The Influence of Appearance and Interaction Strategy of a Social Robot on the Feeling of Uncanniness in Humans

Maike Paetzel
Dept. of Information Technology
Uppsala University, Sweden
maike.paetzel@it.uu.se

ABSTRACT

Most research on the uncanny valley effect is concerned with the influence of unimodal visual cues in the dimensions human-likeness and realism as a trigger of an uncanny feeling in humans. This leads to a lack of investigation how multimodality affects the feeling of uncanniness. In our research project, we use the back-projected robot head Furhat to study the influence of multimodal cues in facial texture, expressions, voice and behaviour to broaden the understanding of the underlying cause of the uncanny valley effect. Up to date, we mainly investigated the general perception of uncanniness in a back-projected head, with a special focus on multimodal gender cues. In the upcoming years, the focus shall shift towards interaction strategies of social robots and their interplay with the robot's appearance.

CCS Concepts

•Human-centered computing → Interactive systems and tools; Interaction techniques; Empirical studies in HCI; •Computing methodologies → Intelligent agents;

Keywords

Uncanny Valley, Perception of Robots, Multimodal Interaction, Robot's Appearance

1. INTRODUCTION

One main goal in social robotics research is to build robots which are accepted as social companions. In many application fields, like elderly care or housekeeping, social robots become more and more human-like in both appearance and interaction. On the contrary, Masahiro Mori [17] suggested in 1970 that making robots more human-like will lead to a drop in their likability at some point in the development. As the uncanny feeling raised in humans at that point will influence the acceptance as a likeable companion, it is important to develop a deep understanding of the so-called uncanny valley effect in order to be able to avoid it. However, the underlying cause of the uncanny valley is still controversial, with different competing explanations such as the perceptual mismatch and categorization ambiguity theory [7][10][12].

Empirical research to date has been primarily concerned with the appearance of the robot and specifically with the dimension of realism in the appearance. However, there is a lack of research carried out to broaden the investigation of uncanniness. In particular, most research only covers unimodal visual cues in the robots appearance, leaving the question how multimodal human-robot interaction might influence the perception of uncanniness unanswered.

While it has been difficult in the past to vary small details in multimodal dimensions of interaction in a real robot setup, the emergence of back-projected heads [3][8][11] made it possible to accurately control facial expressions of a robot and to easily change visual features in the face in a cost-effective manner. This opens up a variety of possibilities to study the influence of multimodal cues on the perception of uncanniness.

Primarily, the research project presented here is concerned with studying...

- ... the influence of multimodal ambiguous categorization cues in different dimensions, like realism or gender, on the perception of uncanniness. Here, multimodal cues refer especially to visual cues (like facial texture or facial expression) and auditory cues (like voice tone, pitch or vocally expressed emotions).
- ... the interplay between appearance of the robot and its interaction strategy.
- ... how results in uncanny valley research gained from experiments with virtual characters can be transferred to real robot applications.

Up to date, our research was mainly focused on investigating the perception of the back-projected robot head Furhat in general and the influence of multimodal gender cues on the perception of uncanniness in particular. Especially because the uncanny valley effect has not yet been investigated using back-projected heads, a series of studies was necessary to close this gap. We found that a mismatch between the perceived gender of the robot's physical mask and the projected facial texture can cause an uncanny feeling in adults [18][20]. On the contrary, adding a mismatch between the gender of the texture and the voice does not trigger an uncanny feeling in children.

In the future, the focus of the project will shift more towards studying the influence of interaction strategies and

ICMI'16, November 12–16, 2016, Tokyo, Japan
© 2016 ACM. 978-1-4503-4556-9/16/11...$15.00
http://dx.doi.org/10.1145/2993148.2997612

embodiment type. We will investigate similarities and differences in the perception of virtual characters and back-projected robot heads and how interaction strategies can purposely increase or decrease an uncanny feeling towards the robot.

This position paper is organized as follows: After discussing the related work in Section 2, Section 3 introduces the main research questions of the project. In Section 4, we will briefly state the experimental results to date, while Section 5 presents a larger picture of the research plan and expected contributions in the future.

2. BACKGROUND AND RELATED WORK

Masahiro Mori [17] first described the relation between the human-likeness and the likability or familiarity of a robot as a non-linear function. He suggested that very human-like robots that are close to looking and behaving like a healthy human being are perceived as uncanny and scary by humans. While Mori's original work was fully theoretical, it was later shown in many empirical research studies that humans feel indeed more uncanny towards some kind of robots. However, the exact shape of the non-linear relation as well as the explanation for this effect are still controversial. Mori originally compared the feeling humans have towards robots with those towards zombies, suggesting that the feeling of uncanniness can be triggered by the appearance of morbidity or illness. Tinwell et al. [22] later related the uncanny feeling with the perception of psychopathy, specifically the trait in psychopathic humans to not feel and display emotions. In their research on virtual characters, they used this theory as an explanation for their finding that male characters are perceived as more uncanny than female characters, claiming male psychopath' have shown to have a more violent behaviour than females.

In contrast to those theories, other recent explanations focus more on the perceptual mismatch in the character's appearance. The *perceptual mismatch theory* claims that any mismatch in the perception of realism in robots and virtual characters increases the sense of eeriness. For example, an increased uncanniness could be observed if the eyes contained conflicting cues [14] or if facial parts were disproportional [13]. Other researchers narrowed this explanation down by claiming the perceptual mismatch only leads towards an uncanny feeling if it pushes the perception of the character to the boundary between two categories [7]. This *categorization ambiguity theory* was supported by Moore [16], who developed a Bayesian explanation of the uncanny valley, in which conflicting cues give rise to a perceptual tension at category boundaries. However, Kätsyri et al. [10] recently reviewed the empirical research related to the uncanny valley effect and found more support for the perceptual mismatch theory. A recent study by MacDorman et al. [12] was designed specifically to investigate the potential of both explanations and found more support for the perceptual mismatch theory as well.

In general, research on the uncanny valley effect has been very focused on the aspect of realism, mostly in the visual appearance of the robot, with some notable exceptions [6][15]. For example, Bartneck et al. [6] found that any lack in social behaviour might lead to a perception of uncanniness. However, they argue that people might have different expectations about appropriate social behaviour of robots compared to humans. A deeper investigation of the interplay between the appearance of the robot and the interaction strategy is still missing. A theory of the uncanny valley, on the contrary, requires to take multiple dimensions of appearance and interaction between robots and humans into account in order to be considered a general explanation. Our research aims to broaden the empirical research on the uncanny valley effect and thereby contribute to closing this gap.

One dimension we add to the uncanny valley research so far is the investigation of the robot's gender as an influence factor [18][19][20]. Research in the field of robot gender is still somewhat rare, most likely because changing gender cues in a robot is not trivial. Eyssel et al. [9] used the hair style of the robot to change its visual gender perception, while Siegel et al. [21] varied the gender only by changing the robot's voice. In our project, the back-projected robot head *Furhat* [3] is used, which gives the possibility to easily change visual gender cues in the robot's facial texture. Furhat is a comparateively new robot platform with very limited usage in research projects to far. Up to now, it has been mainly used to study turn-taking and multimodal multiparty social interaction [4][5]. Al Moubayed et al. could show that the Furhat robot is much more suitable to be used for offering the floor to the next interlocutor in a multiparty communication than a 2D representation of the same face. However, there is no research yet investigating the perception of uncanniness in back-projected robot heads.

3. RESEARCH QUESTIONS

With our research, we aim to contribute to explanatory theories behind the uncanny valley effect. We believe that only if we are able to fully understand the dynamics of the uncanny valley, we will be able to design the appearance and interaction of robots so they can form likeable social companions.

Up to now, the related work is mainly focused on the realism and human-likeness of the robot (cf. Section 2). However, a generalized theory of the uncanny valley effect needs to hold for other dimensions as well. With our research, we want to broaden the empirical research by studying the trigger of uncanniness in other dimensions of perception than realism. We state the following research question:

Research Question 1: Can empirical research using other dimensions than human-likeness and realism support or reject one of the theories behind the uncanny valley effect?

We decided to use *gender* as the dimension of focus for our first research projects. However, we might use another dimensions to further investigate the transferability in the future.

In contrast to the sole appearance of the robot, we hypothesize that the interaction of a robot can trigger an uncanny feeling in humans as well, leading to the following research question:

Research Question 2: Can the interaction strategy of a robot cause or prevent an eerie feeling in humans?

Our aim is to first learn what in the robot's appearance and interaction can cause an uncanny or comfortable feelings in humans. With this experience, we plan on studying the interplay between them and how we can specifically use the robot's behaviour to influence the perception of the robot.

As changing subtle cues in the robot's appearance has shown to be difficult with state-of-the-art robot platforms,

Figure 1: From left to right: 2D image export from FaceGen showing the female and male face, 3D projection of the FaceGen female and male texture to the Furhat mask.

most research on the uncanny valley effect was carried out on virtual agents. However, the transferability of the results has not yet been shown. We aim to conduct our research both on a virtual 2D representation of the robot face and the 3D projection on the Furhat mask to further investigate how well the findings from one embodiment relate to the other. We state the following research question:

Research Question 3: Are the findings related to the uncanny valley gathered in experiments with virtual humans transferable to characters with a physical embodiment?

4. RESULTS TO DATE

Since back-projected robot heads are a comparatively new technology, the perception of uncanniness in these back-projected heads is still not sufficiently studied. Therefore, our research projects to date were mainly dedicated to closing this gap and studying how humans generally perceive the back-projected robot head Furhat. As there has already been much research carried out investigating the effect of realism on the uncanny valley, in our project we aimed to broaden the knowledge about the uncanny valley by using the domain of gender as a primary focus of investigation.

4.1 Applying Gender Cues to Furhat

In order to investigate the influence of gender cues on the perception of uncanniness, we required a facial texture and voice with clear gender cues. In a first pilot study with 40 participants, we selected two facial textures from *FaceGen Modeller* [2] with very feminine respectively masculine rating and similar perception in trustworthiness and strangeness [18]. Figure 1 depicts the feminine and masculine 2D facial texture and the projection of the same facial texture to the Furhat robot.

In a second pilot-study including 52 participants we selected the voices *William* and *Sarah* from the commercial software *CereProc* [1] as a feminine and masculine robot voice [18].

4.2 Perception of Uncanniness in Furhat

In the first user study including the Furhat robot head, our aim was to investigate the general perception of the masculine and feminine version of the platform in terms of uncanniness [18][20]. Following the findings by Tinwell et al. [22], we hypothesized that the gender of the robot has an influence on its perceived uncanniness. In a between-subject experiment with the two independent variables robot gender and modality including 48 participants we found that *not the gender itself, but the congruency of the gender cues influence the perception of uncanniness.* The physical mask of the robot was perceived as very masculine and dominant. When projecting the female face texture onto the face, this lead to a decrease in trustworthiness and familiarity compared to the male face texture. In addition, participants had significantly more difficulties assigning a gender to the robot. However, adding a voice to the face texture clearly helped resolving the ambiguity in the perceived gender and lead to a more positive rating of the feminine robot compared to the unimodal face perception.

4.3 Multimodal Gender Ambiguity

In the second study, we planned to further investigate the influence of incongruent gender cues on the perception of uncanniness [19]. We hypothesized that a robot with incongruent multimodal gender cues is perceived as more uncanny than a robot with congruent cues. To test our hypothesis, we designed a between-subject experiment with the independent variables gender of the voice and gender of the facial texture. In combination, they formed two congruent (male face and male voice; female face and female voice) and two incongruent conditions (male face and female voice; female face and male voice).

The experiment was conducted during a science festival for children. 106 children between 8 and 13 years saw a short presentation of the Furhat robot and rated their perception afterwards. Contrary to our hypothesis and the findings from the first study, we found that *multimodal opposing gender cues did not trigger the feeling of uncanniness in children.* This supports other recent research which states that the categorical ambiguity theory cannot fully explain the uncanny valley effect. In addition, we found that children relate more on the vocal cues than on the facial cues when assigning a gender to the robot. This is important since it gives confidence in the findings in robot gender research which were accomplished by only changing the robot's voice.

One possible explanation of our findings is that children have a different perception of uncanniness in robots. In ongoing work, we analyse data acquired from teenagers and adults using the same experiment setup to investigate this theory further. Another reason could be that the cues in the first study where much more subtle and difficult to mentally grasp for participants, while the difference between voice and face was more obvious. Further research is necessary to investigate the difference in the findings from the first and the second study and support one of the mentioned hypotheses.

5. RESEARCH PLAN

Since our first studies gave us initial insights in how the back-projected robot head Furhat is perceived, we are planning to move towards a more advanced interaction with the Furhat robot in the future. In addition, we will work on different embodiments, both to compare a 2D against 3D representation of a face, but also to ensure the transferability of our results to other physical embodiments.

5.1 Ongoing Work

Our first studies have shown that the possibility to change the appearance of the robot is limited by the physical shape of the mask [20][18]. As the only currently existing adult mask of the Furhat robot is perceived as very masculine and dominant, a second mask is required in order to continue research with a feminine robot as well. In particular, we would like to study how the results of the first study (cf. Section 4.2) change if we have a robot which is perceived as truly feminine without ambiguous gender cues and if we are then able to reproduce the findings by Tinwell et al. [22]. To reach that goal, we are collaborating with Furhat robotics to design two new masks, one with an even more masculine appearance and one with a feminine appearance. The design process is inspired by a crowd-sourced online rating of different physical face shapes and textures. Once two new masks have been designed and produced, we will confirm our design by an on-site experiment involving the Furhat robot.

As a first step towards researching the interaction rather than the sole appearance of Furhat, we set up a study to link the mimicry of a robot to the feeling of uncanniness. As our previous studies have shown the difference in perception of the feminine and masculine representation, the study has a between-subject design with the gender as independent variable. For the first time, we also have subjects interacting both with the Furhat and a 2D virtual representation of a face to investigate the transferability of the findings.

It is well known in the community that the perception of robots is highly influenced by the novelty effect. However, only few related research projects directly focused on investigating the novelty effect on the perception of uncanniness. In a recently started research project with children, we will design a robot with a purposely uncanny appearance. In a moderated interaction lead by a human, we want to investigate if and how the interaction strategy of the human moderator and the robot can help the children overcome their uncanny feeling. We hypothesize that this might even lead to a strong positive and encouraging feeling in the children when overcoming the initial scare towards the robot, which means we might potentially be able to turn the initial negative feeling of uncanniness into a positive feeling during a longer interaction with the robot.

5.2 Future Work

In the future, the focus of the project shall shift from fully scripted behaviours to real interactions with the robot. In particular, we want to investigate what in the behaviour of a robot can cause an uncanny feeling in humans and how the appearance of the robot can increase or decrease this feeling. We aim to study both adults and children in their interaction with the robot, to improve the understanding of the difference between the perception of uncanniness in different age groups. As already started in the current work, we are planning to conduct more studies with the embodiment type (2D versus 3D) as an independent variable in the future. By that, we hope to deepen our knowledge about similarities and difference in their influence on the uncanny valley effect.

6. CONCLUSION

With this research project, we contribute to the theories behind the uncanny valley effect. While the theories are currently mainly supported by empirical research on the visual appearance, we aim to broaden the theories by applying a more multimodal approach. By investigating the influence and interplay of both appearance, voice, behaviour and interaction strategy, we hope to find stronger support for one of the current uncanny valley theories. The Furhat back-projected robot platform is excellent for both varying the appearance of the robot in an easy and cost-effective manner and bridging the gap between research in the field of robotics and virtual agents. By using both a 2D representation of the face and the 3D projection on the robot's face in our studies, we aim to contribute to the understanding on how the findings from one field can be related to the respective other field.

7. REFERENCES

[1] CereProc Synthesizer. https://www.cereproc.com/. Accessed: 2016-05-08.

[2] FaceGen Modeller. http://facegen.com/. Accessed: 2016-05-08.

[3] S. Al Moubayed, J. Beskow, G. Skantze, and B. Granström. Furhat: a back-projected human-like robot head for multiparty human-machine interaction. In *Cognitive Behavioural Systems*, pages 114–130. Springer, 2012.

[4] S. Al Moubayed and G. Skantze. Turn-taking control using gaze in multiparty human-computer dialogue: Effects of 2d and 3d displays. In *International Conference on Audio-Visual Speech Processing 2011, Aug 31-Sep 3 2011, Volterra, Italy*, pages 99–102. KTH Royal Institute of Technology, 2011.

[5] S. Al Moubayed, G. Skantze, J. Beskow, K. Stefanov, and J. Gustafson. Multimodal multiparty social interaction with the furhat head. In *Proceedings of the 14th ACM international conference on Multimodal interaction*, pages 293–294. ACM, 2012.

[6] C. Bartneck, T. Kanda, H. Ishiguro, and N. Hagita. My robotic doppelgänger - A critical look at the uncanny valley. In *The 18th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, pages 269–276. IEEE, 2009.

[7] M. Cheetham, P. Suter, and L. Jäncke. The human likeness dimension of the "uncanny valley hypothesis": behavioral and functional MRI findings. *Frontiers in Human Neuroscience*, 5(126):10–3389, 2011.

[8] F. Delaunay, J. De Greeff, and T. Belpaeme. Towards retro-projected robot faces: an alternative to mechatronic and android faces. In *The 18th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, pages 306–311. IEEE, 2009.

[9] F. Eyssel and F. Hegel. (S)he's Got the Look: Gender Stereotyping of Robots. *Journal of Applied Social Psychology*, 42(9):2213–2230, 2012.

[10] J. Kätsyri, K. Förger, M. Mäkäräinen, and T. Takala. A review of empirical evidence on different uncanny valley hypotheses: support for perceptual mismatch as one road to the valley of eeriness. *Frontiers in Psychology*, 6, 2015.

[11] T. Kuratate, Y. Matsusaka, B. Pierce, and G. Cheng. "Mask-bot": A life-size robot head using talking head animation for human-robot communication. In *11th IEEE-RAS International Conference on Humanoid Robots (Humanoids), 2011*, pages 99–104. IEEE, 2011.

[12] K. F. MacDorman and D. Chattopadhyay. Reducing consistency in human realism increases the uncanny valley effect; increasing category uncertainty does not. *Cognition*, 146:190–205, 2016.

[13] K. F. MacDorman, R. D. Green, C.-C. Ho, and C. T. Koch. Too real for comfort? Uncanny responses to computer generated faces. *Computers in Human Behavior*, 25(3):695–710, 2009.

[14] L. F. Meah and R. K. Moore. The uncanny valley: A focus on misaligned cues. In *6th International Conference on Social Robotics (ICSR)*, pages 256–265. Springer, 2014.

[15] W. J. Mitchell, K. A. Szerszen, A. S. Lu, P. W. Schermerhorn, M. Scheutz, and K. F. MacDorman. A mismatch in the human realism of face and voice produces an uncanny valley. *i-Perception*, 2(1):10–12, 2011.

[16] R. K. Moore. A Bayesian explanation of the 'Uncanny Valley' effect and related psychological phenomena. *Scientific Reports*, 2, 2012.

[17] M. Mori, K. F. MacDorman, and N. Kageki. The uncanny valley [from the field]. *Robotics & Automation Magazine, IEEE*, 19(2):98–100, 2012.

[18] M. Paetzel, C. Peters, I. Nyström, and G. Castellano. Congruency matters - How ambiguous gender cues increase a robot's uncanniness. In *8th International Conference on Social Robotics (ICSR)*, 2016.

[19] M. Paetzel, C. Peters, I. Nyström, and G. Castellano. Effects of Multimodal Cues on Children's Perception of Uncanniness in a Social Robot. In *18th ACM International Conference on Multimodal Interaction (ICMI)*, 2016.

[20] M. Paetzel, C. Peters, I. Nyström, and G. Castellano. Preliminary results from using a back-projected robot head in uncanny valley research. In *The 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), Interactive Session*, 2016.

[21] M. Siegel, C. Breazeal, and M. I. Norton. Persuasive robotics: The influence of robot gender on human behavior. In *IEEE/RSJ International Conference on Intelligent Robots and Systems, 2009. IROS 2009.*, pages 2563–2568. IEEE, 2009.

[22] A. Tinwell, D. A. Nabi, and J. P. Charlton. Perception of psychopathy and the Uncanny Valley in virtual characters. *Computers in Human Behavior*, 29(4):1617–1625, 2013.