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The Uncanny Valley Phenomenon

Why do more realistic characters look less human?

Name: Natalya Bashnyak
Matrikelnummer: 617232
E-Mail-Adresse: natalya.bashnyak@student.hu-berlin.de
Fachsemester: 2
Studiengang: B.A. Kunst- und Bildgeschichte

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1. Introduction

In our digital age computer graphics have made dramatic progress. Surfaces are rendered sleek and perfect and can barely be distinguished from reality. In our everyday life we come across highly realistic animated figures and avatars in a variety of screen-based media, such as animation, cinema, video games, and synthetic worlds. These worlds awaken feelings in us we never knew we had and can even expand our physical skills. It can provoke also negative feelings, even disgust. As interaction increases, it is important to investigate their effects on our embodied dispositions and our identity as humans. [1] So, when encountering something that gets close to human appearance and behavior, but not quite right, our instincts are to pick up on those signs and be uncomfortable. The uncanny valley is a challenge for designers when creating a realistic virtual character, so the characters must be designed using consistent levels of realism.

> "This effect is thought to be a combination, perhaps a blending, of repulsion and attraction, an 'unsettling delight' felt in the presence of figures whose visually apparent features are very close to, but not exactly like, those of a healthy human being." [2]

In the first section, I describe the effect of the uncanny valley and present its problems in cinema. In the second section, I examine failed characters traits of the uncanny valley problem in *The Polar express* (USA 2004, Zemeckis). In the final section of my paper, I sketch an overview of some alternative guidelines developed for CGI (computer generated imagery) to prevent the problem of the uncanny valley based on the example of *Alita: Battle Angel,* (USA 2019, Rodriguez/Landau/Cameron).

When, if ever, do animated objects trigger "creepy" and "weird" feelings of the uncanny valley effect in the cinema? Why do realistic characters look less human? What are the ways out of the valley for the movie industry?

[1] Bissonnette, *Affect and Embodied Meaning in Animation: Becoming-Animated,* 1.
[2] Gross, *Puppet: An essay on uncanny life*, 2.

2. Masahiro Mori's concept of the uncanny valley

Freud popularized the idea of the uncanny, the blend of attraction and repulsion we feel for something we can't quite categorize. [3] A Japanese engineer and designer Masahiro Mori adapted the notion in his influential essay in 1970 for work in robotics (the Japanese term is *Bukimi no tani*), and the idea was later extended to animation. [4] In Mori developed a graph that describes the non-linear relationship between human likeness and affinity (Fig.1). On Mori's hypothesis, as the appearance of an object approaches that of a healthy person (the 'human likeness' indicated on the horizontal axis), the familiarity an observer experience is increasingly positive (vertical axis), that is, until a sudden drop off in familiarity is reached when the experience becomes strikingly negative (hence the term 'valley'). The dotted line represents movement. And the contrast between the dotted and solid lines shows that the experience of familiarity that an observer has is enhanced by perception of motion, both positively and negatively. [5]

In his essay, Mori explains: "At first, the increasing resemblance elicits a growth in empathy and a feeling of familiarity from the viewer. But then, "as robots appear more humanlike, our sense of their familiarity increases until we come to a valley. I call this relation the "uncanny valley". [6] A threshold is crossed where the imitation becomes so close and exacting that its remaining incompleteness points to its status as a surrogate, as something not real, and this results in a loss of empathy from viewers, a pulling back, as what had seemed so familiar becomes defamiliarized. Mori pointed out a converse principle, namely that perceptions of high familiarity can be induced by non-human or semi-humanlike designs.
Mori felt when working with some robots, that he counseled robotics designers to avoid creating robots that would fall into the uncanny valley. His example was Japan's bunraku puppet theater: "I don't think a bunraku puppet is similar to human beings on close observation." (Fig.2) This form of musical puppet theater dating from the 17th century. The puppets range in size but are typically about a meter in height, dressed in elaborate costumes, and controlled by three puppeteers obscured only by their black robes. [7]

[3] Hamilton, "The 'uncanny valley' and spectating animated objects", 61.
[4] Prince, *Digital visual effects in cinema (The seduction of reality)*, 121.
[5] Mori, "The Uncanny Valley", 1970.
[6] Ibid.
[7] Ibid. MacDorman, translator note.

But the audience sits some distance from the puppets that move in humanlike ways. "So although the puppet's body is not humanlike, we can feel that they are humanlike owing to their movement. And from this evidence, I think their familiarity is very high." [8]

Mori takes the example of a hand prosthesis, which looks quite natural, but nevertheless still feels unnatural. Many consider the characters in *Final Fantasy: The Spirits Within* (USA 2001, Sakaguchi, the science fiction film*)* a prime example of the uncanny valley's effect on the audience's emotional reaction. Photorealistic on the surface, these characters lack various human traits. They seem not to breath and they have a very limited expressive repertoire. In short, they seem somehow dead. According to Mori, it is this association with death, or more precisely with the living dead (that is, zombies), which evokes the distancing effect. Another conceivable explanation would be the sense of strangeness that occurs when a human being's behavior deviates from social and cultural norms, such as when someone maintains no eye contact when addressed, but instead rolls their eyes, without any evident impairment accounting for his violation of these norms. [9]

In fact, Mori's theory was not empirically tested until some twenty years later. And when it was, a number of questions emerged. Not least was the question of whether there is a genuine phenomenon here at all. More Recent research by Debaleena Chattopadhyay and Karl F. MacDorman indicates that the uncanny valley triggers these feelings in humans to mark a potential threat or the risk of being infected with a transmissible disease. Interestingly, it has been shown that the uncanny valley occurs only when looking at humans and animals, not inanimate objects. [10]

As a result, our disgust is an adaptive system for disease avoidance behavior. In the same way, AI (Artificial Intelligence) is also disturbing because humans are biologically incentivized away from people who look sick, unhealthy, or "off". This is known as "pathogen avoidance," which serves to protect us against dangerous diseases.

2.1. Stylization and photorealism problem

Barbara Flueckiger points out that the different aspects of a character should be situated at a

[8] Prince, *Digital visual effects in cinema (The seduction of reality)*, 122.
[9] Flueckiger, *Visual Effects. Filmbilder aus dem Computer*, 41.
[10] MacDorman, Chattopadhyay, "Familiar faces rendered strange", 2016.

similar distance from a transparent mode of representation. Between photorealistic and stylized depictions there runs a fine yet essential line, which separates fundamentally different forms of representation. Every feature of a digital or artificial character can be projected, whereby "appearance" and "behavior" need to be treated as isolated entities for analytical reasons. [11]

Animators of the classical school incessantly emphasize how important it is to adhere to Disney's tenth rule of animation namely, to exaggerate movements to convey the (stylized) character's emotions. Humans readily accept unrealistic characters when they are consistently unrealistic, as frequently seen in cartoons. [12] Many fully computer-animated movies – from *Shrek* (USA 2001, Adamson/Jenson/Marshall) over *Finding Nemo* (USA 2003, Stanton/Unkrich) to *The Incredibles* (USA 2004, Brad Bird) – refer to the rules of cartoons by using artificial characters and strongly accentuated plot elements, that is, in accordance with the model of distance. [13] Moris's insight is consistent with the realization by Disney and Pixar animators that caricature provides an effective model for expressing emotion and for eliciting audience participation in the narrative and the lives of the characters. Caricature conveys emotion in concentrated form. Viewers intuitively understand what the exaggeration conveys, and no sense of the uncanny is evoked. [14]

Digital characters whose stylization avoids photorealism are very effective in reaching an audience. [15] Some features are more difficult to sculpt, texture, and render than others. Prince specifies that the biggest problem for digital photorealism is faces, and partly the problem is a function of its complexity. The face contains fifty-three muscles that move in complex, subtle ways to generate a multitude of expressions, and these movements cannot be captured as vertex data. [16]

Until the mid-2000s, the process involved an actor wearing a motion-capture suit (catsuit, ping-pong ball) and a camera literally capturing the action that would eventually be laid over with animation. MoCap (*motion capture* abbreviation) is a technique whereby an individual being's performance is captured and translated for use in driving a CG (computer graphics)

[11] Ibid. 43.
[12] Schwind et al., "Avoiding the uncanny valley in virtual character design", 2018.
[13] Flueckiger, *Visual Effects. Filmbilder aus dem Computer* , 41.
[14] Prince, *Digital visual effects in cinema (The seduction of reality)*, 122.
[15] Ibid.
[16] Ibid.

being's performance. Also knows as performance capture, used widely by VFX studios, sports therapists, neuroscientists, and for validation and control of computer vision and robotics. [17]

It is Christmas Eve and a young boy is restless in his bed. At 11:00 pm, he wakes up and hears the humming sound of a distant train. As the train approaches near his house, everything in his bedroom starts shaking. Objects begin to fall around him. The boy decides to sit on his bed to look out of the window and find out what is causing all the trouble. While he is observing the scene, a close-up calls attention to his suprised reaction. Despite having detailed eyelashes and reflecting pupils, his eyes look lifeless and peculiar. [18]
Tom Hank's face was outfitted with 152 markers for the mocap sessions employed on *The Polar Express*, and while the markers furnished some information about the flexing and stretching of his face, it was incomplete information. With respect to faces, mocap aims to sample an information-rich analog process using relatively few data points. These do not provide enough information to work backward from the sampled points to a reconstruction of the surface deformation. On *The Polar Express*, the actor's eyes were not mocapped, and the animator had to infer the behavior of eyes and the precise direction of the actor's gazes from markers placed around the eyes. This resulted in one of the films' most widely criticized qualities – the vacant and lifeless appearance of the character's eyes. [19]

The Polar Express was groundbreaking in the way they used motion capture on the actor Tom Hanks but unfortunately it was poorly received. *New York Times* considered *The Polar Express* a failure and characters "*creepily unlifelike".* The uncanny valley was present here because the characters came across as almost completely human. Considering the relation between stylization and photorealism allows us to better understand this failure. Part of the problem, Barbara Flueckiger would argue, arises from the curious dissonance between a too human behavior and a stylized appearance. However, she claims that this dissonance mainly concerns the children, the father, and the character of the conductor, of which no less than three are played by Tom Hanks. The characters like Hobo and Father Christmas are situated withing fantasy, through the narration as part of the parallel fantasy universe and through their motion, which is more cartoony. The gap between appearance and movement patterns is

[17] Okun, Zwerman, *The VES Handbook of Visual Effects*,1033.
[18] Bissonnette, *Affect and Embodied Meaning in Animation: Becoming-Animated,* 167.
[19] Prince, *Digital visual effects in cinema (The seduction of reality)*, 123.

closed even further, since characters are artificial. And this fits perfectly into the theory of the uncanny valley. [20]

The narration in *The Polar Express* cannot perform the fundamental task of endowing the characters with psychological depth. The narrative center is missing. Both the individual characters and their constellation fall apart. *The Polar Express* is based on a very well-known children's book, and the film was a commercial success. Arguably, its success was probably due to the famous literary source. [21]

2.2. How does movie industry avoid the problem of the uncanny valley on the example of Alita: Battle Angel?

Unless the intention is to create a creepy character or evoke a feeling of unease, there are certain design principles to avoid the uncanny valley. "The effect can be reduced by not creating robots or computer-animated characters that combine features on different sides of a boundary — for example, human and nonhuman, living and nonliving, or real and artificial," MacDorman says. Tinwell recommends ensuring that a character's facial expressions match its emotive tone speech, and body movements are responsive and reflect its hypothetical emotional state. Extra attention must be paid to the face, such as the forehead, eyes, and mouth, which show the complexities of emotion and thoughts. If the mouth is modeled and animated correctly the character doesn't appear aggressive or portray a "false smile" when they are genuinely happy. [22]

Alita: Battle Angel is an American cyberpunk action film adapted by new facial capture technologies which are pushed to the extreme and try to avoid the uncanny valley. Alita drew upon the expertise of James Cameron and Robert Rodriguez, Jon Landau, Lightstorm, Troublemaker Studios, 20th Century Fox and, Weta digital studio. The movie is based on Japanese manga artist Yukito Kishiro's 1990s series and takes place 600 years in the future. It starts as a journey of discovery, where Dr. Dyson Ido (Christoph Waltz) an expert in cybernetics, in the times of machine-vs.-humanity war rescues a unique female cyborg human head in the junkyard and brings it back to life. He gives her a new body and name: Alita (Rosa Salazar). Alita is like a video game character, but she enjoys every bit of her new

[20] Flueckiger, *Visual Effects. Filmbilder aus dem Computer* , 45-46.
[21] Ibid.
[22] Caballar, "What is the Uncanny Valley?", 2019.

surroundings in Iron City, makes friends, falls in love. She comes with no memory of who she is, but through the movie, she feels her significant role to change the world. Alita discovers a sky city called Zalem and finds out that Dr. Dyson Ido, her creator, has a secret life as a bounty hunter and joins him. She discovers her fighting abilities and battles to save her new friends and family. Eventually she joins robot games, replacing her normal feet for rollerblades.

The principle and the most notable CGI in the movie is Alita's big eyes, she looks like an anime and manga character come to life, or like a Disney character. (Fig. 3) "She looks at this world with wide-eyed wonder because she has no memory of it. She sees a melting pot of society, cultures from all over the world who migrated to Iron City after the wars" – says Jon Landau, movie producer. [23] With her appearance, she reminds viewers that she is a digital creation, but this mimic has some convincing human expressions and her movements are humanlike, with special attention from the animators toward realistic eye behavior. Alita's smile and kind eyes are very appealing, they bring hope to a technologically cruel world. There is also physical contact between the cyborg and biological characters, which is frequent and intimate. Alita was birthed from the New Zealand visual effects studio Weta Digital. The motion-capture performances help to achieve realistic motion and give the body accurate weight, and the facial expressions their life-like appearance. Weta advanced its facial capture system by using two CG puppets (one for the actress and one for the character), re-targeting one onto the other to achieve closer unity. (Fig.4)

The countless cameras on the set recorded markers on the actress's physical body, afterwards, they were recognized and put into three-dimensional space to create a skeleton for a CG model and manipulate performance. According to Rodriguez, the idea of the movie was to use two high-definition cameras, to be able to create a much more user-director, actor-centric process on the set. He calls it "technology-enabled".[24] The character is completely computer-generated. It's a lot like the human birthing process. To make her eyes absolutely convincing, they added an obscene amount of depth and detail to her eyes: about 8.5 million polygons in each one. But Alita's face is wider than Rosa's, and her eyes are twice as large, which changed the perspective. It took a year to work on the eyes alone and then another four months of refinement. The eyes actually contained more detail than all of Gollum (was also

[23] Landau, interview.
[24] Ibid.

conjured using an animation technique of motion capture, the CGI masterpiece from *The Lord of The Rings*, USA 2001, Jackson), another creation of this studio, with Weta doing the simulation of fibers for the first time taken from a baby's eyes. [25] Robert Rodriguez about the process:

"We wanted all of the little idiosyncrasies that she brought in her audition to be there. We learned from doing *Avatar* (USA 2009, Cameron) that when you're scanning someone's facial structure that it was important to get the lower part of someone's face right — it's harder than you think. Once we knew we could do that, we started working with them on the whole digitial process of creating what Alita would look like." [26]

For most of the digi-FX heavy shoot in the movie, it was opted to shoot as much as humanly possible on actual sets built on the backlot of Rodriguez's Austin, Texas-based Troublemaker Studios. The team decided to have real sets, props, and real textures. Alita was shot with Cameron's own state-of-the-art 3D cameras that he'd used for deep-sea documentaries. "Using 3D should not be a world coming out of a window," Landau says. "It should be a window *into* a world." [27]

As a result of the long and hard work of the animation team, Alita doesn't look like anyone around her, firstly the way she moves and talks feels very unsettling, but as the story of the film progresses, she learns and becomes more natural. She is a cyborg, and a cyborg is not a robot, it is a modified human, with a prosthetic body. The fusion of synthetic action and live, motion, and performance capture in one single frame increase the viewer's level of familiarity towards Alita, and she as the digital character doesn't fall into the uncanny valley. Weta was able to pick up the smallest facial expression by capturing the real human performance and this is the reason why this film manages to avoid the uncanny valley. In Landau words:

"You can't hide behind the blue skin [of 'Avatar'] or an ape's face. Yet she's a cyborg. We're not saying she's a human; we have that little bit of wiggle room. I think Weta really applied everything they've learned the last 20 years. It's a process of layering. And Rosa has unusual idiosyncrasies that her face does,

[25] Desowitz, "Alita: Battle Angel Preview: How Weta escaped from the Uncanny Valley", 2018.
[26] Rodriguez, Landau, interview.
[27] Ibid.

which convey emotion, where the eyebrow goes up and the mouth goes down. But I believe, whether it's five minutes in or 10 minutes in, you're going to realize she's that character."[28]

3. Conclusion

The history of cinematography consists of countless movies with bad and not appealing special effects, where there is still the uncanny valley to deal with. It is technically hard to replace human beings, creating cartoony monstrosities instead. Face and motion capture-based animation tend to almost solve this problem. The example of *Alita: Battle Angel* shows emotionally expressive digital performance elicited from performance capture data and that achieves credible perceptual realism. Alita's performance preserves the character's humanity and shows the animation with an emotional center, but it is arguably still imperfect.

Increased realism and the uncanny valley pose a serious challenge for designers and filmmakers. Mori originally suggested that designers should avoid a high level of human likeness to achieve high levels of affinity. So, can avatars and virtual characters help us to decrease mental workload and increase social presence? [29]

Mocap technologies proved to be more like theater, with the actors performing in very long takes covered by multiple cameras. John Malkovich, (American actor) and others said they experienced a new kind of freedom in these methods. Even though these methods of working proved to be exhilarating for many cast members, the downside was that much facial information from their performances could not be rendered into the final screen characters. [30] Of course, CG (computer graphic) characters are not cinema's exclusive future. Live-actor-centered dramas will continue to proliferate because they are less expensive to make. Animation doesn't substitute for acting. Digital tools look backward as well as forward; they embrace tradition while configuring new possibilities. Digital effects provide arenas in which actors may continue to furnish human presence so vital to the medium. [31] Technology alone does not suffice – but if the technology fails, sophisticated narration can offset its shortcomings only to a certain extent. [32]

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[28] Landau, interview.
[29] Schwind et al., "Avoiding the uncanny valley in virtual character design", 2018.
[30] Prince, *Digital visual effects in cinema (The seduction of reality)*, 126.
[31] Ibid., 143.
[32] Flueckiger, *Visual Effects. Filmbilder aus dem Computer* , 46-47.

More research and development is needed to enable us to achieve perfectly believable artificial characters. With the rapid developments in Machine Learning technologies ever advancing, one likely outcome is the use of these neural networks to assist in bringing traditional CGI characters out of the Uncanny Valley. Neural networks trained specifically on datasets of real human faces can often surpass the realism achievable by a team of human compositing artists and can do so in far shorter time. One can already start to see Machine Learning based technology being used in films such as *The Irishman*. Here a combination of CGI and Machine Learning (also sometimes referred to as 'Deepfake') technology was used to make a younger version of Robert Deneiro, to critical acclaim. It is also possible to find rogue Machine Learning artist on the internet such as Thiago Porto (aka TpoComp) and Shamook who, in their own free time, have trained and implemented their own 'DIY' Machine Learning based effects on both Deneiro [33] and Alita [34] . Both show very promising results when considering these are individuals working with suboptimal source material, with no backing from studios or big budget production companies.

As more research and successful examples of this technology arise we can expect to see more directors and studios making use of Machine Learning and future technologies, hopefully eventually surpassing the Uncanny Valley and leaving this phenomenon behind as a relic of the past.

[33] Shamook, "De-aging Robert Deniro in The Irishman (DeepFake)."
[34] Tpo Comp, "Alita with Neutral Networks DF experiment."

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5.Figures

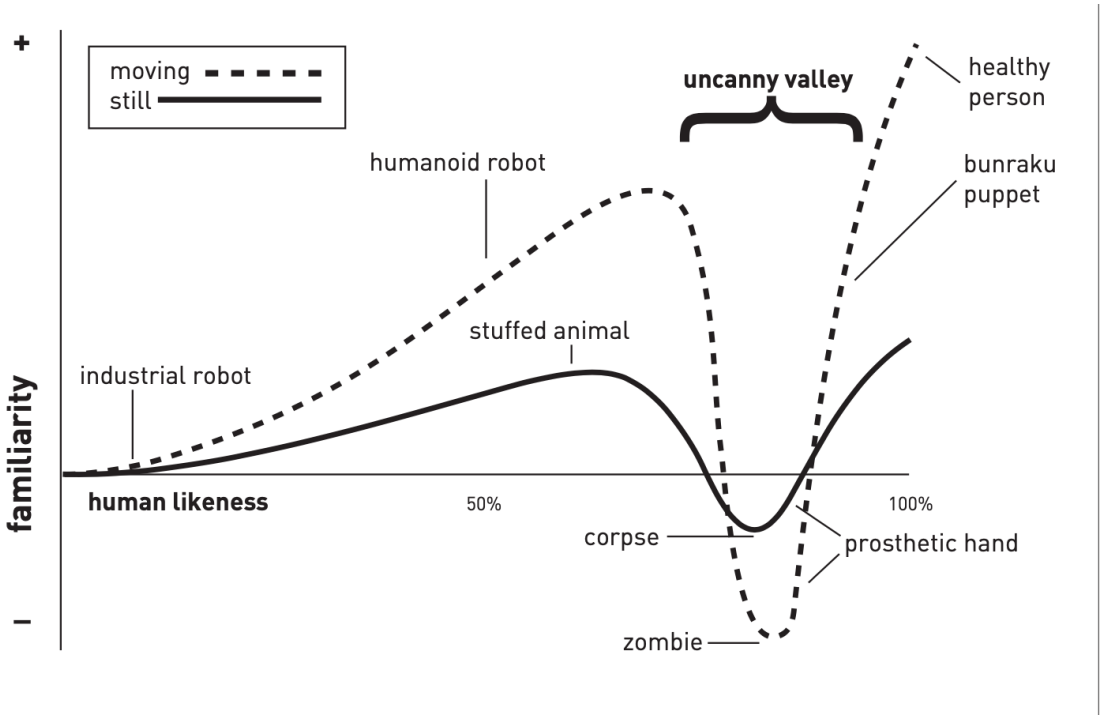

Figure 1
The theory of the Uncanny Valley by Masahiro Mori, translated and simplified by MacDorman.

Figure 2
Bunraku puppet

Figure 3
Alita, female cyborg

Figure 4
Alita and her real prototype actress Rosa Salazar wearing facial motion capture

6. List of figures

Humboldt-Universität zu Berlin
Kultur-, Sozial- und Bildungswissenschaftliche Fakultät

Name: Bashnyak Vorname: Natalya

Matrikelnummer: 617232

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Prüfungsform: Hausarbeit

Studentin: Natalya Bashnyak, 617232
Prüferin: Dr. Angelika Seppi

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Identität geprüft: Ja / Nein
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