Uncanny Valley in Video Games: An Overview

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Abstract: The uncanny valley is an idea proposed by Masahiro Mori (1970) regarding negative emotions present in contacts with almost human-like characters. In the beginning, it was considered only in the context of humanoid robots, but this context was broadened by the development of highly realistic animations and video games. Particularly evident are players' interests in the uncanny valley. Recently there have been a growing number of reports from empirical studies regarding participants' perception of highly realistic characters. In the paper, a review of publications concerning the uncanny valley hypothesis in video games is presented, as are deliberations about the impact of the uncanny valley on the game industry. According to the results, there is a need to recognise which attributes of virtual characters cause the uncanny valley effect.

Keywords: uncanny valley, virtual characters, video games, CGI

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1. Introduction

The aim of this paper is to consider whether the expected further increase of rendering power in the creation of video games will allow to overcome the problems with perceptions of virtual characters. Nowadays, an unrealistic look of human characters causes eerie sensations or even reluctance in players and these issues are often attributed to the uncanny valley effect (see e.g. Kätsyri, Mäkäräinen & Takala, 2017; Misselhorn, 2009). Some authors (e.g. Perry, 2014) suggested that with the advancement of computing power, the characters in games would be able to become fully realistic in the close future. However, inconclusive results concerning the uncanny valley make such a statement uncertain. In the following paragraphs, I present an overview of the previous studies concerning the uncanny valley, summarise important results regarding the graphical aspects of video games, describe methods that users can employ to avoid the feeling of discomfort and offer conclusions on the validity of aforementioned expectations.

2. Uncanny valley hypothesis

The uncanny valley hypothesis was proposed by Masahiro Mori in 1970 as a concept referring to robotics and prosthetics. According to the hypothesis, the increasing human-likeness of robots and humanoid characters entails the likability of the characters only up to a certain limit. After this limit, the relation changes and further increment of human-likeness entails eeriness or even disgust. Furthermore, for fully human-like figures, the likability is high again. The decrease in likability is called the uncanny valley. A simplistic illustration of the hypothesis is the *naïve uncanny valley* phenomenon described by Kätsyri, Förger, Mäkäräinen & Takala (2015, p. 4). They claim that "almost humanlike characters will elicit more negative affinity (lower familiarity and/or more negative emotional valence) than any other more artificial or more humanlike characters" (see figure 1). Mori (1970) emphasised that the movement of characters probably strengthens the emotional impact.

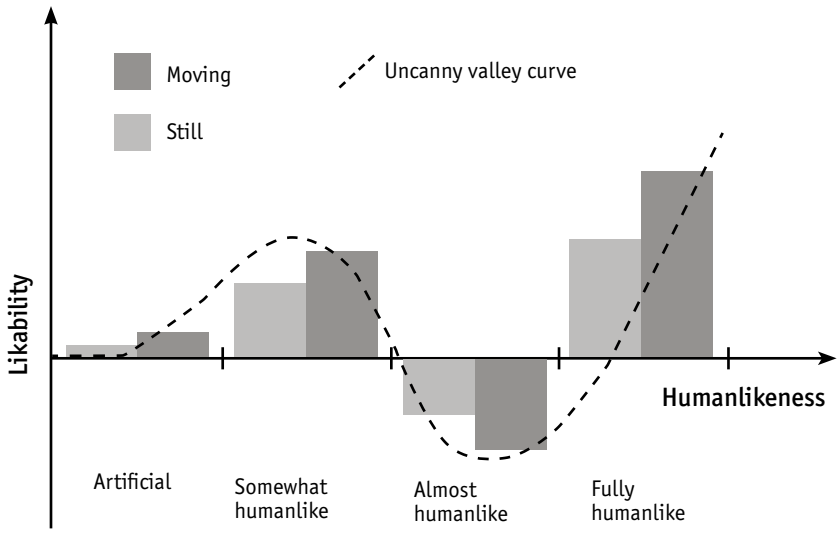

Fig. 1. Naïve uncanny valley. Adapted from Kätsyri et al. (2015)

The uncanny valley effect may also occur in computer-generated imagery (CGI), including animations and video games (see e.g. Kätsyri, Mäkäräinen & Takala, 2017; Misselhorn, 2009). It has been extensively debated whether the uncanny valley impedes the constant attempts to create more realistic characters and sceneries, and thus more immersive games (Tinwell, 2014). In addition, despite many unsolved questions of the uncanny valley hypothesis, financial problems of several animated movies box offices were attributed to this effect (Geller, 2008; Misselhorn, 2009). The presence of the uncanny valley in CGI is particularly apparent in opinions of viewers. As an example, an expressive comment after the "Polar Express" movie release is quoted below.

> But when it comes to the "humans", the atmosphere collapses. Unnervingly smooth, mouths moving in strange, even frightening formations, the Polar people are the least convincing things on-screen, glaring impostors amid the otherwise painstakingly rendered scenery (Metacritic, n.d.).

There is no agreement in the scientific community about the origin of the uncanny valley. There are several different explanations regarding evolutionary, cognitive and perceptual perspectives. Two example approaches are described below.

One common explanation is the perceptual mismatch hypothesis (Kätsyri et al., 2015; Pollick, 2009). According to it, the discomfort while watching almost human-like characters would be caused by inconsistent sensory cues, e.g. extensively large, artificial eyes incongruent with real skin texture. Designers are forced to focus on detailed features of characters while attempting to create photorealistic figures in computer games (Tinwell, 2014). Such an effort may result in different levels of realism and cause the uncanny valley effect. This hypothesis is related to the atypicality and attractiveness of characters. According to the extended uncanny valley research review (Kätsyri et al., 2015), it is the most plausible explanation.

Another explanation refers to the theory of mind. The appraisal of the intentions of others in the community is particularly important for humans (Blakemore & Decety, 2001). In order to properly infer others' mental states, humans have to consider subtle changes in facial expressions and eye movements. Incongruence in these and the resulting difficulties in the assessment of intentions of human-like characters may be the cause of eeriness. This is due to the fact that, according to several studies, human-looking entities are able to activate the brain circuits responsible for mentalisation (MacDorman, Green, Ho & Koch, 2009), whereas less human-like characters may not cause such effect.

3. Previous studies

In 2004 Wages, Grünvogel, & Grützmacher raised concerns that the development of more and more realistic environments would not lead to greater immersion [immersion is generally understood as the ability to create an illusion of a virtual environment for a player (Schubert, Friedmann & Regenbrecht, H., 2001)]. Their considerations are particularly relevant to virtual and augmented reality games. According to them, attempts to create a virtual environment with maximal similarity to reality emphasise subtle differences between the two. The smaller the differences are, the greater they appear subjectively. Wages et al. (2004, p. 9) concluded that as regards computer games, "production should be free from the «corset of realism»", focusing on non-realistic graphics, and furthermore, the problems with realism will always be up-to-date.

Issues with realism and immersion in video games may be considered in terms of the uncanny valley. The relation is confusingly similar. Greater realism causes greater immersion only up to a certain limit; after that, the immersion is worse (according to Wages, Grünvogel & Grützmacher, 2004). Brenton, Gillies, Ballin & Chatting (2005) considered the connection between the uncanny valley and the feeling of presence (the subjective feeling related to immersion). In both cases, the human mind confronts positive cues (evidence of realism of characters/environment) and negative cues (evidence of fakeness of characters/environment). Evaluation of these cues may lead to the formulation of a hypothesis that a character/environment is real or not. In these terms, the uncanny valley effect may be caused by a sudden switch between these hypotheses or suspension between them. The negative emotional state may be present only while contacting characters due to evolutionary reasons. Although this might sound counterintuitive, such a formulation of hypotheses about the reality is not a detached idea. In case of the body illusions, the human mind may accept relatively peculiar hypotheses due to some extraordinary cues. For example, in the Pinocchio illusion (Lackner, 1988), when a subject simultaneously touches a different person's nose and feels (while blindfolded) that their own nose is touched by an experimenter, they may experience the sensation of nose stretching.

On the contrary, Brenton et al. (2005) expressed a different opinion than Wages et al. (2004), suggesting that in the future we would overcome the uncanny valley because players will get used to the effect.

More recently, several studies have been conducted in order to empirically test the uncanny valley hypothesis in reference to video games. The typical studies concerning the issue are based on CGI images as stimuli and self-report questionnaires for emotion evaluation. Participants assess the human-likeness/realism of characters and report their attitude to them. Because most characters combine CGI from movies and games, sometimes it is hard to distinguish them. There is also a strong branch of studies applying morphed characters, but they are less relevant to the video games topic.

Schneider et al. (2007) examined 75 virtual characters from Japanese video games and animated movies. These were robots, anthropomorphised animals and animated humans. Researchers asked participants to rate the human-likeness and attractiveness of characters. The results corresponded to Mori's hypothesis and researchers interpreted the dip in attractiveness

ratings for nearly human-like figures as the uncanny valley. The conclusion was that designing robots and animals in games is much safer than designing highly anthropomorphised characters. The safest combination is clearly non-human appearance with the ability to express human emotions.

A similar study was conducted by Dill et al. (2012). They used moving characters (short movies) as stimuli besides the static images. They also checked the participants' acquaintance with characters. Their results support the uncanny valley hypothesis. The highest discomfort level of participants was found for almost human-like characters for both static and moving stimuli. One of the results was also a correlation between the effects of the uncanny valley and the popularity of a given character among the public. The authors hypothesised that good knowledge of characters determines greater levels of familiarity. It is also worth mentioning that the question about the personality of characters (whether they were villains or "good guys") did not give any valid outcome.

McDonnell, Breidt & Bülthoff (2012) used the motion-capture technology to create virtual characters ranging from cartoonish to highly realistic. They tested the appeal, familiarity, friendliness, and trustworthiness of the figures. After ordering the rendering styles from the most abstract to the most realistic, they found two drops in examined features which can be interpreted as uncanny valleys. This result is consistent with the voices of scientists who claimed that we should consider more than one uncanny valley (Kätsyri et al., 2015). The authors also discovered that unappealing characters appear even less appealing when moving than when still and that motion anomalies are considered more unpleasant with human styles than with cartoonish ones. McDonnell et al. (2012) also suggested that render styles and photorealism of CGI movies should not be considered causes of box office failures in the entertainment industry and that motion-captured animations are enough to convince participants about the emotions of characters.

4. Still uncanny

The results of the above-mentioned studies may be misleading. All show the valley of emotional attitude and two positive hills on both sides of it.

Therefore one may say that the uncanny valley causes no substantial problems because we can create CGI characters which avoid the uncanny valley. But the situation is far more complicated. Although some authors optimistically state that uncanny valley has been skipped by CGI characters (e.g. Perry, 2014), this is not clear yet. As an example of perfect render in movies, Perry (2014) introduced the virtual character of Brad Pitt from *The Curious Case of Benjamin Button* (2008), but he supported this only with a single opinion. There are also inconsistencies in the studies. For example, the most human-like characters with the highest familiarity ratings which overcome the uncanny valley in Dill et al.'s study (2012) were the ones from the *Beowulf* movie (2007). Conversely, the same characters used in Kätsyri et al.'s research (2017) scored the highest ratings in eeriness.

The presence of problems with highly photorealistic characters seems to be supported by the study of Mustafa, Guthe, Tauscher, Goesele & Magnor (2017). They tested participants while watching different types of virtual characters and real people footage with EEG event-related brain activity. The results showed the highest probability for experiencing uncanny valley for highly realistically rendered humans.

The public opinion is also very convincing in this matter. The web page Tvtropes.org contains a list of hundreds of video games classified as "uncanny valley". It is a huge database that lists exact issues with games, e.g. "problems with facial animations", "creepy look of character".

Tinwell (2014) upholds the idea with the quotation of a persuasive comment from the debate around *GTA IV* (2008):

> Grand Theft Auto IV should employ the cel shaded look. The in-game graphics shown so far for the game are ugly as hell – far uglier than anything seen previously in the series. Sometimes too much detail and a near miss at realism is far worse to look at... (Knotts, 2007, p. 1, as cited in Tinwell, 2014).

More recently, there were problems with the weirdness of characters of *Mass Effect: Andromeda* (2017). The outcry of players on the Internet was so strong that it forced the producers to release a series of patches trying to improve the characters' appeal, although with poor results (Schreier, 2017).

Furthermore, it seems that currently the uncanny valley hypothesis is more important for video games than for animated movies. It is much

easier to create an authentic character in a movie because of the possibility to adjust every frame of it (Perry, 2014). Video games require many more frames to be generated and it is nearly impossible for designers to adjust them all. MacDorman et al. (2009) stated that the uncanny valley worries especially video game designers because their animations are rendered instantaneously, without time for careful staging or touching up. Additionally, movie viewers only follow the narration passively and there is no direct interaction (Grodal, 2000). Video games are often experienced as a simulation of reality and they can cause great emotional arousal (Grodal, 2000). This may require greater authenticity from video games characters. Schwind & Jäger (2016) remarked also that human-CGI figures interaction could be improved by more credible eyes and eye-related areas. For example, in real life, it is natural to indicate our desired objects by focusing our eyesight on them. If a CGI wants a player to focus on something, it should direct them with its eyes and respond to their eyes movement. The study of Wilms et al. (2010) showed that if an illusion of real-time interaction with anthropomorphic virtual characters is to be created, these characters must follow a participant's gaze. Such behaviour might be viewed as passing the "social" Turing test by CGI characters (cf. Wilms et al., 2010). CGI would have to be supported by artificial intelligence due to the complexity of such a task. If this turns out to be true, optimistic expectations of fully realistic games in the close future are groundless.

In order to determine if we will overcome the uncanny valley effect in video games in the near future, we have to discover what causes the emotional effect. If the perceptual mismatch hypothesis is true, the effect is caused by physical attributes of characters; therefore it is hoped that the uncanny valley will be overcome in the close future concurrently with decreasing costs of computational power. If the theory of mind is relevant to the uncanny valley issue, probably we will have to wait longer for fully realistic video games.

Nevertheless, it has been shown that the realism of inanimate objects does not cause the uncanny valley effect (MacDorman et al., 2009). Additionally, Łupkowski, Rybka, Dziedzic, & Włodarczyk (2018) showed that background context is not an important factor for the uncanny valley. For that reason, it is important for game designers to focus on the creation

of characters in high realism environments. Tinwell (2014) stated that the growing need for effective communication in games imposes proper emotion expression of CGI characters and hence it is important to focus on facial expression and its imperfections. Earlier, Brenton et al. (2005) pointed out that eyes are crucial elements of CGI characters.

5. Backdooring the uncanniness

The previous sections lead to the conclusion that there is a problem in video games and we do not know yet if a simple increase in computational power will solve it. However, there is a way of designing appealing characters in games: stylisation. Creation of high realism is demanding – difficult to accomplish, terribly expensive, and yet less preferred than stylised environments (Geller, 2008). Already in 2005 Fischer, Bartz & Straber observed that, for augmented reality, stylised (non-photorealistic) images are more immersive than images with varying degrees of realism. Conversion of the whole image (background with inserted virtual objects) gives better results than conventional AR (virtual objects inserted into camera images).

A similar remark was made by Schwind, Wolf, & Henze (2018). They offered several suggestions as to how users can avoid negative emotions, including stylisation. When designers try to maximise the effectiveness of the realistic set-up, they should avoid atypicalities of characters. It is also worth creating physically attractive characters – it is easier to avoid the uncanny valley with appealing features.

Zell et al. (2015) tested which elements of stylisation have the greatest impact on the attractiveness of characters. They suggested that material properties of figures (i.e. shader, shader parameters, and textures) mostly affect appeal, eeriness, and attractiveness. However, the shape of characters determines mainly how realistic they appear. The greatest disturbance is caused by the conflict between extreme stylisation levels, e.g. between the high realism of material effects and the most cartoonish shape. Furthermore, the authors acknowledged that emotion expressed by characters does not change perceived realism, except for anger, which seems to be seen as eerier due to defensive mechanisms.

The uncanny valley is not always undesirable. Schwind et al. (2018) noticed that the uncanny valley effect can be utilised positively, in the creation of deliberately repulsive characters (e.g. Gollum from *The Lord of the Rings* trilogy). As for the game industry, Tinwell (2014) indicated that characters in a crime-thriller game *LA Noire* (2011) belong to the uncanny valley but this improves the game experience.

6. Conclusions

The development of highly realistic animations and video games revealed that the uncanny valley may be recognised in virtual characters. Players' comments on the Internet show the importance of this matter in a particularly intensive way and current research has to confront the growing expectations of players about the more convincing realism of games.

The uncanny valley research may answer whether it is worth focusing only on physical aspects of characters or it is needed to go beyond it. Up-to-date studies state that the most important aspect of characters is the face and particularly eye-related areas, which may indicate the relevance of the theory of mind. Currently, it is hard to predict whether a simple increase in computational power will allow creating fully realistic computer games. The insights from the literature overview suggest that the time when we see convincing and not uncanny characters is rather distant. However, to the best of our knowledge, studying the eerie features of characters may at least lead to a decrease in the uncanny valley effect. Certainly, this will be much harder in virtual reality due to the greater complexity of environments (Schwind et al., 2018). Whereas the multidimensionality of the uncanny valley effect seems to impede the progress and we still do not know what causes the effect, it is important to stress that not all unpleasant receptions of game characters are related to the uncanny valley. In order to ascribe the emotional reactions to the effect, one needs to test for that connection.

Realistic games may suffer from the uncanny valley and lose financial gains due to it. Stylisation is cheaper and preferred by users, but it is rather unlikely that game producers will resign from attempting to create convincing realistic virtual environments.

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Dolina niesamowitości w grach komputerowych: przegląd badań

Abstrakt: Dolina niesamowitości (ang. *uncanny valley*, UV) to pojęcie zaproponowane przez Masahira Moriego (1970) dotyczące negatywnych emocji pojawiających się w kontaktach z niemal ludzkimi postaciami. Początkowo opisywane było w kontekście robotów humanoidalnych, lecz rozwój realizmu w animacjach i grach komputerowych wpłynął na rozpatrywanie UV również w tych obszarach. Szczególnie widoczne jest duże zainteresowanie doliną niesamowitości po stronie graczy. W ostatnim czasie wzrosła liczba doniesień z badań, które empirycznie testują wpływ UV na odbiór realistycznych postaci w grach. W artykule przedstawiono przegląd badań dotyczących UV w grach wideo oraz rozważania nad tym, czy UV faktycznie wpływa na rozwój gier komputerowych. Jak wynika z dotychczasowych badań, istnieje potrzeba odpowiedzi na pytanie, jakie atrybuty postaci powodują efekt doliny niesamowitości.

Słowa kluczowe: dolina niesamowitości, postacie wirtualne, gry komputerowe, CGI