# Is the Perceived Comfort With CG Characters Increasing With Their Novelty?

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***Realistic characters from movies and games can cause strangeness and involuntary feelings in viewers, an effect known as the uncanny valley (UV). This article revisits the central UV hypothesis, proposed by Masahiro Mori in 1970, to evaluate its impact on people's perception of characters created using computer graphics (CG). More precisely, our goal is to answer the following questions: 1) Are people feeling more comfortable with more recent CG characters than the older ones? 2) Does charisma or familiarity with virtual humans correlate with perceived comfort? To answer these questions, we first replicated an experiment from 2012 and compared the perception concerning CG characters then and now, and then we included images of more recent CG characters in our analysis. Our results indicate that the perceived comfort increased over time when comparing the characters of 2012 and 2020. However, it did not change significantly for the characters of 2012. In addition, we found a correlation between perceived charisma and familiarity, at all levels of realism, and between charisma and comfort. Interestingly, more charisma was perceived in videos than in images. In addition, unrealistic characters were also perceived as more charismatic.***

In recent years, advances in computer graphics (CG) have allowed the entertainment industry to create very realistic virtual humans[1] in terms of animation of their bodies and faces.[2] In some movies, real actors have been replaced by CG characters (such as Disney's 2016 *Rogue One* movie, 2019 *Aladdin* movie, and 2020 *The Mandalorian* series), and often this substitution is not even perceived by the public; however, there are still some perceived artifacts, such as the movement of the mouth and eyes.[3] Avoiding these oddities can be important to generate a CG character more similar to a human being, making the experience of watching a movie, a game, or interacting with a character more fluid. Concerning characters with anthropomorphic traits, viewers' biggest complaints are generally related to the discomfort that these characters can generate. Specifically, about Luke Skywalker in *The Mandalorian*, Tarkin in *Rogue One*, and the Genius in *Aladdin*, people complained about the strangeness these characters conveyed.[a,b,c] However, they are considered adored and charismatic characters.

According to the dictionary, charisma is compelling attractiveness or charm that can inspire devotion in others and is very much linked to leadership.[4] According to Max Weber,[5] charisma is a type of authority, or domination, or leadership, which one person can exercise over another. According to Adair-Toteff,[6] Max Weber referred to authority as the likelihood that a specific group of people would obey an order with specific content. Many famous cartoon characters (with human anthropomorphic traits) are adored by children and adults (for example, Disney's Moana, and Elsa and Anna from *Frozen*), and just as in the definition of charisma, people generally follow all trends (e.g., products, clothing, party themes) about

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[a]https://thewrap.com/the-mandalorian-that-cgi-character-luke-skywalker-was-really-weird/
[b]https://www.quora.com/Why-does-Tarkins-CGI-in-Rogue-One-look-so-plastic-y-Could-they-have-made-it-look-more-realistic
[c]https://screenrant.com/aladdin-will-smith-genie-blue-bad-why/2/

these characters. However, is there a similar devotion to very realistic CG characters? Are they charismatic? If they are unknown, can they be charismatic too? Is there any lesson we can learn to provide more charismatic and attractive characters in games and movie productions?

The perception area is essential for CG since many techniques developed in the past were based on knowledge of how the human visual system interprets visual stimuli.[7] Human perception is also a theme present in many pieces of research in CG,[8,7] and it is considered very relevant when discussing the evolution of virtual humans and realistic faces. According to Mori,[9] robots made to appear too similar to real humans can fall into the uncanny valley (UV), where sometimes a high degree of human realism evokes an eerie feeling in the viewer. According to Tinwell *et al.*,[10] the technological advancements that help develop realistic characters is accompanied over the years by people's discernment about this content. With that, Tinwell *et al.* believed that the UV would never be surpassed since discernment can help people to observe the technical tricks better. The UV hypothesis on CG characters has become increasingly influential in scientific studies,[11,12] but some questions are still unanswered. In this work, we are particularly interested in the two following ones: 1) Are people feeling more comfortable with newer CG characters than older ones? 2) Are the perceived charisma and familiarity of virtual characters related to how comfortable the characters are perceived to be?

To answer these questions, we first recreated the experiment by Flach *et al.*[13] using the same questionnaire containing the same images and videos, as presented in 2012. Flach's work was chosen because the images and videos are still available and they present a varied origin (games, movies, and Internet). We compared people's perception nine years ago with recent perceptual data regarding the UV effect. We not only applied the same questionnaire[13] to allow a fair comparison, but also included images and videos of more recent characters. Our main goal is to observe the UV effect with the new characters compared to the ones from the previous work.[13]

We separated perceptual data into the following three groups.

1) Old characters ($O$), represented by images and videos that were used in Flach's work[13] in 2012;
2) new characters ($N$), which are also comprised by images and videos included in this work, but from the last six years;
3) all characters ($A$), i.e., the full set with old and new characters.

To make this text easier to read, we used $O$ and $N$ to represent the perceived stimuli in 2012 and 2020, respectively. Therefore, in the text, we used tuples to refer to the evaluated group of characters and the period of analysis; for example, $(O, O)$ represents old characters and stimuli evaluated in 2012. To answer the first question of our research, we proposed the following five null hypotheses:

- $H0_1$ defining that $(O, O) = (O, N)$, i.e., the perceptual data obtained in 2012 indicate similar comfort with data obtained in 2020, about the characters from 2012.
- $H0_2$ defining that $(O, O) = (A, N)$, i.e., the perceptual data obtained in 2012, w.r.t. 2012 data, indicate similar comfort with data obtained in 2020, concerning all characters (from 2012 and 2020).
- $H0_3$ defining that $(O, O) = (N, N)$, i.e., the perceptual data obtained in 2012, w.r.t. 2012 data, indicate similar comfort with data obtained in 2020, about new characters.
- $H0_4$ defining that $(O, N) = (N, N)$, i.e., the perceptual data obtained in 2020, w.r.t. 2012 data, indicate similar comfort with data obtained in 2020, about new characters. Also, we performed this hypothesis for realism, charisma, and familiarity with the character.
- $H0_5$ defining that variation of comfort (difference) $|(O_{\text{image}}, O) - (O_{\text{video}}, O)|$ is similar to $|(N_{\text{image}}, N) - (N_{\text{video}}, N)|$ and also similar with $|(A_{\text{image}}, N) - (A_{\text{video}}, N)|$, where $image$ and $video$ refer to specific domain instead of global data. In addition, we also performed this hypothesis for charisma and familiarity with the character.

To answer our second research question, we asked subjects about their familiarity with the characters and their perception regarding the characters' charisma.

The rest of this article is organized as follows. The section "Related Work" mentions some related work presented in the literature, and the section "Methodology" describes the proposed methodology. Results are detailed and discussed in the section "Results," whereas the section "Discussion" addresses final comments and future work.

## RELATED WORK

This section discusses existing work related to the analysis of UV effects caused by CG characters. The UV is a theory created by roboticist Masahiro Mori[9]

who analyzed the emotional reaction of humans to artificial beings. According to his theory, if robots have a high degree of realism close to real humans, they may fall into the UV, which can cause an eerie impression on the viewer. From Mori's seminal work, several other researchers have used the UV theory to measure artificial characters' discomfort (robots, CG characters). For example, Katsyri *et al.*[11] reinterpreted the original UV hypothesis and revisited empirical evidence for the theoretically motivated UV hypotheses. One of their findings suggested that UV exists only under specific conditions, such as inconsistencies in realism (e.g., artificial eyes on a humanlike face). In this work, we used the UV theory to measure comfort and perceived realism related to characters created using CG. In addition, as already mentioned, we also included the perceived charisma in our analysis.

Concerning the perception of CG characters, many papers have evaluated the same variables (and others) that we used in our work. For example, the work of Zell *et al.*[7] was essential to understand the perception process (i.e., how to create a stimulus, how to measure and evaluate perceptual data, etc.). They analyzed two traits of appearance: 1) shape and 2) material, and with the help of artists, they designed elaborate stimuli consisting of different stylization levels for both parameters. They analyzed how different combinations affect the perceived realism, appeal, eeriness, and familiarity. Also, the authors investigated how such combinations affect the perceived intensity of different facial expressions, and concluded that the shape of a character is relevant to its realism and expression. Chaminade *et al.*[14] investigated how the appearance of animated characters can influence the perception of their actions. The authors presented different animated characters with movement data captured from human actors or by interpolation between poses and asked the participants to categorize movement as biological or artificial. The results showed that the more anthropomorphic, the less biological bias the character had.

The effect of the UV theory on human perceptions of 3-D models also has been investigated by the CG community. MacDorman and Chattopadhyay[15] aimed to determine whether reducing realism in visual characteristics would increase the uncanny effect. The authors based themselves on the theory of inconsistency in realism, which states that an entity can cause the Valley without some characteristic of an anthropomorphic being. Schwind[16] conducted nine studies that examined the effects of UV on human perception, how it affects interaction with computer systems, what cognitive processes are involved, and the causes that may be responsible for the phenomenon. Hyde *et al.*[17] conducted two experiments showing how exaggerated facial movement influences the impressions of cartoons and more realistic characters, and stated that an essential factor in diminishing the sensation of strangeness is the attempt to replicate human expressions (body and facial) in CG characters. Ruhland *et al.*[18] used algorithms to synthesize real-time motion capture of human expressions with animation data created by designers. To validate synthesized animations, they conducted a perceptual study, and results indicated that the animations had an expressive similarity to animations made by hand.

Flach *et al.*[13] investigated the UV theory to evaluate its effects on the perception of CG characters used in movies, animations, and computational simulations. The authors evaluated the human perceptions about these characters through a questionnaire containing images and videos of these characters. In the present work, we recreated their experiment with the same questionnaire, and also the same images and videos of CG characters (shown in the sections "Methodology" and "Results"). In addition, we performed statistical analyses to compare our results as opposed to Flach's study, which did not include it.

Regarding the perceived charisma, we did not find papers that related UV, comfort, or realism with charisma concerning CG characters. However, we found similar studies related to robots. For example, MacDorman[19] has hypothesized that an uncanny robot can cause innate fear of death and create culturally supported defenses to deal with the inevitability of death. Concerning charisma, in one of the experiments the author showed speeches by two politicians, one charismatic and one relationship-oriented, and asked participants which candidate they would vote for. Participants who previously saw uncanny robots preferred more charismatic speeches than participants who previously saw a human being. Rosenthal-von der Pütten and Krämer[20] provided an overview and categorization of explanatory approaches to the UV effect. The authors presented images and videos of humanoid robots and uncanny androids to participants to explore their evaluations of robots, their attitudes about these robots, and their emotional reactions toward these robots. The results showed that the appearance of robots was important for participants since some characteristics matched specific skills. For example, participants described charisma as a human characteristic.

With regard to characters, according to West and Armstrong,[21] one of the ways to study the complexities of charisma is through fiction. Goethals and Allison[22] related charismatic characters to their appearances, citing as examples that Obi-Wan "Ben" Kenobi from *Star Wars* and Dumbledore from *Harry Potter* had archetypes of sages, which could increase the emotional impact on viewers. In terms of charismatic leadership, Awamleh and Gardner[23] reported the importance of vocal variety, eye contact, relaxed posture, and lively facial expressions. Riggio[24] already described charismatic individuals as animated, charged with emotion, and full of life. However, concerning CG characters, we found no work related to charisma.

## METHODOLOGY

This article revisits the UV theory to observe its effect on people's perception regarding CG characters. This section is divided into three parts: 1) the section "Characters" presents all characters used in this work. 2) The section "Questionnaire" presents the proposed questionnaire related to comfort, realism, charisma, and familiarity. 3) Finally, the section "Creating the Comfort Chart" defines how the comfort chart is modeled in our work.

### Characters

To try to answer our first research question—"Are people feeling more comfortable with newer CG characters than older ones?," we reproduced the work of Flach *et al.*[13] Therefore, we use the same set of 10 characters, comprised of images and videos, which are listed in Figure 1(a)–(j). In addition to the characters from 2012, we added 12 CG characters that were created within the last six years, shown from (k) to (v). With these data, as proposed by Flach *et al.*,[13] we evaluated the human-likeness criterion, which contributes to the order the characters are placed in the horizontal axis of the UV chart (detailed in the section "Creating the Comfort Chart"). To ensure the variation of human-likeness, we chose some characters that could represent a human being more realistically, as shown in the cases (k), (p), (t), and (v) in Figure 1. Therefore, we needed characters that escape from realism (i.e., stylized, unrealistic, badly designed, etc.), counteracting the others cited earlier, such as the cartoon characters shown in Figure 1(m), (q), (s), and (u). This counterpoint is necessary to form the horizontal axis of the UV chart. All pictures and movies were obtained from the YouTube platform. We limit our search to videos with large amounts of views and descriptions that contain copyright to avoid amateur videos.[d]

In addition to the realism factor, we follow other restrictions as proposed by Flach *et al.*[13] concerning the choice of each character.

1) The character has to represent a human being (i.e., avoiding animals, for instance).
2) It should not be placed in an unreal place.
3) The character should wear normal (and not) minimal clothes to avoid distortions in perceptions.
4) The scene should be focused on the character's face so that the participants could catch the movement of the mouth, the eyes, among other expressions.

All of these restrictions were used to avoid possible negative influences on human perceptions. Regarding people's familiarity with the tested characters, we chose characters that can be considered known to the general public (e.g., from movies) as characters (l, m, n, o, q, s, u), as done in the work by Flach *et al.*[13] Furthermore, we also included little-known characters, e.g., k, t, and v, as in the work by Flach *et al.*[13]

### Questionnaire

First, as we wanted to compare human perceptions about CG characters with the results obtained by Flach *et al.*,[13] we used the same structure of five questions, as presented in Table 1. Following this structure, we used questions with categorical answers, where Q2 and Q5 are explicitly used to build the comfort chart. Q2 is the only one with three possible answers (based on Likert scales with three scores), and it is used to measure the participants' perception of realism regarding the characters. Q2 answers are used to define the order the characters in the comfort chart (*X*-axis). Q5 aims to measure the perceived comfort quantitatively and indicates values in the chart (*Y*-axis). The entire questionnaire was assembled using Google Forms, and before answering the survey, participants received no explanation about the original intent of the research. This was done to avoid any type of influence on the participants' responses. We used demographic and CG familiarity questions to try to avoid bias. Also, we follow the ethical guidelines for applying the questionnaire, where all participants were asked if they agreed to grant access to their answers and personal information to our survey regarding age, gender, educational level, and familiarity with CG.

[d]Copyrighted images reproduced under "fair use policy."

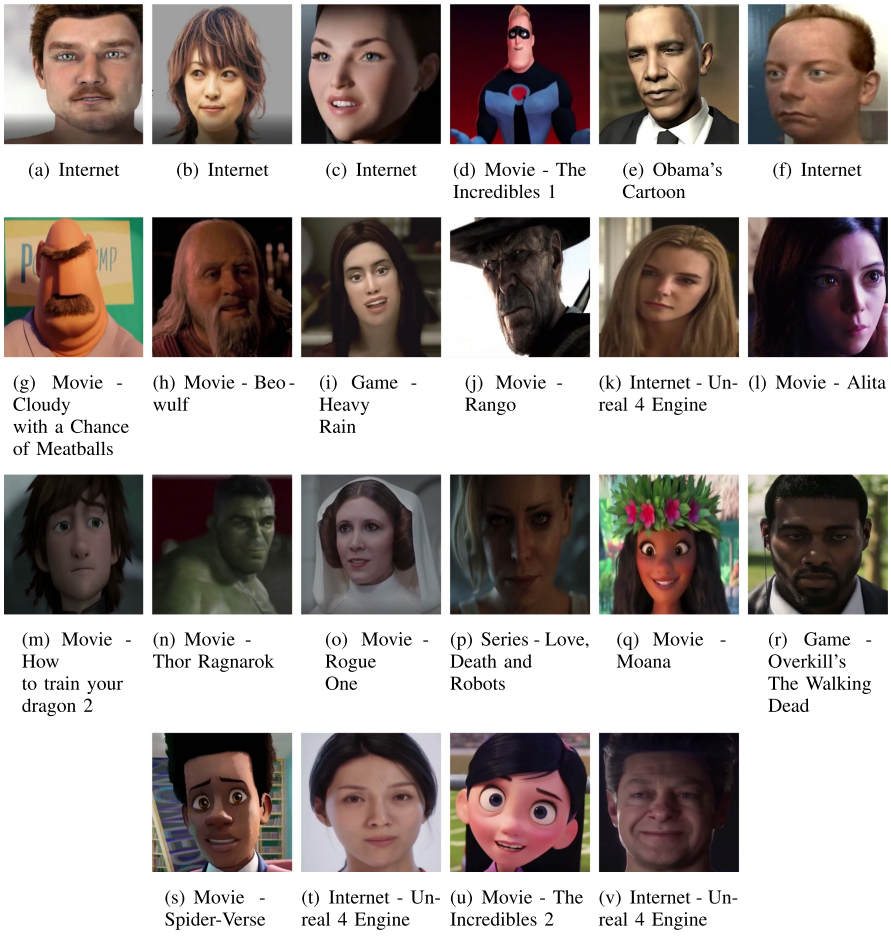



**FIGURE 1.** All characters used in this work. From (a) to (j), there are the characters used in the work of Flach *et al.*,[13] and from (k) to (v), there are the most recent characters added in this article (all the characters' pictures and short sequences have been taken from YouTube videos).

The process was divided into two steps, in which the presented characters (from Figure 1) were selected randomly. In the first step, an image of each character was shown before all five questions, as referred to in Table 1. In the second step, performed just after the first step, a video of each character was shown before asking the same five questions. These steps evaluate people's comfort level when observing characters in the pictures, where they are static, and also in the videos, where characters are moving (animations). The level of comfort is asked in question Q5, as shown in Table 1.

## Creating the Comfort Chart

As mentioned before, the comfort chart is represented by a 2-D plot, where the *X*-axis indicates the level of character realism from less to more realistic (from left

**TABLE 1.** Questions regarding human perception applied to the participants.

| Question | Possible answers |
|---|---|
| **Q1**: Do you think that the character in the picture/video above is: | *a*) A real person |
| | *b*) Created using CG |
| **Q2**: If created using CG, how realistic does it seem? | *a*) Very realistic |
| | *b*) Moderately realistic |
| | *c*) Unrealistic |
| **Q3**: Do you know this character? | *a*) Yes |
| | *b*) No |
| **Q4**: How do you would describe it? | *a*) Charismatic |
| | *b*) Non charismatic |
| **Q5**: Do you feel some discomfort (strangeness) looking to this character? | *a*) Yes |
| | *b*) No |

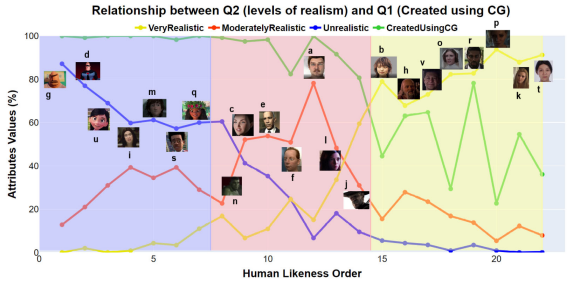



**FIGURE 2.** Our final order of the Human Likeness axis (horizontal) is presented. The vertical axis shows the percentage of answers "unrealistic," "moderately realistic," "very realistic" (Q2); and "created using CG" (Q1) of each character, respectively, represented by the blue, red, yellow, and green lines. In addition, the background of each group of realism is highlighted using the same colors used in the captions of Q2's answers.

to right, having higher values for realism on the right). The *Y*-axis defines the perceived comfort (%) of people when watching the characters. It goes from less to more comfortable, where less comfortable is associated with small values in the *Y*-axis. We used only positive values in both axes.

To define the order the characters in the horizontal axis, we used the averages of scores of Q2 answers. Thus, each character presents an average value of realism. As a result, the Human Likeness axis is shaped by the increasing order of each character's realism value. In addition to such analyses, we wanted to compare characters through levels of realism. According to Katsyri *et al.*,[11] at least three levels of human similarity are necessary for comparisons between them regarding the levels of realism. We divided characters into the three levels of realism based on the three possible answers from Q2 (i.e., "unrealistic," "moderately realistic," and "very realistic") according to the following rule:

1) characters defined as unrealistic when having realism values $\leq 1.5$;
2) characters defined as moderately realistic when having values of realism $\leq 2.5$;
3) characters defined as very realistic when presenting realism values $> 2.5$.

Figure 2 shows the final order of the 22 images in *X*-axis, and the average percentages of answers "unrealistic" (blue line), "moderately realistic" (red line), and "very realistic" (yellow line) of all characters on the *Y*-axis. The green line represents the percentages of answers "created using CG" (Q1 in the form) of all characters. Therefore, it is interesting to see that on the right side of Figure 2, subjects seem to be more confused when asked to define whether or not the very realistic characters were created using CG.

Once we generated the horizontal axes data, we used the perceived comfort to compose our comfort chart. The vertical axis (Comfort) is given by the percentage of the "No" answers to Q5, which yields larger values if the character presents more comfort. The following section presents our analysis.

## RESULTS

The results discussed in this section were obtained with the questionnaire shown in the section "Methodology." The questionnaire was applied on social networks, and all participants were volunteers. It was answered by 119 participants, from which 42% were women and 58% men; 77.3% were at most 30 years old, 63.8% had completed high school, and 68.1% were familiar with CG.[e] The experiment (project number—46571721.6.0000.5336) was conducted with ethics approval from the Research Ethics Committee (Comitê de Ética em Pesquisa—CEP) of Pontifical Catholic University of Rio Grande do Sul, Brazil. In all statistical analyses, we used 5% of significance level (paired and independent *T*-tests, and *Chi-square* test). In addition, we used terminology as defined before by using tuples where the first element is related to the data and the second to the perception. For example, $(O, N)$ represents data acquired in 2012 (Old characters) and evaluation performed in 2020 (New evaluation). Table 3 presents all data used in this work, and the next sections discuss our analysis.

### Analysis of Perceived Realism of CG Characters

As shown in the section "Methodology," Q2 evaluates realism through responses using 3-Likert scales. With that, each character had an average value of perceived realism, as shown in ascending order in the last column of Table 2, that is, following the order of human likeness. In addition, we also computed the average of perceived realism for each group of characters, i.e., $A, N$, Old, and New, and according to the levels of realism (Unrealistic, Moderately Realistic, and

[e]Flach's work does not contain demographic data, so we could not compare it with our results.

**TABLE 2.** All data (comfort, charisma, familiarity, and realism) in images and videos (data obtained in Flach's work presented as Old, comfort obtained in our work presented as New) of all characters.

| Character Id | Character Figure | Image Comfort Old | Video Comfort Old | Image Comfort New | Video Comfort New | Image Charisma New | Video Charisma New | Image Familiarity New | Video Familiarity New | Image Realism New |
|---|---|---|---|---|---|---|---|---|---|---|
| g |  | 61% | 63% | 52.1% | 57.98% | 15.12% | 34.45% | 63.02% | 56.3% | 1.10 |
| d |  | 88% | 86% | 84.87% | 83.19% | 84.03% | 79.83% | 92.43% | 91.59% | 1.23 |
| u |  | - | - | 67.22% | 78.15% | 73.94% | 81.51% | 73.1% | 72.26% | 1.29 |
| i |  | 29% | 31% | 24.36% | 32.77% | 26.05% | 31.09% | 3.36% | 2.52% | 1.38 |
| m |  | - | - | 88.23% | 87.39% | 84.87% | 89.07% | 80.67% | 81.51% | 1.39 |
| s |  | - | - | 89.07% | 84.03% | 78.99% | 78.99% | 48.73% | 48.73% | 1.43 |
| q |  | - | - | 94.95% | 90.75% | 94.11% | 94.11% | 78.99% | 78.99% | 1.49 |
| n |  | - | - | 71.42% | 65.54% | 54.62% | 58.82% | 96.63% | 93.27% | 1.56 |
| c |  | 50% | 53% | 26.89% | 45.37% | 37.81% | 52.94% | 2.52% | 2.52% | 1.65 |
| e |  | 74% | 73% | 65.54% | 59.66% | 63.86% | 68.9% | 83.19% | 80.67% | 1.75 |
| f |  | 35% | 34% | 35.29% | 33.61% | 10.08% | 19.32% | 2.52% | 0.84% | 1.91 |
| a |  | 27% | 12% | 41.17% | 32.77% | 39.49% | 47.89% | 1.68% | 1.68% | 2.08 |
| l |  | - | - | 37.81% | 53.78% | 46.21% | 68.06% | 31.93% | 36.13% | 2.1 |
| j |  | 65% | 63% | 77.31% | 67.22% | 6.72% | 9.24% | 21.84% | 14.28% | 2.43 |
| b |  | 70% | 33% | 68.9% | 46.21% | 70.58% | 57.14% | 3.36% | 2.52% | 2.5 |
| h |  | 88% | 78% | 73.1% | 76.47% | 47.05% | 42.01% | 14.28% | 11.76% | 2.54 |
| v |  | - | - | 79.83% | 68.9% | 47.89% | 33.61% | 15.96% | 16.8% | 2.6 |
| o |  | - | - | 92.43% | 86.55% | 84.03% | 84.03% | 71.42% | 71.42% | 2.67 |
| r |  | - | - | 81.51% | 88.23% | 21.84% | 34.45% | 6.72% | 3.36% | 2.72 |
| p |  | - | - | 91.59% | 91.59% | 21.84% | 50.42% | 17.64% | 14.28% | 2.73 |
| k |  | - | - | 91.59% | 87.39% | 54.62% | 61.34% | 1.68% | 0.84% | 2.78 |
| t |  | - | - | 85.71% | 72.26% | 55.46% | 72.26% | 4.2% | 5.04% | 2.79 |

Obs: All values are percentages, except the last column (realism), which are averages.

**TABLE 3.** Results of perceived comfort, charisma, and realism (image and video for the first two, and only image for the last) of characters, in 2012 ($O$) and 2020 ($N$), and standard deviation values.

| Dataset Comfort | Evaluation Time | Percentage All | Standard Deviation (SD) | Percentage Unrealistic | Standard Deviation (SD) | Percentage Moderately Realistic | Standard Deviation (SD) | Percentage Very Realistic | Standard Deviation (SD) |
|---|---|---|---|---|---|---|---|---|---|
| $O_{image}$ | $O$ | 58.70% | 22.72% | 59.33% | 29.53% | 50.2% | 19.71% | 79% | 12.72% |
| $O_{video}$ | $O$ | 52.60% | 24.12% | 60% | 27.62% | 47% | 24.3% | 55.5% | 31.81% |
| $O_{image}$ | $N$ | 54.95% | 21.95% | 53.78% | 30.28% | 49.24% | 21.28% | 71% | 2.97% |
| $O_{video}$ | $N$ | 53.52% | 18.34% | 57.98% | 25.21% | 47.73% | 15.41% | 61.34% | 21.39% |
| $N_{image}$ | $N$ | 80.95% | 16.06% | 84.87% | 12.13% | 71.42% | 37.81% | 87.11% | 5.56% |
| $N_{video}$ | $N$ | 79.55% | 11.93% | 85.08% | 5.37% | 59.66% | 8.31% | 82.49% | 9.43% |
| $A_{image}$ | $N$ | 69.13% | 22.74% | 67.64% | 25.6% | 50.78% | 20.07% | 83.08% | 8.88% |
| $A_{video}$ | $N$ | 67.72% | 19.86% | 70.58% | 20.88% | 51.14% | 14.28% | 77.20% | 14.99% |
| **Dataset Charisma** | **Evaluation Time** | **Percentage All** | **Standard Deviation (SD)** | **Percentage Unrealistic** | **Standard Deviation (SD)** | **Percentage Moderately Realistic** | **Standard Deviation (SD)** | **Percentage Very Realistic** | **Standard Deviation (SD)** |
| $O_{image}$ | $N$ | 40.08% | 26.48% | 41.73% | 37.03% | 31.59% | 23.57% | 58.82% | 16.63% |
| $O_{video}$ | $N$ | 44.28% | 21.73% | 48.45% | 27.22% | 39.66% | 24.68% | 49.57% | 10.69% |
| $N_{image}$ | $N$ | 59.87% | 23.81% | 82.98% | 8.66% | 50.42% | 5.94% | 47.61% | 23.51% |
| $N_{video}$ | $N$ | 67.22% | 20.09% | 85.92% | 6.94% | 63.44% | 6.53% | 56.02% | 20.37% |
| $A_{image}$ | $N$ | 50.87% | 26.45% | 60.5% | 31.31% | 36.97% | 21.46% | 50.42% | 21.48% |
| $A_{video}$ | $N$ | 56.79% | 23.46% | 65.82% | 25.92% | 46.45% | 23.41% | 54.41% | 17.93% |
| **Dataset Realism** | **Evaluation Time** | **Average All** | **Standard Deviation (SD)** | **Average Unrealistic** | **Standard Deviation (SD)** | **Average Moderately Realistic** | **Standard Deviation (SD)** | **Average Very Realistic** | **Standard Deviation (SD)** |
| $O_{image}$ | $N$ | 1.86 | 0.52 | 1.24 | 0.13 | 1.96 | 0.3 | 2.52 | 0.02 |
| $N_{image}$ | $N$ | 2.13 | 0.64 | 1.4 | 0.08 | 1.83 | 0.38 | 2.71 | 0.07 |
| $A_{image}$ | $N$ | 2.01 | 0.59 | 1.33 | 0.13 | 1.93 | 0.3 | 2.67 | 0.1 |

For both comfort and charisma, we used percentages, whereas for realism, we used averages.

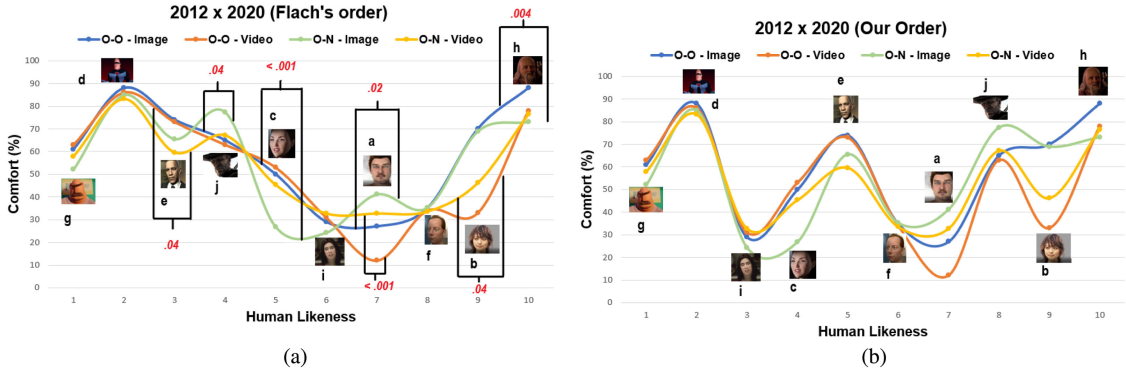
Very Realistic), as shown in the last three lines of Table 3. With these data, we performed two types of statistical analysis with these values: 1) between levels of realism (for example, unrealistic $\times$ moderately realistic), in order to assess the differences between the groups of perceived realism; and 2) between the groups, $(N, N)$ and $(O, N)$, in order to compare the perceived realism between old and new characters. In all of these analyses, we used an independent *T*-test. With respect to all characters $(A, N)$, we found significant *p*-values in all comparisons ($< 0.001$ for Unrealistic $\times$ Moderately Realistic, $< 0.001$ for Unrealistic $\times$ Very Realistic, and $< 0.001$ for Moderately Realistic $\times$ Very Realistic). Therefore, *for all characters, we can say that all groups of realism were different from each other.* Regarding the old characters $(O, N)$, we only found no significant result in the comparison between the groups Moderately Realistic and Very Realistic (0.009 for Unrealistic $\times$ Moderately Realistic, and 0.001 for Unrealistic $\times$ Very Realistic). Therefore, *for old characters, we can only say that the Unrealistic group was different from the other two.* In the case of the new characters $(N, N)$, we only found no significant result in the comparison between the groups Unrealistic and Moderately Realistic ($< 0.001$ for Unrealistic $\times$ Very Realistic, and $< 0.001$ for Moderately Realistic $\times$ Very Realistic). Therefore, *for new characters, we can only say that the group of Very Realistic was different from the other two.* In the comparisons between $(O, N)$ and $(N, N)$ (i.e., $H0_4$), we only found a significant result between the Very Realistic groups (0.01). With that, looking at the averages in Table 3, *we can say that new characters from the Very Realistic group were considered more realistic than the old characters from the Very Realistic group.*

## Analysis of Perceived Comfort of CG Characters

### *Comparing $(O, O)$ and $(O, N)$ by Character*

First, it is essential to mention that Flach's work used another ordering criterion for the Human Likeness axis, based on the evaluation performed in 2012. We compared the two ordering schemes in Figure 3, where (a) shows both evaluations performed in 2012 and 2020 concerning data from 2012, using Flach's order. On the other hand, Figure 3(b) shows the same data but using our order. When comparing the two orders, it is interesting to note that only characters (g) and (d) (the first two characters in the two charts) remained in the same positions. The characters (j) and (i) were the ones that moved the most, the first being in the fourth position in Flach's work, becoming more realistic in perception in 2020, whereas the second dropped three positions. Also, one can see that the Valley is present in Figure 3(a) (Flach's order), whereas in (b), there was more than one Valley. While Flach[13] defined the order on (*X*-axis) based on data observed in 2012, we used scores from Q2 answers, as evaluated in 2020.

Regarding comfort analysis in Figure 3, comparing only images, the green line (evaluation in 2020) was




(a) (b)

**FIGURE 3.** All the characters used in the work of Flach *et al.*[13] with Flach's order in (a), and our order in (b). Both blue and orange lines, in (a) and (b), represent the percentages of comfort of each character in image and video, as perceived in 2012. The green and yellow lines represent the same in (b), however, evaluated in 2020. In addition, in (a), we can see the significant results (highlighted in red) of the comparisons of the characters perceived in 2012 and 2020 (the results related to images were above the lines, the results related to videos were below the lines).

only above the blue line (evaluation in 2012) in characters (a) and (j), i.e., the perceived comforts of all other characters have decreased or remained the same, over the years. Assuming that perception responses from 2012 and 2020 are independent data, we used the *Chi-square* test and evaluated perceived comfort in image and video for each character. In Figure 3(a), in the part above the lines, the significant results (highlighted in red) of the differences between characters from 2012 and 2020 in images are presented, whereas the significant results of the videos are presented below the lines. In addition, as we can also see in Table 2, characters (c) and (h) were more comfortable in 2012 and (a) and (j) were more comfortable in 2020. In videos, character (e) was more comfortable in 2012, and characters (a) and (b) were more comfortable in 2020. In conclusion, *only 4/10 characters present differences in perceptual data in images, and 3/10 in the video, and only one in both media.*

### *Comparing* $(O, O)$ *and* $(O, N)$*, Globally*

Regarding our hypothesis $H0_1$ (($O, O$) = ($A, N$)), we performed a paired *T*-test to compare perceptual comfort percentages assessed in 2012 and 2020 (shown in Table 3). However, we did not find any significant results (image and video), i.e., *in general, the comfort perceived by the participants is similar when comparing the assessments made in 2012 and 2020 concerning the old characters.*

In another analysis, we used an independent *T*-test to compare comfort ratings for each level of realism ("Unrealistic," "Moderately Realistic," and "Very Realistic") separately. As Flach's work did not provide levels of realism, we only used our order (Human Likeness) in this analysis. However, we did not find any significant results. With that, *we can say that both in 2012 and in 2020, the perceived comfort about characters from 2012 was not influenced by levels of realism.*

### *Comparing* $(O, O)$ *and* $(A, N)$

Comparing the perceived comfort between the 10 characters in 2012 and 22 characters in 2020 ($H0_2$) (all characters shown in Figure 5), no significant *p*-values were obtained (for image or video). Hence, *the results indicated that considering old and new characters, people in 2020 felt as comfortable as people in 2012 about old characters.* We also used the independent *T*-test for the analysis of all characters ($A, N$) at different levels of realism. In this case, we found significant results in the comparisons between moderately realistic and very realistic characters (0.001 in images and 0.004 in videos), and between unrealistic and moderately realistic characters (0.03 in images). Therefore, *we can say that for all characters, in image analysis, people felt more comfortable with very realistic characters than with moderately realistic ones. In videos, people felt more comfortable with unrealistic and very realistic characters than with moderately realistic ones.* These conclusions are in accordance with Mori,[9] in the UV theory.

### *Comparing* $(O, O)$ *and* $(N, N)$

Regarding $H0_3$ (($O, O$) = ($N, N$)) (new characters shown in Figure 4), we also used an independent *T*-test to measure the difference between the obtained comfort percentages (shown in Table 3), and obtained

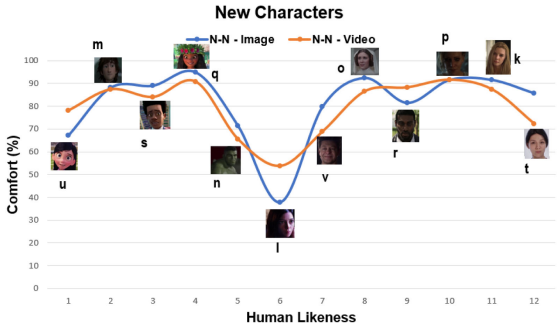



**FIGURE 4.** Recent characters evaluated in this work. The blue and orange lines represent the comfort percentages of each of the new characters w.r.t. image and video.

the significant *p*-values 0.01 (images) and 0.002 (videos). As the comfort perceived in 2020 was superior to the one reported in 2012, *we can conclude that people in 2020 felt more comfortable with current characters than people in 2012 with characters from 2012 (at that time).* Regarding levels of realism for $(N, N)$, we found significant results in the comparisons between moderately realistic and very realistic characters (0.01 in images and 0.02 in videos), and between unrealistic and moderately realistic characters (0.009 in images). Therefore, *we can say that for new characters, in the analysis of images, people felt more comfortable with very realistic characters than with moderately realistic characters. In the videos, people were more comfortable with unrealistic and very realistic characters than with moderately realistic characters.* As for $(A, F)$, these conclusions were in accordance with the UV theory.

### *Comparing* $(O, N)$ *and* $(N, N)$

Regarding $H0_4$, we also used independent *T*-test, and

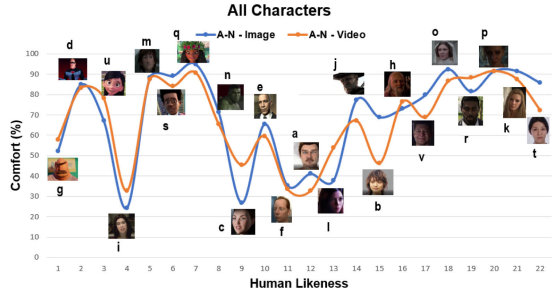



**FIGURE 5.** All characters evaluated in this work. Characters (g), (d), (i), (a), (e), (c), (f), (j), (h), and (b) were the 10 characters that were also evaluated in 2012.[13] The blue and orange lines represent the comfort percentages of each character analyzed in 2020.

again obtained significant *p*-values (0.004 for images and $< 0.001$ for videos). Hence, *we can conclude that people are more comfortable with the new characters than with the old ones.* In the analysis of the three levels of realism in $H0_4$, we found a significant difference between very realistic characters (0.009 in images) through the independent *T*-test. With that, *we can say that people in 2020 felt more comfortable with very realistic new characters than with very realistic characters from 2012.*

### *Comparing Movement Effect in the Perceived Comfort Between 2012 and 2020*

To measure the theory of movement proposed by Mori,[9] we defined $H0_5 : |(O_{\text{image}}, O) - (O_{\text{video}}, O)| = |(N_{\text{image}}, N) - (N_{\text{video}}, N)| = |(A_{\text{image}}, N) - (A_{\text{video}}, N)|$, that is, the difference between image and video comfort perception is similar over the years. The difference modules of comfort between image and video, for each one of the performed analysis, are as follows:

1) $|(O_{\text{video}}, O) - (O_{\text{image}}, O)| = 7.5\%$, (SD = 11.34%);
2) $|(A_{\text{video}}, N) - (A_{\text{image}}, N)| = 7.75\%$, (SD = 5.82%);
3) $|(O_{\text{video}}, N) - (O_{\text{image}}, N)| = 8.65\%$, (SD = 6.96%);
4) $|(N_{\text{video}}, N) - (N_{\text{image}}, N)| = 7\%$, (SD = 4.87%).

To test $H0_5$, we used paired *T*-test, but we did not find any significant results. Concerning the three levels of realism, we also found no significant results for these analyzes. So, it indicates that the characters' motion (videos) did not influence the perceived comfort, contrary to Mori's movement theory.

## Analysis of Perceived Charisma of CG Characters

We also performed statistical analysis to compare percentages of charisma for each level of realism separately, to compare $H0_4$ ($(O, N) = (N, N)$), and to compare charisma perceived in image and video ($H0_5$). Regarding levels of realism, we only found significant results in $(N, N)$, in the comparisons between the unrealistic level and the moderately realistic (0.009 in images and 0.01 in videos) and very realistic levels (0.02 in images and 0.02 in videos). With that, analyzing the percentages in Table 3, *we can say that people perceived more charisma in the new unrealistic characters than in the other realism groups of new characters.* In all comparisons of $H0_4$, we only found a significant result when we compared all characters (0.01) and the unrealistic groups (0.04 in videos). Therefore, *we can say that people perceived more charisma in new characters than in old characters (in videos), mainly in unrealistic characters (in videos too).* Regarding $H0_5$, we found significant results in

$(A, N)$ (0.01 in all characters without separating groups of realism and 0.01 in moderately realistic characters) and in $(N, N)$ (0.04 also in all characters and 0.01 in moderately realistic characters). So, *we can say that people perceived more charisma in videos than in images, both concerning $(A, N)$ (all characters and moderately realistic characters) and with $(N, N)$ (also all characters and moderately realistic characters).*

### *Correlating Comfort and Charisma*

To answer the question "Is the perceived charisma and familiarity of virtual characters related to how comfortable the characters are perceived to be?," we first investigated the correlation between comfort (Q5) and charisma (Q4). The charisma and comfort percentage values for each character are shown in Table 2, and we used *Pearson's correlation* to measure the relationship between charisma and comfort. The correlation obtained for images was 0.5059, and for video was 0.5029. Therefore, *we can confirm that comfort and charisma are directly correlated, even the values are not very high.* We also measured the correlations between comfort and charisma using three levels of realism (data presented in Table 3). The exciting thing is that we only found high values of correlation between charisma and comfort for unrealistic characters (0.88 in images and 0.94 in videos), and *this result indicates that the more people perceive charisma in an unrealistic character, the more comfortable they feel about this character.*

### *Additional Analysis of Perceived Charisma*

In addition to charisma, following Awamleh and Gardner,[23] a question was also opened: "Is the perceived charisma represented by a character's facial expression?" In addition to the characters' charisma analysis, we measured virtual characters' facial emotions to relate them with their charisma. We used *OpenFace*,[25] free open-source face-recognition software that uses deep neural networks to capture features and up to 17 action units[26] (AU—facial expressions) on images and videos. Using *OpenFace*, we are able to obtain the intensity of each action unit on each image in the interval $[0; 100]$. For each virtual character viewed in Figure 1, we executed *OpenFace* and processed the AUs activated in Happiness as the only positive emotion, and in Fear, Angry, and Disgust as the negative emotions. We used the percentage value of all active AUs for each of these mentioned emotions, and included this analysis because we wanted to evaluate if the perceived charisma was affected by a character's facial expression.

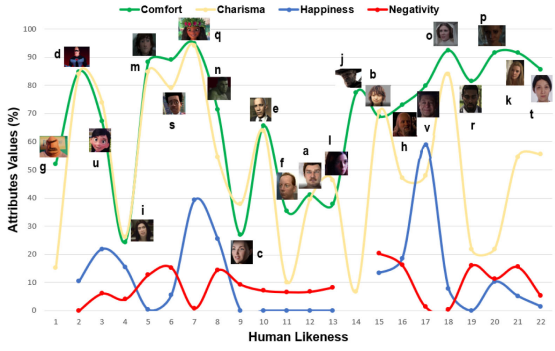



**FIGURE 6.** Charts show the attributes values obtained in images in the *Y*-axis and our order of the characters based on human likeness in the *X*-axis. The attributes values used are charisma (yellow line), comfort (green line), happiness (blue line), and negativity (red line). Each character was represented by a point on each of these lines.

Figure 6 shows the values of charisma, comfort, happiness, and negative emotions obtained for all 22 characters[f] evaluated in this work. As we expected, the facial expressions of almost all characters, as detected by *OpenFace*, seem more neutral than highly negative or positive, not only when analyzing the *OpenFace* result but also when doing a visual inspection. The highest value obtained of happiness was from character (v). Even with that, some characters had more than 75% of charisma values and some characters less than 25%. *It indicates that facial expressions did not influence the classification of the charisma of the characters in this work.*

## Analysis of Perceived Familiarity of CG Characters

Regarding familiarity with characters, we also performed statistical analysis to compare percentages of familiarity for each level of realism separately, $H0_4$ analysis ($(0, N)$ = $(N, N)$), and analysis between image and video ($H0_5$). Regarding the comparisons between the levels of realism, we found significant results in $(A, N)$ (0.004 in images and 0.005 in videos) and $(N, N)$ (0.008 in images and 0.008 in videos) in the comparisons between the unrealistic and very realistic levels. So, *we can say that people were more familiar with unrealistic characters than very realistic characters, both in $(A, N)$ and in $(N, N)$.* In $H0_4$, we did not find any significant results. Regarding $H0_5$, we found

[f]Two characters (g and j) were not recognized in *OpenFace* so we did not have information about their AUs.

significant results in $(A, N)$ (0.02 in all characters without separation into groups of realism) and in $(N, N)$ (0.02 also in all characters). So, *we can say that people were more familiar with characters in images than in videos, both in* $(A, N)$ *and* $(N, N)$.

### *Correlating Comfort and Familiarity With Characters*

We also investigated the correlation between comfort and familiarity with the evaluated characters. As in the charisma section, we calculated the percentage of people who answered "YES" in Q3, but in this case, to know if the subjects knew the character. The values of percentage of familiarity for each character are shown in Table 2, and values of general percentages and levels of realism are shown in Table 3. We use *Pearson's correlation* to measure the relationship between familiarity and comfort. The correlation in the images is 0.35, and in the videos is 0.41, i.e., both variables seem to be weakly correlated. Therefore, *we cannot say that there is a correlation between comfort and familiarity with characters*. Regarding levels of realism, we found correlations between comfort and familiarity at the unrealistic (0.78 in images and 0.87 in videos) and moderately realistic (0.68 in images and videos) levels.

In another analysis, we also decided to measure the correlation between charisma and familiarity. For both image (0.59) and video (0.65), *the correlation between charisma and familiarity was strong*. Regarding the levels of realism, we found correlations between charisma and familiarity at the levels of unrealistic (0.64 in images and 0.76 in videos), moderately realistic (0.68 in images and 0.58 in videos), and very realistic (0.54 in videos) characters.

## DISCUSSION

This section discusses our main findings when testing our selected characters with 119 participants. We start with the findings about *perceived realism*.

- For ALL characters, all groups of realism are significantly different.
- Very realistic group from NEW characters is more realistic than very realistic group from OLD characters.

We can conclude that people perceive the different levels of realism, and also can assess the difference between the very realistic groups in 2012 and 2020. The recommendation here is that we can invest, if there are resources, to provide very realistic characters because people will have this qualitative assessment.

Regarding the *perceived comfort*, comparing ALL, NEW, and OLD characters, we observed the following.

- For OLD characters, all subjects, in 2012 and 2020, perceived similar comfort, and it was not impacted by the level of realism, i.e., $(O, O) = (O, N)$, so we confirm $H0_1$.
- People evaluated in 2020 felt similar comfort w.r.t. ALL characters, as people in 2012 about OLD characters, i.e., $(O, O) = (A, N)$, so we confirm $H0_2$.
- In 2020, people felt more comfortable with current characters than people in 2012 with characters from 2012 (at that time), i.e., $(O, O) < (N, N)$, so we refuse $H0_3$.
- In 2020, people felt more comfortable with current characters than with characters from 2012, i.e., $(O, N) < (N, N)$, so we refuse $H0_4$. Besides, in 2020, people felt more comfortable with very realistic characters from 2020 than those from 2012.
- We did not find any significant results concerning the comparison between comfort in images and videos, globally and with different levels of realism, in 2012 and 2020, so we confirm $H0_5$.

Based on tested evaluations, we can confirm that perceived comfort in 2020 is higher than that in 2012 when evaluating OLD and NEW characters. So designers can invest in more advanced resources to model the characters. However, it is also interesting to see that the comfort perceived w.r.t. 2012 characters did not change as a function of time. We speculate that even if the audience can perceive the improvement in realism and comfort, OLD likewise characters can still cause comfort. Hence, designers have a wider range of possibilities, e.g., from advanced to not so advanced techniques to model the characters, which can be good news to those designers that do not have many resources. Still regarding the *perceived comfort*, comparing image and video stimuli, we observed the following.

- For ALL characters, in image analysis, people felt more comfortable with very realistic and unrealistic characters than with moderately realistic ones. In videos, people felt more comfortable with unrealistic and very realistic characters than with moderately realistic ones.
- For NEW characters, in image analysis, people felt more comfortable with very realistic and unrealistic characters than with moderately realistic characters. However, only between very

realistic and moderate characters a significant difference exists. In the videos, people were more comfortable with unrealistic and very realistic characters than with moderately realistic characters.

These results align with expectations of the UV theory in terms of perceived comfort, being higher in very realistic and unrealistic characters than that in moderately realistic. However, we could not see the expected difference in terms of comfort obtained in videos and images, as suggested by Mori.[9] Regarding the *perceived charisma*, we observed the following.

- People in 2020 perceived more charisma in NEW characters than in OLD characters (in videos), mainly in unrealistic characters (in videos too).
- Comfort and charisma are directly correlated, even if the values are not very high.
- Facial expressions did not influence the classification of the charisma of the characters in this work.
- For ALL and NEW characters, people perceived more charisma in videos than in images.

It is interesting to see that people perceive more charisma in new characters than in old ones, and the perceived charisma is higher in videos than in images. So, charisma is connected with motion. In addition, facial expressions do not impact the charisma in the evaluated characters. Furthermore, regarding the *perceived familiarity*, the following are our findings.

- In 2020, people are more familiar with unrealistic characters than very realistic characters, both in the groups of ALL and NEW characters.
- In 2020, people are more familiar with characters in images than in videos, both in the groups of ALL and NEW characters.
- There is no correlation between comfort and familiarity.
- There is a positive correlation between charisma and familiarity.

Although there is no correlation between comfort and familiarity, it is interesting to see that familiarity correlates with charisma. Also, while people perceive more comfort in unrealistic and very realistic characters, charisma is more present in unrealistic characters. We believe that to convey charisma and comfort, designers (and the industry, generally) can focus on cartoon and unrealistic characters. Very realistic characters can be comfortable, but it may be more difficult for them to convey charisma. With the correlations between charisma and familiarity, we can also see that characters more familiar to the public were more charismatic. Maybe it happens because the image/video brings the context of the character. For example, Leia (o) was the only very realistic character with high charisma and familiarity values. Although it is only one character and more analyses are needed, it is an indication that the industry can think about focusing on transmitting charisma in very realistic characters through famous actors, as LucasFilm did with Leia and Tarkin in *Star Wars Rogue* One movie and, recently, Luke Skywalker in *The Mandalorian* series. As suggested by Goethals and Allison,[22] the appearances of the characters can have an emotional impact on viewers. In the cases of the characters mentioned, the familiarity of these characters may have impacted the feeling of comfort.

## FINAL CONSIDERATIONS

This article proposes a set of experiments to evaluate how people perceive CG characters in the contexts of still images and animations. In this work, we tried to answer the following questions: 1) Are people feeling more comfortable with newer CG characters than older ones? and 2) Is the perceived charisma and familiarity of virtual characters related to how comfortable the characters are perceived to be? To answer these questions, we reproduced the same experiment done by Flach *et al.*[13] in 2012, in which the authors revisited the UV theory to study such impact on CG characters. Regarding our first research question, we had two main results: 1) For OLD characters, all subjects, in 2012 and 2020, perceived similar comfort and it was not impacted by the level of realism; and 2) the perceived comfort of people from 2020 over characters from 2020 was higher than the comfort of people from 2012 over characters from 2012, noticing that 2012 and 2020 are two defined checkpoints where Flach *et al.*[13] and our group performed the analyses. While characters from 2012 may still be viewed by people from 2020, new characters could not be seen by people from 2012. Therefore, we show that the percentage of perceived comfort has increased during those years and that the percentage of comfort about old characters remained similar to 2012. This result confirms with stated by Tinwell *et al.*[10]: the technological advancement helps the development of very realistic characters, and it is accompanied over the years by people's discernment about the specific content. Regarding the second question, we found a correlation between charisma and comfort, especially in

unrealistic characters, but comfort does not correlate with familiarity. In addition, we also found a correlation between perceived charisma and familiarity with characters (at all levels of realism). In another analysis, we found no influence of the characters' facial expressions on the perceived charisma. As a contribution of this article, we have the analysis of charisma and familiarity. Interestingly, more charisma was perceived in videos than in images, and in unrealistic characters than other groups of realism. With regard to recommendations and how this research can be useful, we highlight two main aspects: 1) If there is an available resource, very realistic characters can be proposed with new and advanced techniques, since increased realism should evoke comfort and maybe charisma. 2) On the other hand, a good option is to propose an unrealistic character, which should convey comfort and increase the chance to evoke charisma. In addition, the techniques used in characters from 2012 currently generate the same comfort as before (inferior to advanced techniques), but not decreasing over time, so it is also a possibility for designers.

For the UV theory analysis, our results show that comfort is higher in the first (unrealistic) and third groups of realism (very realistic), than with the second group (moderately realistic), from left to right in the comfort chart. This behavior was observed in all tested groups: OLD, NEW, ALL, with images and videos, and it agrees with the theory proposed by Mori.[9] On the other hand, we did not observe more comfort in images than in videos, as expected in the UV theory.

As future work, we plan to expand experiments with more participants and more CG characters. We plan to control variation of levels of realism (for example, changing facial features) for each character and analyze comfort, charisma, and familiarity at those levels. In the case of varying realism, as comfort and charisma were correlated at the unrealistic level, we plan to change the realism of characters from the moderately realistic and very realistic groups to the unrealistic level to assess whether perceived charisma and comfort can increase. We also plan to look at other variables, such as attractiveness.

## ACKNOWLEDGMENTS

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