which tend to be perceived as less eerie [MBB12]. Taken together, these results align with our observations on the male character.

6. Limitations and Future Work

The results of this study provide interesting guidelines to design virtual characters. Yet, it should be mentioned that the complexity of the triple interaction effects led us to focus on discussing the most relevant aspects with regard to our hypotheses in section 5. It should also be mentioned that we focused on a specific set of stimuli with stylized characters inspired by occidental productions (e.g. Disney or Pixar). Depending on cultures, results might be shaped in a different way. Therefore, it would be interesting to conduct additional studies using, for instance, virtual characters inspired by traditional Japanese productions. Furthermore, given the high variability of the panel and the already complex interaction effects observed in the results, it would have been difficult to carry out robust statistical analyses based on participant demographics in the context of this experiment.

Regarding the intensity of facial expressions, as stated in the discussion, it could be argued that exaggerated stimuli were still plausible on realistic human faces, leading us to partly reject some hypotheses. Indeed, it was expected that very intense facial expressions would have induced lower attractiveness scores and higher eeriness ones on realistic characters. Further experiments should consider stimuli with greater magnitude. Additionally, future experiments may also consider focusing on full-body animations fitting facial expressions, as the different stylization levels also affect the shapes of the virtual bodies.

While it was outside the scope of this paper, we intend to adapt the content of this experiment in social virtual reality contexts. Indeed, the stylization level of virtual characters could affect the way users interact and impact their sense of social presence in immersive environments [Gar03, NB03, OBW18]. Such an experiment could be developed using modern virtual reality headsets using gaze, face and body tracking technologies. Such a setup would allow users to interact using their natural body language. Remapping facial expressions using adjustable gains would make it possible to compare different expressiveness levels in virtual social interactions.

7. Conclusion

The reported study aimed at investigating the effect of stylization and expressiveness on the perception of virtual characters. We used a 3x4x2 experimental design, with three levels of stylization (stylized, semi-realistic and realistic), four levels of expressiveness (idle, low intensity, moderate intensity and exaggerated intensity) on both a male and a female character. This online investigation consisted in watching a set of 24 videos lasting 30 seconds. In each video, a virtual character was performing a series of facial expressions. Participants had to evaluate the perceived realism, the attractiveness and the eeriness after each stimulus. 135 participants took part in the experiment. Significant three-way interaction effects were observed for each dependent variable. Overall, results indicated that the stylization level was the main contributor to virtual characters perceived realism. Even with exaggerated facial expressions, realistic characters were perceived as more realistic. However, attractiveness scores tended to decrease as the intensity of facial expressions increased. The semi-realistic female character was preferred over the stylized and the realistic ones at the highest expressiveness intensity, whereas the realistic male characters scored higher than the others. According to some participants, the realistic female character was perceived as more tired than the male one, despite the fact that they shared a similar level of detail in their skin materials. We argued that the semi-realistic female character preserved most of human proportions, but with slightly larger eyes and a smoother skin, potentially explaining the higher attractiveness scores. Finally results indicated that perceived eeriness rises along with the intensity of facial expressions. This result is consistent with previous work demonstrating that virtual characters with a greater resemblance to humans tend to be perceived as more attractive, but are evaluated with higher eeriness scores, as observed with the male character. Taken together, these results provide useful guidelines for the design of avatars and autonomous agents, while further emphasizing the interrelation of factors that influence the perception of virtual characters.

References

- [BB04] BAIENSON J. N., BLASCOVICH J.: *Encyclopedia of human-computer interaction*. Berkshire Publishing Group, Great Barrington, MA, USA, 2004, ch. Avatars, pp. 64–68. 2
- [CRNL10] CHEN H., RUSSELL R., NAKAYAMA K., LIVINGSTONE M.: Crossing the ‘uncanny valley’: Adaptation to cartoon faces can influence perception of human faces. *Perception* 39, 3 (2010), 378–386. doi:10.1068/p6492. 2, 3
- [CZ14] CHEN F., ZHANG D.: Evaluation of the putative ratio rules for facial beauty indexing. In *2014 International Conference on Medical Biometrics* (New York, NY, USA, 2014), IEEE, pp. 181–188. doi:10.1109/ICMB.2014.38. 3
- [DFH*12a] DILL V., FLACH L. M., HOCEVAR R., LYKAWKA C., MUSSE S. R., PINHO M. S.: Evaluation of the uncanny valley in cg characters. In *Intelligent Virtual Agents* (Berlin, Heidelberg, 2012), Nakano Y., Neff M., Paiva A., Walker M., (Eds.), Springer Berlin Heidelberg, pp. 511–513. 2
- [DFH*12b] DILL V., FLACH L. M., HOCEVAR R., LYKAWKA C., MUSSE S. R., PINHO M. S.: Evaluation of the uncanny valley in cg characters. In *Intelligent Virtual Agents: 12th International Conference, IVA 2012* (Berlin, 2012), Springer-Verlag, pp. 511–513. doi:10.1007/978-3-642-33197-8_62. 2
- [DIG13] DIONISIO J. D. N., III W. G. B., GILBERT R.: 3d virtual worlds and the metaverse: Current status and future possibilities. *ACM Computing Surveys* 45, 3 (2013), 34:1–34:38. doi:10.1145/2480741.2480751. 2
- [EF72] EKMAN P., FRIESEN W. V.: Hand Movements. *Journal of Communication* 22, 4 (1972), 353–374. doi:10.1111/j.1460-2466.1972.tb00163.x. 3
- [FBMD12] FINK B., BUNSE L., MATTS P. J., D’EMILIANO D.: Visible skin colouration predicts perception of male facial age, health and attractiveness. *International Journal of Cosmetic Science* 34, 4 (2012), 307–310. doi:10.1111/j.1468-2494.2012.00724.x. 2
- [FM18] FERSTL Y., MCDONNELL R.: A perceptual study on the manipulation of facial features for trait portrayal in virtual agents. In *Proceedings of the 18th International Conference on Intelligent Virtual Agents* (New York, NY, USA, 2018), IVA ’18, Association for Computing Machinery, p. 281–288. doi:10.1145/3267851.3267891. 2, 7
- [FPM21] FRIBOURG R., PEILLARD E., MCDONNELL R.: Mirror, mirror on my phone: Investigating dimensions of self-face perception induced by augmented reality filters. In *2021 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)* (New York, NY, USA, 2021), IEEE, pp. 470–478. doi:10.1109/ISMAR52148.2021.00064. 2, 7
- [Gar03] GARAU M.: *The Impact of Avatar Fidelity on Social Interaction in Virtual Environments*. PhD thesis, University College London, 2003. 7
- [HPDW21] HEPERLE D., PURPS C. F., DEUCHLER J., WÖLFEL M.: Aspects of visual avatar appearance: self-representation, display type, and uncanny valley. *The Visual Computer* (2021), 1–18. 2
- [Kea85] KEATING C. F.: Gender and the physiognomy of dominance and attractiveness. *Social psychology quarterly* 48, 1 (1985), 61–70. doi:10.2307/3033782. 2
- [MBB12] MCDONNELL R., BREIDT M., BÜLTHOFF H. H.: Render me real?: Investigating the effect of render style on the perception of animated virtual humans. *ACM Transactions on Graphics* 31, 4 (2012), 1–11. doi:10.1145/2185520.2185587. 2, 4, 7
- [MC16] MACDORMAN K. F., CHATTOPADHYAY D.: Reducing consistency in human realism increases the uncanny valley effect; increasing category uncertainty does not. *Cognition* 146 (2016), 190–205. doi:10.1016/j.cognition.2015.09.019. 2
- [McD12] MCDONNELL R.: Appealing virtual humans. In *International Conference on Motion in Games* (Berlin, Heidelberg, 2012), Kallmann M., (Ed.), Springer, Springer, pp. 102–111. doi:10.1007/978-3-642-34710-8_10. 2, 3, 7
- [MGHK09] MACDORMAN K. F., GREEN R. D., HO C.-C., KOCH C. T.: Too real for comfort? uncanny responses to computer generated faces. *Computers in Human Behavior* 25, 3 (2009), 695–710. doi:10.1016/j.chb.2008.12.026. 2, 7
- [MI06] MACDORMAN K. F., ISHIGURO H.: The uncanny advantage of using androids in cognitive and social science research. *Interaction Studies: Social Behaviour and Communication in Biological and Artificial Systems* 7, 3 (2006), 297–337. doi:10.1075/is.7.3.03mac. 2
- [MKT14] MÄKÄRÄINEN M., KÄTSYRI J., TAKALA T.: Exaggerating facial expressions: A way to intensify emotion or a way to the uncanny valley? *Cognitive Computation* 6 (2014), 708–721. doi:10.1007/s12559-014-9273-0. 2, 3
- [MMK12] MORI M., MACDORMAN K. F., KAGEKI N.: The uncanny valley [from the field]. *Robotics & Automation Magazine, IEEE* 19, 2 (2012), 98–100. doi:10.1109/MRA.2012.2192811. 2
- [Mor70] MORI M.: Bukimi no tani [the uncanny valley]. *Energy* (1970), 33–35. 2
- [NB03] NOWAK K. L., BIOCCHA F.: The effect of the agency and anthropomorphism on users’ sense of telepresence, copresence, and social presence in virtual environments. *Presence: Teleoperators*

- and *Virtual Environments* 12, 5 (2003), 481–494. doi:10.1162/105474603322761289.7
- [OBW18] OH C. S., BAIENSON J. N., WELCH G. F.: A systematic review of social presence: Definition, antecedents, and implications. *Frontiers in Robotics and AI* 5 (2018), 114. URL: <https://www.frontiersin.org/article/10.3389/frobt.2018.00114>, doi:10.3389/frobt.2018.00114.7
- [SFM10] SAMSON N., FINK B., MATTS P. J.: Visible skin condition and perception of human facial appearance. *International Journal of Cosmetic Science* 32, 3 (2010), 167–184. doi:10.1111/j.1468-2494.2009.00535.x.7
- [SN07] SEYAMA J., NAGAYAMA R. S.: The uncanny valley: Effect of realism on the impression of artificial human faces. *Presence: Teleoperators and Virtual Environments* 16, 4 (2007), 337–351. doi:10.1162/pres.16.4.337.2
- [SO18] STEIN J.-P., OHLER P.: Uncanny... but convincing? inconsistency between a virtual agent's facial proportions and vocal realism reduces its credibility and attractiveness, but not its persuasive success. *Interacting with Computers* 30, 6 (2018), 480–491. doi:10.1093/iwc/iwy023.2
- [SRK17] SEYMOUR M., RIEMER K., KAY J.: Interactive Realistic Digital Avatars-Revisiting the Uncanny Valley. In *Proceedings of the 50th Hawaii International Conference on System Sciences* (Honolulu, HI, USA, 2017), University of Hawaii, pp. 547–556. doi:10.24251/HICSS.2017.067.3,7
- [SWHK15] SCHWIND V., WOLF K., HENZE N., KORN O.: Determining the characteristics of preferred virtual faces using an avatar generator. In *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play* (New York, NY, USA, 2015), CHI PLAY '15, ACM, p. 221–230. doi:10.1145/2793107.2793116.2,3,7
- [TCM*19] TORRE I., CARRIGAN E., MCDONNELL R., DOMJAN K., MCCABE K., HARTE N.: The effect of multimodal emotional expression and agent appearance on trust in human-agent interaction. In *Proceedings of the 12th ACM SIGGRAPH Conference on Motion, Interaction and Games* (New York, NY, USA, 2019), MIG '19, ACM, pp. 1–6. doi:10.1145/3359566.3360065.2,3,4
- [TGNW11] TINWELL A., GRIMSHAW M., NABI D. A., WILLIAMS A.: Facial expression of emotion and perception of the uncanny valley in virtual characters. *Computers in Human Behavior* 27, 2 (2011), 741–749. doi:10.1016/j.chb.2010.10.018.2
- [YDR*19] YUAN L., DENNIS A., RIEMER K., ET AL.: Crossing the uncanny valley? understanding affinity, trustworthiness, and preference for more realistic virtual humans in immersive environments. In *Proceedings of the 52nd Hawaii International Conference on System Sciences* (Honolulu, HI, USA, 2019), University of Hawaii, pp. 1748–1758. doi:10.24251/HICSS.2019.213.2,3,7
- [ZAJ*15] ZELL E., ALIAGA C., JARABO A., ZIBREK K., GUTIERREZ D., MCDONNELL R., BOTSCH M.: To stylize or not to stylize?: The effect of shape and material stylization on the perception of computer-generated faces. *ACM Transactions on Graphics* 34, 6 (2015), 1–12. doi:10.1145/2816795.2818126.2,3,4,7
- [ZM92] ZEBROWITZ L. A., MONTEPARE J. M.: Impressions of baby-faced individuals across the life span. *Developmental Psychology* 28, 6 (1992), 1143–1152. doi:10.1037/0012-1649.28.6.1143.3
- [ZVC96] ZEBROWITZ L. A., VOINESCU L., COLLINS M. A.: "wide-eyed" and "crooked-faced": Determinants of perceived and real honesty across the life span. *Personality and social psychology bulletin* 22, 12 (1996), 1258–1269. doi:10.1177/01461672962212006.2