

# Walking Through the Uncanny Valley of Robots

Kemal Akbay

Human Factors in Information Design, Bentley University, USA

akbay\_kema@bentley.edu

## ABSTRACT

This paper describes the uncanny valley phenomenon. The first section of the paper discusses the myth behind the semantic meaning of the uncanny, where it stemmed from, how it's interpreted over time and what it related to in a psychological perspective, especially the death drive. The second part discusses the hypotheses revolving around this phenomenon and what it refers to in our daily lives. Examples from the arts, media and culture are used. The third section of the paper focuses on animation and game industries, how the uncanny valley effected the outcomes of projects and what lied behind the successes and failures of these features. The fourth part discusses two approaches to production in design: stylization in order to abandon using a humanoid form altogether, and photo-realization in order to create a very humanoid form, but either way, avoiding every chance to fall down the valley.

## Author Keywords

uncanny valley; anthropomorphism; robotics; humanoid; death drive; dead eye syndrome; animation; games; photorealism; stylization

## ACM Classification Keywords

Design, Human Factors

## THE UNCANNY VALLEY PHENOMENON

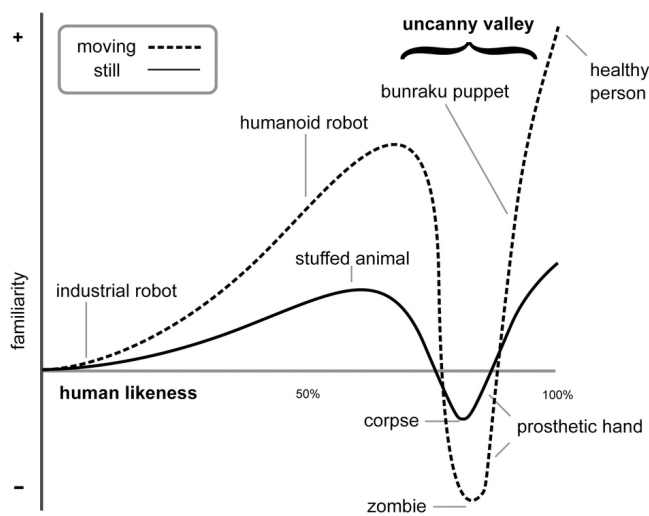


Figure 1. The Uncanny Valley Graph

The uncanny valley term is coined by Masahiro Mori, a robotics professor in Tokyo Institute of Technology. Mori's insight was that human beings "react with revulsion to humanlike robots, whose appearance resembled, but did not quite replicate, that of a real human" (Kageki, 2012).

Actually, anthropomorphic forms are appealing to humans (Lidwell et al., 2010), however, when a form gets indistinguishably close to a human form, it suddenly loses its appeal and becomes distinctly unappealing. This sharp decline in the graph seen in Fig. 1 is called the uncanny valley.

## Sandman's Olimpia

The "uncanny" word in uncanny valley refers to a psychological concept rooted in an inversely depicted short story based on an Eastern European folklore character, the Sandman, who brings good dreams by sprinkling magical sand onto the eyes of people sleeping at night.

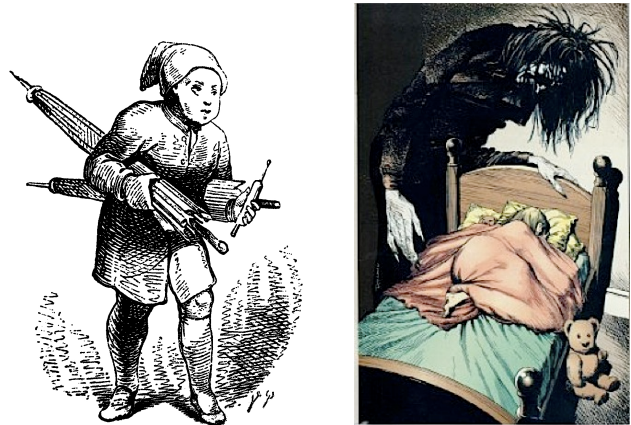


Figure 2&3. The Sandman drawings. Good dream bringer in Andersen tales vs. the evil version in Neil Gaiman's.

However, in Hoffman's new version ("Der Sandmann"), the story takes an eerie twist. This time, the Sandman (named Coppélius in the story) is known to throw sand in the eyes of the children who refuse to go to bed, then steal their eyes and puts them in his bag, later to feed his own kids. Nathanael, already traumatized by having met Coppélius in his childhood, is the protagonist of the story.

One day, he meets Olimpia. On one hand, he is deeply struck by the beauty of this woman, on the other hand, he is very disconcerted by her stiff moves, cold touch, fixed gaze and motionless glance. After a course of events, Nathanael goes mad when he sees Olimpia's eyes carved out lying on the ground, assuming they were stolen by the Sandman. The story is filled with twists and turns and tragic events; however, the most critical point of the story comes when the identity of Olimpia is revealed; she is an automaton, a robot in disguise. The trauma caused by this deception is explored by a German psychiatrist, Ernst Jentsch, who describes this uncanny feeling as a cognitive dissonance where the individual is unable to decide what is real and what is not, or what is alive and what is dead (1906).

### Freud's Death Drive

Freud defined the uncanny as a seemingly familiar object behaving in an unfamiliar manner. He attributed the uncanny to "an exposure of what should otherwise be concealed; the uncanny occurs as a revelation of the repressed, not only that which should be kept hidden in others, but also in one's self" (Grimshaw, 2013).

Freud also extensively analyzed the Sandman tale in his essay, "Das Unheimliche", which may also be translated as the uncanny, however, he criticized Jentsch's approach to the story. To him, it was not the uncanny, Olimpia, who was central to the story but the tormented, whose eyes were robbed of. To Freud, the fear of blindness by having eyes stolen represents castration anxiety, the inability to proliferate. It is also where Freud stresses that "an instinct is an urge inherent in organic life to restore an earlier state of things" which also is likely to trigger the repetition compulsion, where the person tries to achieve control in the situation by differentiating the real from the unreal by repeating the trauma or its circumstances over and over again. This repetition compulsion is also related to the death drive, since it is the voice of seduction that drives men to their death instinct, where the individual unconsciously arranges for variations for an original theme he has not learned to live with.

Nicholas Royle interpreted the psychoanalytic meaning of the uncanny and its connection with the death drive: "The uncanny seems to be about a strange repetitiveness. It has to do with the return of something repressed, something no longer familiar, the return of the dead, the constant recurrence of the same thing, a compulsion to repeat. It's this notion of constant recurrence that leads Freud to his theory. Something comes back because in some sense it was never properly there in the first place". Thus, the reason behind the uncanny phenomenon may be interpreted as a trauma, where reality and fantasy are entangled: a person goes through a traumatic event, -such as in the sandman story where the protagonist found out that the woman he fell in love with was not a human but a robot- and the experience turns out to be in conflict with the prior knowledge.

### HYPOTHESES

In today's world of technology surrounded by computer graphics, human-robot interaction is becoming increasingly popular. The uncanny valley effect is already an important matter in the fields of animators as well as in roboticists. This section of the paper is focused on the hypotheses regarding the uncanny valley effect, mainly from a robotics perspective.

One hypothesis in phase with Freud's approach is related to our "self-awareness of death", the feeling of awareness when one is reminded of the fact that they will cease to exist one day. Another aspect related to our fear of death is our fear of losing control over our body, especially when we grow old, since a robot that acts far from perfect will also trigger that fear (Macdorman, 2006).

There is a debate on the issue whether an assembled android robot that consists of different pieces awaken the same feelings or not and also some claims that we subconsciously think that we, just like anthropomorphic robots with humane appearances, are also machines with no soul. Also, the broken and destroyed humane-looking robots is likely to remind us of a battlefield image. Another aspect is that the uneasy feeling that these robots that look very similar to us like a "doppelgänger", and they may replace our jobs and even our relationships.

There are recent examples from the scientific movie genre that touches on this subject: "Her", a 2013 Spike Jonze drama about a relationship that develops between a human and an AI (the voice of an intelligent operating system) where the AI suggests human to interact with a woman who would simulate her so that they could have physical interaction. "Ex-Machina" (2015) is another thriller that includes a romantic relationship between a human and a humanoid robot with human expressions and a body language.

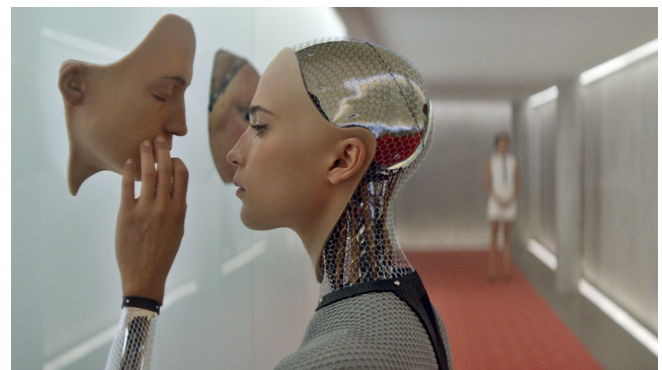


Figure 4. Scene from "Ex-machina" (2015)

Another hypothesis points out the evolutionary aspect, stating that one of the triggers might be that an instinctual, evolutionary mechanism programmed to keep us away from the unattractive plays an important role: disturbing facial and bodily features may be a sign of an individual less likely to be fertile, display unhealthy hormone levels or have a deficient immunity system (Rhodes & Zebrowitz, 2002).

Avoidance from pathogens may be the reason for our repulsion. Such an encounter with a humanoid robot may trigger our mental mechanisms which evolved to instinctively avoid our system from pathogens that may arise. As they look very similar to us, any deficiencies or errors in the details of these robots will be distracting to our eyes, thus, they will give the impression that these deficiencies may be the preview of something more threatening such as a bacteria, virus or other parasites, similar to how we feel when we look at people with sick people or people with deformed appearances. Therefore, it is possible that the external pattern disorders we come across in these robots may trigger our fear, terror or disgust towards corpses or people with serious illnesses (Macdorman, 2009). According to Rosenblum, our visceral reaction to the zombielike appearance of near realistic humans could be a byproduct of evolutionary pressures to avoid corpses, and their possible diseases (Rosenblum, 2010).

Infringement of human norms might be considered as another issue. If an existence such as a robot appears to be nonhuman enough, it's possible to empathize with its humanoid features, such as in Asimo as a robot or as in Wall-E as an animated one. "The brain doesn't seem tuned to care about either biological appearance or biological motion per se. What it seems to be doing is looking for its expectations to be met – for appearance and motion to be congruent," says Saygin. Therefore, it can be said that, if the robot is too realistic, anything out of the ordinary human will be problematic since we will have difficulty processing the new information as it will not pair with what we already know (Kiderra, 2011).

#### UNCANNY VALLEY IN ANIMATIONS AND GAMES

Many attempts by several production companies to animate realistic human faces have failed, and some of the blockbusters such as Beowulf and Grendel or Final Fantasy: The Spirits Within have been the center of harsh criticisms. The attempts to animate a human face is a real challenge, especially it's been extremely hard for the animators to achieve "human-enough" eyes.

When a non-human form character such as Gollum in Lord of the Rings or E.T., or a human form character in a cartoon such as Cartman in South Park or Fred in the Flintstones, it's easy to distinguish the animation from the reality, thus it's easy to find them engaging without being creepy.

However, the problem arises with the animated faces when they move closer to realism. That's why an animation like Polar Express has been perceived as an extremely creepy movie, since it raised awareness in the "dead eye syndrome".



**Figure 5&6. Scenes from "Polar Express" (2004), depicting dead eye syndrome**

The reason for uncanny valley effect to mostly occur within the facial expressions is estimated to be related with the way we evolved: we have a high sensitivity to facial expressions and extremely attentive to nuances. The mirror neurons in our brain, in which the resemblance of a human-like form engages a part of our brain thought to internally mirror the actions of another person, warns us of even the subtlest aspects. Thus, the uncanny valley experience may be a by-product of our brain's disposition to mirror human actions (Rosenblum, 2010).

A recent good example in the world of digital effects is the movie, The Curious Case of Benjamin Button, where the animators knew the 'dead eye' challenge, thus, they showed extra attention to upper facial patterns, especially the eyes.



**Figure 7. Scene from "The Curious Case of Benjamin Button" (2008), rendering in detail.**

During the rendering of Benjamin Button's eye movements, the animators took a close-up of the eye movements. They realized that when a real eye moves, "the thin film of moisture covering the eye builds up more on the side toward which the eye is moving" (Rosenblum, 2010). Therefore, they changed the amount of moisture in the eyes depending on where the eyes leaned towards to. This change in the glimmers between each eye gave the eyes a more soulful, natural look. In the end, Brad Pitt's face was computer-animated for a total of 52 minutes of the movie, and the result was so convincingly naturalistic that the movie won several awards worldwide, including the Oscar for the Best Visual Effects category.

Systematic research on the topic suggests that there are many cases where high fidelity virtual characters are rated as uncanny (Seyama and Nagayama, 2007; Tinwell et al., 2011). This effect is even bigger, especially when upper facial movement regarding emotional expressions is restricted (Tinwell et al., 2011). In addition to this, video recordings of robots have been found to show different patterns of brain activity than actual or less humanlike robots (Saygin et al, 2012).

Carter and Pollick suggest that "future behavioral and brain research using realistic virtual characters must ensure that the characters are not uncanny in order to avoid the introduction of a potential confound: the visceral response of the viewer" (Grimshaw, 2013).

Carter and Pollick (2013) also point out the importance of not overlooking the role that "person perception research involving real humans can play in informing social interactions with virtual characters; as virtual characters increase in quality, it will be possible to introduce increasingly human-like characteristics into avatar-mediated conversations" (Grimshaw, 2013); such as communication posture (Kendon, 1970), mimicry (Chartrand and Bargh, 1999), head nodding (Boker et al., 2011) and facial expression dampening (Boker et al., 2011).

## APPROACHES

Regarding artists and gamers have been working on the uncanny valley effect for more than a decade. Graphically, games have advanced to a point where this effect has turned into a problem in the gaming industry, too. Graphically it is meaningful to look for images that are visually appealing. So, there are two approaches to both in order not to fall into the valley. The first approach is not to work on a humanoid form, or work on it but stop somewhere before the downfall curve in the graph –which represents the beginning of the valley- starts. This may be called the stylization.

All the animated characters in animations and games have stylized characters, from simplistic drawings of Super Mario to complexity of Mortal Kombat. Although they are visually very appealing, none of them are perceived to belong to our world. Although they sometimes look very

real, it's not possible to mistake them for a "seemingly familiar" form so we do not feel cheated. Conversely, since they are not human, it makes their human characteristics to stand out. It also may be a much less costly option than trying to achieve human-like forms.

A second approach is photorealism; working on very humanoid forms and pushing the limits in order to create ultra-realistic models. Photorealism represents the other side of the valley and may be described as simulating reality in the most visually appealing way. However, the designers have to be very careful to make sure they are not falling short while striving to create a realistic interaction. Photorealism is a hard to achieve yet easy to lose battle; besides, it is highly costly as well. It not only deals with model detail or texture resolution but various dynamics at once, such as how we detect nuances in movement patterns of other individuals. Another issue is about how the animation interacts with its environment, such as in geometric constraints within the world in the game.

## CONCLUSION

It's been known for some time that using human forms in virtual characters such as robots with humanoid forms have proven to be a valuable tool, especially in psychological and neurological research on how human actions are perceived, recognized and interpreted by the brain. The results gained from these studies have assisted us in understanding how and to what extent the parameters should be created in order to visualize these virtual characters, while making sure the characters do not fall down the uncanny valley, in other words, not seemingly familiar but perceived as perfectly real. These studies focused mainly on creating a very realistic simulation to trick our perceptual senses have been ongoing for decades in many areas including military robotics researches, medical surgeries, animations and gaming, and much progress has already been made. However, it may be meaningful to keep in mind that, while pushing the boundaries will help us move further to see what the other side of the valley holds, we have to be fully aware of the fact that graphical fidelity is not equal to human fidelity, and uncanny valley effect is the perfect example to remind us of that difference. Thus, although there is hope, there also is still a lot to be known to find a way to fully specify the design of a virtual character that manipulates our perception of what looks real and what goes down the valley.

## REFERENCES

Boker, S. M., Cohn, J. F., Theobald, B. J., Matthews, I., Mangini, M., Spies, J. R., ... & Brick, T. R. (2011). Something in the way we move: Motion dynamics, not perceived sex, influence head movements in



conversation. *Journal of Experimental Psychology: Human Perception and Performance*, 37(3), 874.

Chartrand, T. L., & Bargh, J. A. (1999). The chameleon effect: the perception-behavior link and social interaction. *Journal of personality and social psychology*, 76(6), 893.

Grimshaw, M. (Ed.). (2013). *The Oxford handbook of virtuality*. Oxford University Press.

Jentsch, E. (1997). On the psychology of the uncanny (1906) 1. *Angelaki: Journal of the Theoretical Humanities*, 2(1), 7-16.

Kageki, N. (2012). An Uncanny Mind: Masahiro Mori on the Uncanny Valley and Beyond. *IEEE Spectrum*, 12.

Kendon, A. (1970). Movement coordination in social interaction: Some examples described. *Acta psychologica*, 32, 101-125.

Kiderra, Inga (2011). Your brain on androids <http://ucsdnews.ucsd.edu/archive/newsrel/soc/20110714BrainAndroids.asp>

Lidwell, W., Holden, K., & Butler, J. (2010). Universal principles of design, revised and updated: 125 ways to enhance usability, influence perception, increase appeal, make better design decisions, and teach through design. Rockport Pub.

Macdorman, K. F. (2006). Introduction to the special issue on android science. *Connection Science*, 18(4), 313-317.

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.

Rhodes, G., & Zebrowitz, L. A. (2002). *Facial attractiveness: Evolutionary, cognitive, and social perspectives* (Vol. 1). Ablex Publishing Corporation.

Royle, N. (2003). The uncanny. Manchester University Press, p. 84

Rosenblum, L. D. (2011). *See What I'm Saying: The Extraordinary Powers of Our Five Senses*. WW Norton & Company. p. 177-179

Saygin, A. P., Chaminade, T., Ishiguro, H., Driver, J., & Frith, C. (2011). The thing that should not be: predictive coding and the uncanny valley in perceiving human and humanoid robot actions. *Social cognitive and affective neuroscience*, nsr025.

Seyama, J. I., & Nagayama, R. S. (2007). The uncanny valley: Effect of realism on the impression of artificial human faces. *Presence: Teleoperators and Virtual Environments*, 16(4), 337-351.

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.