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On the Ugliness and Distortedness: The Observers' Perception of "Uncanny Valley" Phenomenon in Photorealistic Computer Animated Faces

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This study aims at investigating students' assessments when observing the photorealistic computer animations of faces, which were previously categorized as belonging to the "uncanny valley". The participants of the study included 72 students of Novi Sad Business School (aged between 20 and 30 years, *M* = 21.81, *SD* = 1.59, 76.4% women). The Stimuli consisted of six photographs of faces (3 male and 3 female faces). There were two instruments. The first one consisted of four bipolar seven-point scales in the form of semantic differentials (e.g., ugly/beautiful; distorted/normal; creepy/pleasing and robot-likeness/human-likeness). The second instrument measured the components (cognitive, affective, and conative) of *Connotative Dimension of Meaning* using 15 seven-point bipolar rating scales of opposite adjectives. The results have shown that the affective component stands out. The students' assessments are ambivalent when rating photorealistic computer animations of faces. Ugliness positively predicts the cognitive, affective and conative component. In addition, distortedness negatively predicts the cognitive component, while creepiness positively predicts the affective one. These findings indicate that the response aroused by a photorealistic computer animation which is "barely human" plays a significant role in relation to the uncanny valley phenomenon. On the basis of these findings, the possibilities of application of the obtained results are discussed.

Key words: photorealistic computer animation, faces, uncanny valley, observers' assessments

Introduction

In the last twenty years, there has been a rise in the interest for doing research in computer animation. Many of those studies focused on the effect that computer animations have on the consumers. One of those effects is the "uncanny valley" phenomenon, which can significantly influence the consumers'

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behavior, as well as the development of new technologies. The "uncanny valley" is used in reference to the phenomenon whereby a computer-generated figure or humanoid robot bearing a near-identical resemblance to a human being arouses a sense of uneasiness or revulsion in the person viewing it (Jiang, Cheng, Pan, Shi, Wang, & Xiao, 2022; Mori, 1970; Seyama & Nagayama, 2007; Norman, 2004; Reichardt, 1978; Tinwell, 2014).

Mori (1970), who first reported this phenomenon, hypothesized that the relationship between human-likeness and familiarity of the human-like forms underlies the phenomenon of the uncanny valley. According to Mori (1970), familiarity increases with human-likeness until the *uncanny valley* is reached, which is caused by the sensitivity to the perceived imperfections in near-humanlike forms. A high degree of realism in the physical appearance of human-like objects may result in a negative impression on a human observer (e.g., ugly, uncanny, creepy or unattractive). In other words, Mori (1970) related the uncanny valley phenomenon to the sense of familiarity, explaining that up to a point human-like forms look familiar, however, when there is an appearance which is quite human-like, but familiarity is negative, observers have a sense of strangeness in contact with them.

Although it has been described in the field of robotics, the uncanny valley can also be found in video games and computer-animated movies (Kätsyri, Mäkäräinen, & Takala, 2017; MacDorman, Green, Ho, & Koch, 2009; Tinwell, 2014). Moreover, over the years, research interest in the uncanny valley phenomenon has expanded to humanistic fields such as communication, education, art, and philosophy (MacDorman & Entezari, 2015; Misselhorn, 2009) as well as to the fields of medicine, biology, psychology, and neuroscience (Cheetham, Suter, & Lutz, 2011; Cheetham & Jancke, 2013; Jiang et al., 2022). On one hand, this phenomenon is related to human-like characters in games and animations, in facial caricatures, masks, avatars in virtual reality, facial caricatures, characters in 3D computer animations, lifelike dolls, and any type of human-like objects (Jiang et al., 2022; Mori, 1970; Seyama & Nagayama, 2007; Tinwell, 2014; MacDorman, 2006). On the other hand, recent studies have shown that the uncanny valley phenomenon could be triggered by virtual animals as well (Diel & MacDorman, 2021; Schwind, Leicht, Jäger, Wolf, & Henze, 2018; Sierra Rativa, Postma, & van Zaanen, 2022).

Regarding the virtual characters and the uncanny valley phenomenon, in their analyses of the literature published from 2007 until 2022, Jiang and his collaborators single out three categories of works: those which deal with verifying the uncanny valley and the factors which influence it; those which question the modalities to avoid it; and those which search for the possibility of crossing the uncanny valley (Jiang et al., 2022). In this paper, the uncanny valley phenomenon related to photorealistic computer animated faces is explored from the perspective of psychology and the subjective experience of the observers. The perception of characteristics related to the photographs of characters belonging to the uncanny valley is explored with an attempt to determine specific features of the connotative space of meaning and the position that photorealistic computer animated faces belonging to the uncanny valley occupy in such space.

As it has been reported by earlier studies, highly realistic and "barely human" characters may provoke feelings of eeriness, unease or strangeness in human observers of artificial representations of human beings that closely imitate many, but not all the features and behaviors of actual human beings (MacDorman, 2006; Seyama & Nagayama, 2007; Norman,

2004; Reichardt, 1978; Walters, Syrdal, Dautenhahn, Boekhorst, & Koay, 2008; Green, MacDorman, Ho, & Vasudevan, 2008). After investigating the perception of artificial human faces, earlier studies have shown that facial images provoked the most unpleasant impression when they were highly realistic and had abnormal features such as bizarre eyes, or when observers were ambivalent about the human-likeness of a face (Seyama & Nagayama, 2007; Green et al., 2008).

The current study aims to examine whether the phenomenon of the uncanny valley is as valid for computer-generated characters as it is for robots. Moreover, it attempts to investigate the emotions and meanings which the observers attribute to the uncanny valley photorealistic computer animated faces, in order not to avoid the uncanny valley, nor to cross it, but to find where it could possibly be applied.

The Purpose of the Study

The purpose of the present study is to explore the observers' perception of some features of photorealistic computer animated faces, which have been previously categorized as examples of the uncanny valley phenomenon. Firstly, in order to investigate the perception of characteristics related to the photographs of characters belonging to the uncanny valley, the technique of semantic differential is used (Tucker, 1955; Osgood, Succi, & Tannenbaum, 1957; Osgood, May, & Miron, 1975; Berlyne, 1974). The technique of semantic differential implies seven-step bipolar scales of adjectives with opposite meanings. Adjectives with opposite meanings define the poles of the scales (e.g., ugly – beautiful). By using this technique, which is adequate for the attempt of quantification of subjective experience (Marković, Janković, & Subotić, 2002), in this study, we aim to explore whether the features, which characterize the photographs of animated artificial faces belonging to the uncanny valley, are closer to the positive or the negative pole of the semantic differential scale.

Secondly, the *Connotative dimension of meaning* includes three components – cognitive, affective, and conative (Janković, 2000) and it can serve to determine specific features of the connotative space of meaning and the position occupied by different entities in such space. In other words, the *Connotative dimension of meaning* includes three components in a hypothetical multidimensional semantic space and it refers to the personal, emotional and implicit characteristics which are subjective in nature and derive from the subject that understands, and not the entity that is understood (Janković, 2000, p. 222). An instrument created by Janković (2000) is used to investigate the observers' perception of the connotative dimensions of meaning related to the photographs of characters belonging to the uncanny valley. The instrument is called "Connotative Differential" and it measures three main components. The first component is connected to the affective-evaluative domains of human functioning. The second one is the conative component and it refers to the interest, attention, and the importance of the entity of the person. The third cognitive component refers to the cognitive aspect of experiencing the meaning of the entity. By using this instrument, we aim to explore which position is occupied by the photorealistic computer animated faces, previously categorized as the uncanny valley, in the three dimensional space of connotative meaning. Based on the abovementioned introduction, it can be hypothesized that the characteristics related to photorealistic computer animated faces, which belong to the uncanny valley, will mostly occupy the negative pole on the semantic differential scale, which measures the characteristics and *Connotative*

dimension of meaning. Furthermore, it can be assumed that the affective component of meaning will single out and that the connotative component of meaning will be related to distortedness and ugliness.

Method

The first aim of this study is to investigate the students' assessments of creepiness, ugliness, distortedness, and robot-likeness in faces used in computer 3D animation. The second aim is to investigate the students' assessments of the cognitive, affective, and conative components of the *Connotative Dimension of Meaning* regarding the photographs of faces used in computer 3D animation, previously defined as examples of the uncanny valley (please see: https://www.strangerdimensions.com/2013/11/25/10-creepy-examples-uncanny-valley/).

Participants

An a priori power analysis was conducted using G*Power3 (Faul, Erdfelder, Lang, & Buchner, 2007) to test the difference between two dependent means (matched pairs) using a one-tailed test, a medium effect size (d = .50), and an alpha of .05. The result showed that a total sample of 45 participants was required to achieve a power of .90.

In this research, the participants included 72 students of Novi Sad Business School. There were 17 male and 55 female students between 20 and 30 years of age (M = 21.81, SD = 1.597). The first criterion for the selection of participants was that they did not play video games. The second criterion was that they were naive viewers, i.e., the participants' education was not directed towards animation, design, arts or robotics. The students participated voluntarily and they did not receive course credit or payment.

This research complied with the tenets of the Declaration of Helsinki. Informed consent was obtained from each participant.

The same sample of participants as well as one of the instruments (*Connotative Dimension of Meaning)* was used in the author's previous study dealing with the observers' affective response to the uncanny valley phenomenon. The results of that study were presented in the form of an abstract (Vukadinović, 2021). However, in the present study, research design has been amplified with the investigation of the students' assessments of creepiness, ugliness, distortedness, and robot-likeness in faces used in computer 3D animation. Moreover, the present study is extended by the attempt to explore whether the characteristics related to the uncanny valley phenomenon could predict the components of Connotative Dimension of Meaning.

Stimuli

A set of six photographs was used as stimuli in this study. The photographs were cropped, in color, their dimensions were 1693 x 1693 and they were numbered. The set included six photographs of faces selected on the basis of being previously categorized as examples related to the uncanny valley phenomenon. The original photographs were taken from the Internet and adapted for the purpose of this study (please see: https://www.strangerdimensions.com/2013/11/25/10-creepy-examples-uncanny-valley/).

Instrument

For measuring characteristics related to the uncanny valley phenomenon, the instrument consisted of four bipolar seven-step scales given in the form of semantic differentials: ugly – beautiful, distorted – normal, creepy – pleasing, and robot-likeness – human-likeness. The

participants' task was to rate the extent to which each adjective (e.g., ugly – beautiful, distorted – normal, creepy – pleasing, and robot likeness – human-likeness) characterized the photography they were looking at.

For measuring the *Connotative Dimension of Meaning*, an instrument called "Connotative Differential" is used (Janković, 2000). It serves to determine the specific features of the connotative space of meaning and the position occupied by different entities in such space. Using the "Connotative Differential", the participants could quantitatively evaluate how many semantic components a particular photograph had. This instrument is in the form of semantic differential and it consists of 15 seven-point bipolar rating scales of opposite adjectives, measuring the *cognitive* (understandable, explainable, definite, clear, and sensible), *affective* (pleasant, good, attractive, relaxing, and favorite), and *conative* (impressive, expressive, inspiring, active, and interesting) component of meaning. Each of the 15 adjectives was presented with its opposite (e.g., bad – good, boring – interesting, etc.). Furthermore, each of the 15 seven-point bipolar scales had a negative and a positive pole, for example "Bad -3 -2 -1 0 1 2 3 Good". The task for the participants was to assess each of the six photographs on all 15 scales, by circling the number which most suits their evaluation.

Procedure

After the participants had given their consent to participate in the study, they answered a set of questions related to their socio-demographic characteristics (age and gender). Six photographs were presented to the participants via an LCD projector on a screen, in a randomized order. The stimuli were observed from a distance of around 4 meters and the dimensions of their screen projections were 1.5m x 1.5m. The participants observed the visual presentation in groups, and having finished watching each photograph, they immediately rated them.

Firstly, they rated the four characteristics related to the "uncanny valley" phenomenon. They received the following instructions: "The scale consists of adjectives of opposite meanings which describe the photograph you are looking at. Please rate the intensity of your experience when looking at the face on the photograph on each of the 4 scales by circling the number which most suits your evaluation." Secondly, they made their assessments on the "Connotative Differential" measuring the *Connotative Dimension of Meaning*. The task for the participants was to assess their impression of how each adjective (e.g., pleasant, clear, etc.) characterized the photograph they were looking at. The participants received the following instructions: "The scale consists of adjectives of opposite meanings which describe the photograph you are looking at. Please rate the intensity of your experience when looking at the face on the photograph on each of the 15 scales by circling the number which most suits your evaluation".

For both instruments the same explanation was given: "If your impression is closer to a negative experience please circle one number from -3 to -1, and if it is closer to a positive experience, please circle one number from 1 to 3. If your impression is neither positive nor negative, then circle 0". Moreover, in the data analysis, the assessments on the scales were transformed from a bipolar (-3 – +3) to a unipolar (1 – 7) form. The time given to the participants for rating the photographs after seeing each one was not limited.

Results

In presenting and interpreting our results, one should keep in mind that the medium point of

the scales is 4. The means and standard deviations are computed across all 72 participants and on all of the six presented photographs and the results have shown that ratings of all four adjectives are slightly below 4, which is closer to the negative pole of the semantic differential scale (please see Table 1). However, confidence intervals around the mean values of creepiness, ugliness, distortedness, and robot-likeness suggest that only creepy and ugly do not contain value 4 and are below it, which means that only they are closer to the negative pole of the semantic differential. Please see Table 1.

The results of the *Paired Samples T-Test* have shown that the participants rated the photographs of animated faces as significantly more creepy than ugly, distorted, and robot-like. Moreover, they rated those photographs as more ugly than distorted and robot-like, while they did not differ in their ratings of distortedness and robot-likeness (see Appendix Table A).

Furthermore, the results of the *Independent Samples T-Test* showed no significant gender differences in the assessments of adjectives describing the photographs of animated faces.

Regarding the results obtained on the "Connotative Differential", the results have shown (please see Table 2) that the ratings of the affective component of meaning of all of the six photographs presented across all 72 participants are slightly below 4, which means that they are on the negative side of the semantic differential scale. On the other hand, the participants' ratings of the cognitive and conative component of meaning, regarding all six presented photographs of animated artificial faces, are assessed with values which are also very close to the medium point (4), but they are on the positive side of the semantic differential. These findings, where all components are rated as very close to the middle of the semantic differential, indicate the participants' ambivalence regarding the *Connotative Dimension of Meaning.* Since there was no control group to compare these assessments to, nor an objective test for specifying the proximity to the poles, this result should be taken with reservation.

Table 1 *Arithmetic means and their confidence intervals for the students' ratings of the features characterizing the photographs of animated faces*

The features characterizing the photographs of animated faces	*M*	*SD*	*95% Confidence Interval for Mean*	
			Lower Bound	*Upper Bound*
Creepiness	3.34	.93	3.12	3.56
Ugliness	3.64	.86	3.44	3.85
Distortedness	3.88	.99	3.64	4.11
Robot-likeness	3.90	1.09	3.65	4.16

Table 2 *Arithmetic means and their confidence intervals for the students' ratings of the Connotative Dimension of Meaning related to the photographs of animated faces*

Connotative Dimension of Meaning	*M*	*SD*	*95% Confidence Interval for Mean*	
			Lower Bound	*Upper Bound*
Affective component	3.51	.73	3.34	3.68
Cognitive component	4.15	.78	3.97	4.34
Conative component	4.19	.74	4.03	4.38

The results of the *Paired Samples T-Test* have shown that the participants rated the affective component of connotative meaning with significantly lower values compared to the cognitive ($t(71) = -7.783$, $p < .001$; *Cohen's d (based on differences) with Hedges' correction* = -.907.) and conative ($t(71) = -9.469$, $p < .001$ *Cohen's d (based on differences) with Hedges' correction* = -1.104) components. According to *Cohen's d*, the participants' assessments differ strongly. The participants' ratings of the cognitive and conative components of meaning do not differ significantly.

In order to investigate the relationship between the characteristics related to the uncanny valley and the components of *Connotative Dimension of Meaning*, correlation analysis was applied. The results have shown that there is a positive and significant correlation between the components of the *Connotative Dimension of Meaning* and the characteristics related to the uncanny valley (Table 3).

To explore whether the characteristics related to the uncanny valley phenomenon could predict the components of *Connotative Dimension of Meaning*, three regression analyses were applied. In all three analyses, predictor variables were creepy, ugly, distorted, and human-like. In the first regression analysis, the cognitive component was entered as a criterion. In the second one, it was the affective component, while in the third regression analysis the conative component was entered as a criterion.

The results have shown that the regression model regarding the cognitive component of the *Connotative Dimension of Meaning* is statistically significant ($F(4, 67) = 11.194$, $p < .001$). Based on this set of predictor variables, it is possible to explain the 40% of variations of the criterion variable – cognitive ($R = .633$, $R^2 = .401$). As shown in Table 4, as significant predictors of the cognitive component, distortedness ($\beta = -.201$, $p < .001$) and ugliness ($\beta = -.445$, $p < .001$) have been singled out.

Furthermore, the regression model related to the affective component of the *Connotative Dimension of Meaning* is also significant ($F(4, 67) = 51.144$, $p < .001$). Based on this set of predictor variables, it is possible to explain the 75% of variations of the criterion variable – affective ($R = .868$, $R^2 = .753$). As shown in Table 4, as significant predictors of the affective component, creepiness ($\beta = .327$, $p < .001$) and ugliness ($\beta = .588$, $p < .001$) have been singled out.

Finally, the third regression model related to the conative component of the *Connotative Dimension of Meaning* is statistically significant ($F(4, 67) = 10.096$, $p < .001$). Based on this set of predictor variables, it is possible to explain the 3% of variations of the criterion variable – conative ($R = .613$, $R^2 = .376$). As shown in Table 4, ugliness ($\beta = .447$, $p < .003$) has been singled out as a significant predictor of the conative component.

Table 3 *Correlation between factors of the characteristics related to the uncanny valley and components of Connotative Dimension of Meaning*

Characteristics related to "uncanny valley"	Connotative Dimension of Meaning		
	Cognitive	Affective	Conative
Creepy	.524**	.749**	.513**
Ugly	.550**	.837**	.597**
Distorted	.196	.532**	.387**
Human likeness	.468**	.433**	.331**

Note. ** $p < .001$

Table 4 *Beta partial contribution of characteristics related to uncanny valley and Connotative Dimension of Meaning*

	Connotative Dimension of Meaning		
	Cognitive	*Affective*	*Conative*
Creepy	.150	.327**	.147
Ugly	.445**	.588**	.447**
Distorted	-.201**	.066	.065
Human likeness	.249	-.049	.025
Adjusted R^2	.365**	.739**	.339**

Note. ** $p < .001$

To sum up the results of regression analyses regarding the relationship between the cognitive, affective, and conative component of the *Connotative Dimension of Meaning* and the characteristics related to the uncanny valley, it can be said that ugliness related to faces which belong to uncanny valley is closely related to the *Connotative Dimension of Meaning*. In other words, ugliness positively predicts the cognitive, affective, and conative component of the *Connotative Dimension of Meaning*. In addition, distortedness related to faces which belong to the uncanny valley negatively predicts the cognitive component, while creepiness positively predicts the affective one.

Discussion

The results obtained in this study have shown that some features characterizing the photographs of animated artificial faces which belong to the uncanny valley are closer to the negative pole of the semantic differential scale. In other words, the photographs of animated artificial faces are rated as creepy and ugly. These results are in line with previous findings which reported that when people are confronted with near-humanlike forms, subtle deviations from human norms make those near-humanlike forms look creepy, ugly, and unattractive (MacDorman, 2006; Seyama & Nagayama, 2007).

An interesting finding of this study is that robot-likeness of the photographs of animated faces is rated with values which are in the middle of the semantic differential suggesting that these photographs do not look either robot-like or human-like to the participants. A similar finding was previously reported by Green et al. (2008), indicating that the uncanny valley phenomenon was found when the observers were ambivalent about human-likeness of a face.

Relating human perception with its roots in natural selection, Green et al. (2008) reported that, to be considered as human-like, a robot should have human head shape and face dominated by human characteristics. DiSalvo, Gemperle, Forlizzi, and Kiesler (2002) suggested that nose, eyelids, and mouth most significantly indicate humanness. Thus, when there is a mismatch between experience and expectation related to the human features which appear in animated faces that look human, but not quite, those faces become residents of the uncanny valley (Green et al., 2008; MacDorman, 2006; Mori, 1970).

Moreover, an interesting result of this study is the finding that there are no significant differences in the students' ratings of the adjectives in terms of gender. In other words, the photographs of animated faces are similar in creepiness, distortedness, ugliness, and robot-likeness both to male and female

students. Since the participants in this study were mostly female (75%), this result should be taken with reservation, especially because previous studies, in contrast to the results of this research, reported significant gender differences related to the uncanny valley (Araujo, Dalmoro, & Musse, 2021), as well as an increased acceptance of a wider range of facial proportions by female participants (Green et al., 2008).

Regarding the *Connotative Dimension of Meaning*, the findings of this study suggest that, in the three-dimensional space of the Connotative Dimension of Meaning, the affective component can be singled out based on the participants' assessments of the intensity of the subjective experience of meaning. When it comes to the affective component, adjectives which characterize the photographs of animated artificial faces belonging to the uncanny valley are close to the medium point of the semantic differential, but they are on the negative pole of the semantic differential scale. The observers rated the photographs of animated artificial faces as unpleasant, unattractive, and disturbing.

These results are in line with previous findings, which suggested that feelings of strangeness, unease, and revulsion appear among some observers in contact with artificial representations of human beings, which appear almost, but not exactly, like real human beings (Jiang et al., 2022; Mori, 1970, Seyama & Nagayama, 2007; Norman, 2004; Reichardt, 1978; Walters, Syrdal, Dautenhahn, Boekhorst, & Koay, 2008). Recent evidence indicates that high facial similarity to the faces of real humans but with subtle deviations from human norms tends to provoke the impression of unpleasantness and unattractiveness in a human observer (MacDorman, 2006; Seyama & Nagayama, 2007; Tinwell, Grimshaw, Nabi, & Williams, 2011; Norman, 2004). Furthermore, earlier studies reported that when abnormal facial features are followed by almost perfectly realistic human appearance, it may have a significant emotional "uncanny valley" impact on a human observer (Seyama & Nagayama, 2007; Tinwell et al., 2011).

Moreover, the results of regression analyses are in line with the previous explanation. They have shown that the characteristic of ugliness positively predicts all components of the *Connotative Dimension of Meaning,* while creepiness positively predicts the affective component and distortedness negatively predicts the cognitive component. Ugliness of the representations of human beings, which appear almost but not exactly like real human beings, is not just related to the feeling (affective component) which people have in contact with them, but to their understanding (cognitive component) and motivation (conative component) towards them as well. Since the cognitive component of the *Connotative Dimension of Meaning* is described using adjectives such as understandable, explainable, definite, clear, and sensible, the negative relationship with distortedness as a characteristic related to the uncanny valley is expected and understandable. In addition, creepiness as a characteristic related to the animated faces belonging to the uncanny valley is related to the affective component, which verifies previously described feelings provoked by contact with artificial representations of human faces (Brink, Gray, & Wellman, 2019; McDonnell & Breidt, 2010; Tinwell et al., 2011).

Generally speaking, the results of this study are in line with the findings of previous research, which addresses the observers' reactions when confronted with human-like forms that represent the uncanny valley phenomenon (Jiang et al., 2022; Mori, 1970; Seyama & Nagayama, 2007; Norman, 2004; Reichardt, 1978; Walters, Syrdal, Dautenhahn, Boekhorst, & Koay, 2008; Tinwell, 2014). In this sense, it can be concluded that the phenome-

non of the uncanny valley is as valid for computer-generated characters as it is for robots.

The main attempt of this study was to investigate the emotions and meanings which the observers attribute to the uncanny valley photorealistic computer animated faces, in order to determine where these results could possibly be applied. For example, previous studies defined some possibilities to avoid the uncanny valley as a way of application of their results (Jiang et al., 2022; Mäkäräinen, Kätsyri, & Takala, 2014; Tinwell, 2014). Outlining the affective component in the human response toward the artificial representations of human faces and beings (e.g., unpleasant, unattractive, and disturbing), Mori (1970, p. 34) suggested producing a safe familiarity by a non-humanlike design. A moderate level of realism for physical appearance could be helpful in avoiding the uncanny valley phenomenon (Mori, 1970; Seyama & Nagayama, 2007; Fabri, Moor, & Hobbs, 2004; Wages, Grünvogel, & Grützmacher, 2004). Hanson (2006) applied a technique of adjusting uncanny faces through emphasizing the features identified with friendliness and youthfulness. To escape the uncanny valley, exaggerating or changing the proportion could, also, result in success (Mäkäräinen et al., 2014).

In addition, the results of this study could be applied in design and creation of virtual characters which belong to the horror genre. Namely, horror games or movies could benefit from the findings that characteristics of ugliness and creepiness are essential in arousing the affective component of the meaning which the consumer attributes to the characters or faces belonging to the uncanny valley. This way, the animated faces or characters could be created in such a way that they bring more excitement for those who prefer the horror genre. In addition, distortedness of the face or character belonging to the uncanny valley seems to be crucial in arousing the cognitive component. The less some animated face or character is understandable, explainable, definite, clear or sensible, the more prominent is its distortedness.

So far, some directions in creating some more successful material of the horror genre belonging to the uncanny valley have already been explored. For example, the use of voice (Männistö-Funk & Sihvonen, 2018) or sound (Grimshaw, 2009) is shown to be very important in the elicitation of the consumer's affective response. Furthermore, different fear-evoking aspects of the character's behavior are explored in survival horror games (Tinwell, Grimshaw, & Williams, 2010). However, this domain still remains open for future studies in which different aspects of the relationship between the uncanny valley and horror genre could be empirically tested. Moreover, in the attempt to design a more exciting horror character or face for the consumers who prefer this genre, one should be cautious in future research related to the uncanny valley since this is a delicate subject to investigate. For instance, as it has been shown in a recent study by Brink, Gray, and Wellman (2019), uncanny valley feelings are acquired in childhood. Even though their study was related to the creepiness of human-like robots, they pointed out that children older than 9 judge human-like robots as creepier than machine-like ones. They explain that children made those judgments depending on whether robots have human-like minds. Moreover, the study of Tinwell and Slown (2014) pointed out that children between 9 and 11 years of age are more sensitive to the uncanny valley and to the abnormal facial expressions of animated characters.

In this sense, future studies should focus their exploration on creepy, ugly, and distorted as aesthetic categories (Eco, 2007), which adult consumers find exciting and fascinating within the different forms of the horror genre.

This way, the research results of these studies could contribute to a better understanding of this field and its possible development.

It may be concluded that understanding the uncanny valley phenomenon may provide some useful directions for improving design principles with the goal of creating a better interaction with the consumers. Furthermore, understanding the underlying relationship between familiarity and human-likeness of the uncanny valley phenomenon may represent an important aesthetic guideline not just in building robots but also in creating animated characters or human like forms in virtual reality.

Conclusion

Based on the results of this study, it can be concluded that photographs of artificial faces belonging to the uncanny valley arouse a relatively negative or at least ambivalent affective response in a human observer, their appearance lying between a "barely human" and "fully human". Beside its importance for cognitive psychologists, behaviorists and researchers from the domain of evolutionary aesthetic, the uncanny valley phenomenon also poses a challenge for the designers of computer games, animations and virtual realities who deal with depicting human-like forms. Understanding the uncanny valley phenomenon may not only provide useful directions for improving the cognitive models implemented in androids, but it may also represent an important aesthetic guideline in building robots and creating animated characters or human-like forms in virtual reality. On the other hand, knowing the principles of the uncanny valley phenomenon may serve as an inspiration and a way of achieving success in any domain of virtual reality which belongs to the horror genre.

Although this research provided a better insight into the phenomenon of uncanny valley, it is necessary to mention that this research faced methodological problems, which among other things include control for all the variables which may influence the results, such as, for example, attractiveness of the faces as well as the selection of participants and stimuli. However, to address the questions related to the relationship between the assessments of creepiness, ugliness, distortedness, and robot-likeness of animated faces, photographs belonging to the uncanny valley and characteristics related to the attractiveness of the faces such as youthfulness, symmetry, and hairstyle (Rhodes & Zebrowitz, 2002) require further testing, serving as motivation for future studies. Moreover, the main limitation of this study was the lack of control group that the obtained results could be compared to. In addition, the limitations include the fact that all the participants were students of the same school, as well as that the group was heavily biased toward female participants, which limits the generalizability of the study results to the general population. In future studies, these limitations could be overcome by including a control group and a more balanced sample, both regarding the gender of the participants and their educational background.

When making a choice of how to depict human-like forms, the designers of computer games, animations, and robots have a challenging task requiring not only the understanding of human perception and preferences, but also being familiar with the uncanny valley phenomenon. In order to achieve successful interaction with the consumers, future studies and projects may take interdisciplinary approach, unifying cognitive neuroscience, engineering, behavioral science, aesthetics, psychology, and design.

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References

Araujo, V., Dalmoro, B., & Musse, S. R. (2021). Analysis of charisma, comfort and realism in CG characters from a gender perspective. *The Visual Computer*, *37*(9), 2685–2698. https://doi.org/10.1007/s00371-021-02214-2

Berlyne, D. E. (1974). *Studies in the new experimental aesthetics*. Washington, D.C.: Hemisphere Publishing Corporation.

Brink, K. A., Gray, K., & Wellman, H. M. (2019). Creepiness creeps in: Uncanny valley feelings are acquired in childhood. *Child Development*, *90*(4), 1202–1214. https://doi.org/10.1111/cdev.12999

Cheetham, M., Suter, P., & Lutz, J. (2011). The human likeness dimension of the uncanny valley hypothesis: Behavioral and functional MRI findings. *Frontiers in Human Neuroscience*, *5*, 126. https://doi.org/10.3389/fnhum.2011.00126

Cheetham, M., & Jancke, L. (2013). Perceptual and category processing of the uncanny valley hypothesis' dimension of human likeness: Some methodological issues. *JoVE (Journal of Visualized Experiments)*, *76*, e4375. https://doi.org/10.3791/4375

DiSalvo, C. F., Gemperle, F., Forlizzi, J., & Kiesler, S. (2002, June). All robots are not created equal: The design and perception of humanoid robot heads. In *Proceedings of the 4th Conference on Designing interactive systems: Processes, practices, methods, and techniques* (pp. 321–326).

Diel, A., & MacDorman, K. F. (2021). Creepy cats and strange high houses: Support for configural processing in testing predictions of nine uncanny valley theories. *Journal of Vision*, *21*(4), 1–1. https://doi.org/10.1167/jov.21.4.1

Eco, U. (2007). *On ugliness.* New York: Rizzoli.

Green, R. D., MacDorman, K. F., Ho, C. C., & Vasudevan, S. (2008). Sensitivity to the proportions of faces that vary in human likeness. *Computers in Human Behavior, 24*, 2456–2474. https://doi.org/10.1016/j.chb.2008.02.019

Grimshaw, M. N. (2009). The audio Uncanny Valley: Sound, fear and the horror game. In *Audio Mostly 2009* (pp. 21–26).

Fabri, M., Moor, D., & Hobbs, D. (2004). Mediating the expression of emotion in educational collaborative virtual environments: An experimental study. *Virtual Reality*, *7*(2), 66–81. https://doi.org/10.1007/s10055-003-0116-7

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*, 175–191. https://doi.org/10.3758/BF03193146

Hanson, D. (2006, July). Exploring the aesthetic range for humanoid robots. In *Proceedings of the ICCS/CogSci-2006 long symposium: Toward social mechanisms of android science* (pp. 39–42). Citeseer.

Janković, D. (2000). Konotativni aspekti značenja: Konstrukcija konotativnog diferencijala. [Connotative Aspects of Meaning: Construction of the Connotative Differential]. *Psihologija*, *1-2*, 221–238.

Jiang, H., Cheng, L., Pan, D., Shi, S., Wang, Z., & Xiao, Y. (2022, August). Virtual characters meet the uncanny valley: A literature review based on the Web of Science Core Collection (2007-2022). In *2022 International Conference on Culture-Oriented Science and Technology (CoST)* (pp. 401–406). IEEE. https://doi.org/10.1109/CoST57098.2022.00088

Kätsyri, J., Mäkäräinen, M., Takala, T. (2017). Testing the 'uncanny valley' hypothesis in semirealistic computer-animated film characters: An empirical evaluation of natural film stimuli. *International Journal of Human-Computer Studies, 97*, 149–161. https://doi.org/10.1016/j.ijhcs.2016.09.010

MacDorman, K. F. (2006, July). Subjective ratings of robot video clips for human likeness, familiarity, and eeriness: An exploration of the uncanny valley. In *ICCS/CogSci-2006 long symposium: Toward social mechanisms of android science* (Vol. 4).

MacDorman, K. F., Green, R. D., Ho, C. C., & Koch, C. T. (2009). Too real for comfort? Uncanny responses to computer generated faces. *Computers in Human Behavior*, *25*(3), 695–710. https://doi.org/10.1016/j.chb.2008.12.026

MacDorman, K. F., & Entezari, S. O. (2015). Individual differences predict sensitivity to the uncan-

ny valley. *Interaction Studies*, *16*(2), 141–172. https://doi.org/10.1075/is.16.2.01mac.

Mäkäräinen, M., Kätsyri, J., & Takala, T. (2014). Exaggerating facial expressions: A way to intensify emotion or a way to the uncanny valley? *Cognitive Computation*, *6*(4), 708–721. https://doi.org/10.1007/s12559-014-9273-0

Marković, S., Janković, D., & Subotić, I. (2002). Implicit and explicit features of visual Gestalt. *Psihološka istraživanja*, *11-12*, 49–73.

Männistö-Funk, T., & Sihvonen, T. (2018). Voices from the uncanny valley. *Digital Culture & Society*, *4*(1), 45–64. https://doi.org/10.14361/dcs-2018-0105

McDonnell, R., & Breidt, M. (2010). Face reality: Investigating the uncanny valley for virtual faces. In *ACM SIGGRAPH ASIA 2010 Sketches, 41,* 1–2. https://doi.org/10.1145/1899950.1899991

Misselhorn, C. (2009). Empathy with inanimate objects and the uncanny valley. *Minds and Machines*, *19*(3), 345–359. https://doi.org/10.1007/s11023-009-9158-2

Mori, M. (1970). Bukimi no tani [Uncanny valley]. *Energy*, 7(4), 33–35.

Norman, D. A. (2004). *Emotional design: Why we love or hate everyday things*. New York: Basic Books.

Osgood, C., Succi, G. J., & Tannenbaum, P. (1957). *The measurement of meaning*. Urbana: University of Illinois Press.

Osgood, C., May, W., & Miron, M. (1975). *Cross-cultural universals of affective meaning*. Urbana: University of Illinois Press.

Reichardt, J. (1978). *Robots, fact, fiction and prediction.* Harmondsworth, Middlesex: Penguin Books Ltd.

Rhodes, G., & Zebrowitz, L. A. (2002). *Facial attractiveness: Evolutionary, cognitive and social perspectives*. CT: Ablex, Westport.

Schwind, V., Leicht, K., Jäger, S., Wolf, K., & Henze, N. (2018). Is there an uncanny valley of virtual animals? A quantitative and qualitative investigation. *International Journal of Human-Computer Studies, 111,* 49–61. https://doi.org/10.1016/j.ijhcs.2017.11.003

Sierra Rativa, A., Postma, M., & van Zaanen, M. (2022). The uncanny valley of a virtual animal. *Computer Animation and Virtual Worlds*, *33*(2), e2043. https://doi.org/10.1002/cav.2043

Seyama, J., & Nagayama, R. S. (2007). The uncanny valley: Effect of realism on the impression of artificial human faces. *Presence*, *16*(4), 337–351. https://doi.org/10.1162/pres.16.4.337

Tinwell, A., Grimshaw, M., & Williams, A. (2010). Uncanny behaviour in survival horror games. *Journal of Gaming & Virtual Worlds*, *2*(1), 3–25. https://doi.org/10.1386/jgvw.2.1.3_1

Tinwell, A., Grimshaw, M., Nabi, D. A., & Williams, A. (2011). Facial expression of emotion and perception of the uncanny valley in virtual characters. *Computers in Human Behavior*, *27*(2), 741–749. https://doi.org/10.1016/j.chb.2010.10.018

Tinwell, A. (2014). *The uncanny valley in games and animations*. London & New York: CRC Press, Taylor & Francis Group.

Tinwell, A., & Sloan, R. J. (2014). Children's perception of uncanny human-like virtual characters. *Computers in Human Behavior*, *36*, 286–296. https://doi.org/10.1016/j.chb.2014.03.073

Tucker, W. T. (1955). *Experiments in aesthetics communication*. Ph. D. dissertation. University of Illinois.

Vukadinović, (2021, September). Observers' affective response on ''the uncanny valley'' phenomenon in photorealistic computer animated faces. Abstract presented at *XVII International Conference DAYS OF APPLIED PSYCHOLOGY 2021 ''Psychology in the function of the well-being of the individual and society''.* Niš, (128–129).

Wages, R., Grünvogel, S. M., & Grützmacher, B. (2004). How realistic is realism? Consideration on the aesthetics of computer games. *Lecture Notes in Computer Science*, *3166*, 216–225. https://doi.org/10.1007/978-3-540-28643-1_28

Walters, M. L., Syrdal, D. S., Dautenhahn, K., Boekhorst, R., & Koay, K. L. (2008). Avoiding the uncanny valley: Robot appearance, personality and consistency of behavior in an attention-seeking home scenario for a robot companion. *Autonomous Robots*, *24*(2), 159–178. https://doi.org/10.1007/s10514-007-9058-3

Appendix

Table A. *Results of Paired samples t-test of adjectives describing animated faces*

Pairs of adjectives			95% Confidence Interval of the Difference		
	t(71)	*p*	*Lower bound*	*Upper bound*	*Cohen's d (based on differences) with Hedges' correction*
Creepy – Ugly	-3.756	.001	-.464	-.142	-.438
Creepy – Distorted	-3.712	.001	-.675	-.398	-.899
Creepy – Robot-likeness	-5.416	.001	-.772	-.356	-.632
Ugly – Distorted	-2.529	.014	-.418	-.049	-.295
Ugly – Robot-likeness	-2.083	.041	-.512	-.011	-.243
Distorted – Robot-likeness	-0.269	.789	-.233	.178	-.031

Figure 1 Example of animated faces used in stimuli (www. StrangerDimension.com)