Let Me Get To Know You Better Can Interactions Help to Overcome Uncanny Feelings?

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

Ginevra Castellano
Department of Information Technology
Uppsala University, Sweden
ginevra.castellano@it.uu.se

ABSTRACT

With an ever increasing demand for personal service robots and artificial assistants, companies, start-ups and researchers aim to better understand what makes robot platforms more likable. Some argue that increasing a robot's humanlikeness leads to a higher acceptability. Others, however, find that extremely humanlike robots are perceived as uncanny and are consequently often rejected by users. When investigating people's perception of robots, the focus of the related work lies almost solely on the first impression of these robots, often measured based on images or video clips of the robots alone. Little is known about whether these initial positive or negative feelings persist when giving people the chance to interact with the robot. In this paper, 48 participants were gradually exposed to the capabilities of a robot and their perception of it was tracked from their first impression to after playing a short interactive game with it. We found that initial uncanny feelings towards the robot were significantly decreased after getting to know it better, which further highlights the importance of using real interactive scenarios when studying people's perception of robots. In order to elicit uncanny feelings, we used the 3D blended embodiment Furhat and designed four different facial textures for it. Our work shows that a blended platform can cause different levels of discomfort towards it depending on the facial texture and may thus be an interesting tool for further research on the uncanny valley.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; *Natural language interfaces*; • **Computer systems organization** → **Robotics**; • **Computing methodologies** → *Intelligent agents.*

KEYWORDS

Uncanny Valley, Embodiment, Human-Robot Interaction

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1 INTRODUCTION

With more robots entering personal homes, there is an increasing demand to understand what makes a robot platform being liked and accepted by the general public. In this context, one specific field of interest is the study of uncanny feelings towards robots. Researchers aim to understand what makes people feel uneasy around specific types of robot embodiments. Masahiro Mori suggested that robots exceeding a certain threshold of humanlikeness could fall into what he called the *uncanny valley* and could consequently be rejected by humans [16]. More recent research, however, found the contributing factors to uncanny feelings to be rather complex and multi-dimensional [2]. While much research has been carried out to understand *what* makes a robot uncanny, the question is seldom raised *why* the uncanny valley is worth studying and how it may impact human-robot interactions [21][22].

An underlying assumption behind many related research projects is that uncanny feelings towards robots may harm the relationship between the human and the robot. With few exceptions, however, research on the uncanny valley has been carried out using still images of robots or very brief encounters with a physically present robot [21]. Findings from these studies suggest that people are indeed reluctant towards robots with an uncanny appearance [8][13][15]. Zlotowski et al. further suggest that repeated interactions with a robot can significantly decrease uncanny feelings towards it. *What we know little about, however, is how important the factor of interaction is when studying uncanny feelings towards robots.*

In this paper, we aim to investigate how people's uncanny feelings develop when they are gradually exposed to a robot. More specifically, we want to shed light on the question how people's perception of a robot's competence, humanlikeness, social presence and uncanniness develops from the first impression to after interacting with it.

We use a blended embodiment (cf. Fig. 1) as a novel methodology in uncanny valley related research to address this question. As most of today's robots are not humanlike enough to be considered eerie [13], most of the research on the uncanny valley has been carried out on virtual agents. While the appearance of virtual agents can easily be altered to create different and comparable versions of the same agent, the perception of virtual agents often differs in comparison to robots [12]. Research comparing uncanny feelings between robots and virtual characters is sparse, but first results show that findings from virtual agents do not always translate to a physical counterpart [18]. Back-projected robot platforms are a promising technology for uncanny valley related research since they offer the flexibility of altering the appearance of the robot while at the same time keeping its physical embodiment [1][5][10]. However, it is unclear how exactly an uncanny perception can be

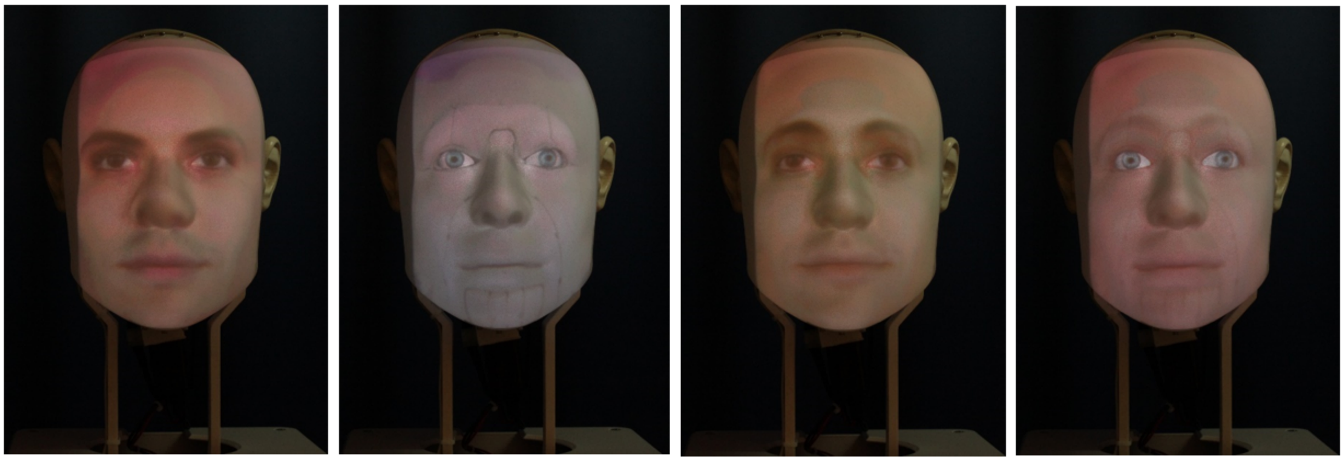

Figure 1: Blended robot platform Furhat with the humanlike, machinelike, sick and morph texture (from left to right) projected onto it.

elicited in such robots. The common approach of morphing between humanlike and machinelike faces may work for virtual agents as it can lead the user to ponder whether a picture depicts an actual or virtual human [15]. The same uncertainty cannot be achieved with back-projected robots since the artificial nature of the stimulus is obvious to observers. In this paper, we investigate whether applying a morphed facial texture to a physical robot can still elicit uncanny feelings in humans. In addition, we explore whether the texture of a sick agent may be suitable to create an uncanny stimulus as well and how the perception of the morph and sick stimulus differ from that of a humanlike and machinelike stimulus applied to the same robot platform.

2 RELATED WORK

The uncanny valley was first introduced by Masahiro Mori in 1970 [16]. He suggested that robots that almost but not quite resemble a real human could elicit uncanny feelings. Today, the existence of the so-called uncanny valley effect and its potential causes are still debated [6]. Kätsyri et al. recently compared empirical investigations on different theories behind the uncanny valley [9]. They found that most of the evidence supports the *perceptual mismatch theory* which explains the feeling of eeriness towards a robot with a mismatch in the perception of realism. Less evidence was found for competing theories like the *categorization ambiguity theory* which claims a perceptual mismatch only leads to uncanny feelings if it pushes the perception to the categorization border between a human and a machine. While Mori originally hypothesized uncanny feeling could be caused by evoking associations with morbidity, little evidence was found to support this theory in artificial agents. A noteworthy exception is the work by McDonnell et al. who found an unhealthy looking virtual agent to elicit uncanny feelings [15].

Studying uncanny feelings towards robots is difficult due to the lack of platforms that are humanlike enough to elicit such feelings. MacDorman investigated how uncanny short video clips of different robot platforms were perceived [13]. Among the fourteen selected platforms only the two android heads were rated as eerie. This observation leads to two core problems: First, android robots are still very rare and not affordable for most research institutes, which significantly limits the research potential in the field. Second, a comparison between an uncanny and likable robot requires the usage of two very different robot platforms. The difference between these platforms is likely not limited to the dimension of humanlikeness. Consequently, related findings may be highly confounded by other perceived differences in the embodiments.

Due to the lack of eligible robot platforms, much research on the uncanny valley has been carried out using virtual characters. McDonnell et al. found morphs between cartoonlike characters and human images to be perceived as eerie if they were difficult to categorize as either cartoonlike or human [15]. Virtual characters also allow the study of subtle changes in the virtual face. Tinwell et al., for example, showed that conflicting emotional cues in the face can lead to an uncanny feeling in humans [20]. Similarly, MacDorman found that changing the facial proportions of virtual humans can elicit eerie feelings [14].

Ideally, it would be possible to create gradual morphs between machinelike and humanlike robots similarly to virtual agents. While this can be achieved in images of robots [8], the technology of robots is not advanced enough to achieve such morphs in real physical embodiments. Hence, research involving uncanny feelings towards robots often conveniently use images or short video clips of robots instead of physically present robots. These stimuli are easier to create and present to a large pool of participants. However, findings from these studies can merely be representative of a first impression of a robot [21]. How this impression impact human-robot interactions is still unknown. In this paper, we use the 3D blended embodiment Furhat that projects a computer modelled virtual face onto a 3D mask [1]. We hope that this technology allows to create physical embodied morphs between machinelike and humanlike robots and thus eases the study of the uncanny valley in robots.

Zlotowski et al. were the first to investigate how uncanny feelings persist over the course of multiple interactions with the same robot [22]. They used a Geminoid HI-2 and a Robovie R2 and studied how the perception of the two platforms changed over the course of three interactions. Their findings suggest that repeated interactions with a robot can significantly decrease uncanny feelings towards it. However, the work by Zlotowski et al. does not include a discussion of whether one interaction with a robot may be sufficient to decrease initial uncanny feelings. The study presented in this paper aims to shed further light on this particular research question. By using different facial textures on the same back-projected robot head, we also aim to decrease confounding variables when researching the persistence of the uncanny valley effect.

3 RESEARCH QUESTIONS

The goal of this paper is to investigate how participants' perception of a robot changes when they are gradually exposed to the robot platform.

(RQ1) How does the perception of a robot embodiment change when participants are gradually exposed to its capabilities?

This research question is investigated by introducing participants to a robot in three different stages. In the first stage, the robot does not show any movement in the face. In the second stage, the robot gives a short introduction about itself using speech, facial expressions and head movements. In the third stage, the robot plays the interactive 20 Questions Game with the participant.

We believe that, once the robot starts showing more sophisticated abilities and exposes social traits, it will be perceived as more competent and socially present:

(H1.1) The more participants are exposed to the robot's capabilities, the more competent they perceive it.

(H1.2) The more participants are exposed to the robot's capabilities, the more socially present they perceive it.

Since the robot will display more humanlike behavior (specifically talking and facial expressions), we believe the robot's perceived humanlikeness will increase after the second and third stage of the introduction:

(H1.3) The more participants are exposed to the robot's (humanlike) capabilities, the more humanlike they perceive it.

Finally, we hypothesize that people will get used to the perceptual mismatch they are exposed to in the uncanny face and thus overcome the uncanny feeling towards it. A perceptual mismatch indicates that an unconscious assumption of how someone or something is supposed to look or move is not met. For example, people expect facial proportions to be within a certain boundary and breaking this assumptions elicits uncanny feelings [14]. However, people may be able to change their expectations towards an agent either by being exposed to it longer (as in the work by Zlotowski et al. [22]) or by getting to know the agent and it's abilities better, which consequently allows them to form a better mental model of the agent they are exposed to. This leads us to hypothesize that the robot's perceived uncanniness will decrease with an increased level of exposure to the robot and its abilities.

(H1.4) The more participants are exposed to the robot's capabilities, the less uncanny they perceive it.

Investigating the uncanny valley in physically embodied robots is a challenging problem (cf. Section 2). In this work, we aim to explore how blended embodiments can be utilized to study uncanny feelings towards physically present robots.

(RQ2) How can different textures projected onto a blended embodiment be used to create both likable and uncanny perceptions of the platform?

We adopt two different approaches that McDonnell et al. successfully used to elicit uncanny feelings towards a virtual agent: (1) Creating a morph between a humanlike and a machinelike face and (2) creating a face that resembles the look of sickness in a human face. We hypothesize that both faces will be perceived as significantly more uncanny in comparison to the original humanlike and machinelike faces.

(H2.1) A morph between a humanlike and a machinelike face is perceived as significantly more uncanny than either one of the originals.

(H2.2) A humanlike face which has been altered to resemble sickness is perceived as significantly more uncanny than the original humanlike face.

4 METHODOLOGY

To answer the research questions stated in Section 3, we conducted an experiment with the two independent variables *embodiment* and *level of exposure*. The robot presented to participants either displayed a humanlilke, machinelike, sick or morphed facial texture (cf. Fig. 1). Each participant was only exposed to one of the facial textures (between-subjects) and was asked about his/her perception of the robot three times over the course of the interaction with it (within-subjects). In stage 1, participants rated their first impression of the robot solely based on its appearance. In stage 2, they judged the robot after it gave an introductory speech to the participant. Finally, in stage 3 participants were asked about their impression after playing an interactive game with the robot.

4.1 Participants

57 students were recruited from an international Master course at Uppsala University to participate in the experiment. Due to technical failures with the robot or the questionnaire system, 9 participants were excluded from the analysis presented in this paper. The remaining 48 participants (13 female, 33 male, 1 other, 1 prefer not to say) were evenly distributed among the four embodiment conditions. Participants were between 21 and 43 years old (M= 26, SD= 15.96) and had at least a high-school degree. All except of one were enrolled in a Computer Science or related program and most of them received course credits for their participation.

4.2 Embodiment

A Furhat robot was used as a blended embodiment in the experiment [1]. Furhat is equipped with a rigid mask of a male face on which a facial texture is projected from within. The robot has two motors to control the head's tilt and pan. Further expressiveness is achieved by using animations in the projected facial texture.

Four different textures were designed for this experiment: The first texture was created based on a photograph of a male human (Fig. 1 left). We used the same texture in previous experiments with the Furhat robot and found it to be rated above average on the scales humanlikeness and likability [18]. In previous work, we have used a cartoonlike face with only indicated lips and eyebrows and created a morph between this facial texture and the humanlike one. While the resulting morph was perceived as uncanny in online pilot studies on virtual faces, the projection on the robot failed to elicit the same uncanny feelings. We believe the morphing effect may have been too subtle and was thus unnoticed by participants when projected on the slightly blurry face of the robot.

In this work, we created a more machinelike version of the face as the non-humanlike counterpart (Fig. 1 second from left). This was based on a photograph of a mechanical robot face consisting of multiple facial parts and screws holding them together. A morph between the humanlike and machinelike texture was created between the skin textures in the Paint.NET digital photo editing package (Fig. 1 right). The face looks more pale than the humanlike face and has less detailed facial features. An indication of the mechanical structures from the machinelike face is still visible, but less dominant. Due to a very different structure of the eye texture used for the machinelike version and the humanlike version, morphing between the two did not provide good results. Thus, we decided to use the original machinelike eyes in the morph between the humanlike and machinelike facial texture and thus strengthen the machinelike details in the morphed face.

Following the approach by McDonnell et al. and findings by Stephen et al. suggesting that skin blood coloration is a cue to perceived health, a sick version of the humanlike texture was created by changing the color to a more pale, yellow version and creating a red shimmer around the eyes (Fig. 1 second from right) [15][19].

4.3 Levels of Exposure

Participants were exposed to the robot in three different stages.
Stage 1 - First Impression (S1): The robot, previously hidden under a blanket, was uncovered. Apart from blinking with the eyes, the robot did not show any movement.
Stage 2 - Introduction (S2): The robot started introducing itself. The introduction was approximately two minutes long and contained speech, facial expressions and head movements. The introduction was pre-recorded and the robot did not react to the participant's behavior in any way.
Stage 3 - Interaction (S3): Participants played the 20 Questions Game with the robot[1]. They were given the rules of the game prior to the interaction. The robot started by saying "Let's play a game. You think of a character and I will ask questions to guess which character you are thinking of. Do you have a character in mind?" When the participant responded positively, the robot started asking the first question. Participants could answer with "yes", "probably", "probably not", "no" and "I don't know" as well as multiple variations of these responses. They could also ask the robot to repeat the question. The robot was tracking the participant over the course of the interaction using a RealSense camera and tried to hold eye contact with the human game partner. Occasionally, the robot would nod or frown before asking the next question, accompanied by a short vocal clip. This was implemented to give the impression of the robot processing or thinking about the participant's response. The robot could attempt a maximum of three guesses. If the robot made more than 3 guesses or asked more than 40 questions it would give up and consider the game lost.

[1]The implementation was based on the Akinator API.

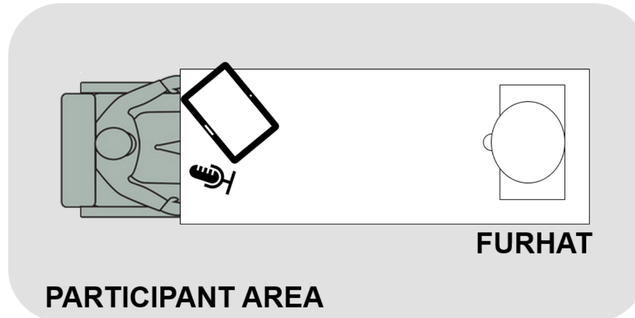

Figure 2: Setup of the experiment space.

4.4 Measures

Before the start of the robot interaction, participants were asked to fill out a short questionnaire (Q1) containing demographic questions as well as an assessment of their negative attitude towards robots (NARS) [17].

The second questionnaire (Q2) was filled out by participants after each of the three stages of the interaction and was designed to investigate their perception of the robot on the following scales:

- *Level of Anthropomorphism* (5 items), sub-scale from the Godspeed questionnaire [3], evaluated on a five point Likert scale.
- *Social presence* (5 items), adapted from [11], evaluated on a 10 point Likert scale.
- *Social attitude* (18 items) to investigate the robots *warmth*, *competence* and *discomfort* [4], evaluated on a 7 point Likert scale. The combination of the robot's warmth and discomfort is used to judge people's *uncanny feelings* towards it.

To conclude the experiment, a semi-structured interview was conducted to capture the participant's experience with the robot and how they subjectively felt their perception of the robot had changed over time. For analysis, the audio-recordings of the interviews were manually transcribed and grouped by the question asked. In a second step, similar content and expressed sentiment in the replies to the same question were grouped together and annotated with an appropriate label.

4.5 Experimental Setup & Procedure

The experiment took place in a laboratory room at Uppsala University. Participants were seated on a table opposite of the Furhat robot which was placed approximately at a distance of 1m from the participant. The fully autonomous robot behavior was controlled by a computer outside of the participant area. The microphone that was placed in front of the participant on the table as well as the RealSense camera in front of the robot were connected to that computer. A sketch of the participant area is shown in Figure 2.

After signing the consent form and reading the game instructions, participants were given an iPad to fill out the questionnaires. (Q1) was filled out while the robot was still covered by a blanket. After

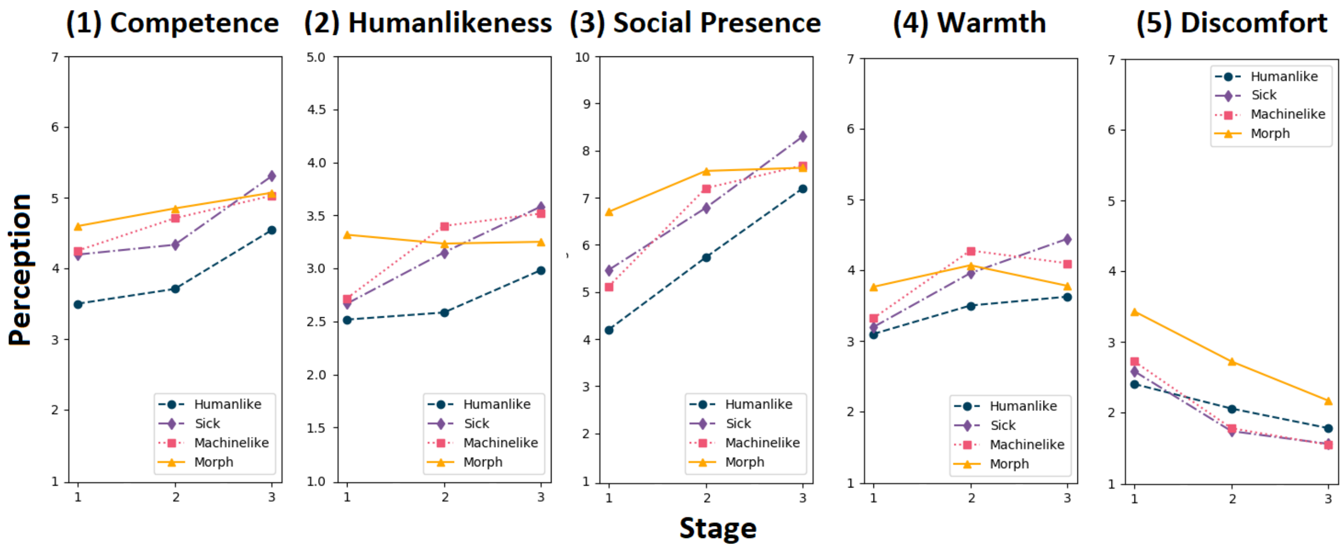

Figure 3: Change of perception of the (1) competence, (2) humanlikeness, (3) social presence, (4) warmth and (5) discomfort over the three stages of interaction classified by the facial texture displayed.

finishing (Q1), the robot was uncovered and participants were asked to fill out (Q2) for the first time. Once they finished (Q2), the robot introduction was manually started by a researcher. Once the robot ended the introduction, participants were prompted to fill out (Q2) on the iPad for the second time. The researcher then enabled the game interaction. (Q2) was filled out for the third and last time after the participant finished playing the game with the robot. The semi-structured interview was conducted after participants finished (Q2) for the last time.

5 RESULTS

In the following, we report the results from participant's responses to (Q2). A 3 x 4 ANOVA with embodiment (humanlike, machinelike, morph and sick) and level of exposure (stage 1, 2 and 3) was performed to analyze the influence of the embodiment and the level of exposure on participant's perception of the robot.

5.1 The Influence of the Embodiment

The embodiment was found to significantly influence the robot's perceived competence, $F(3, 132) = 4.381, p = .006$, humanlikeness, $F(3, 132) = 3.924, p = .01$, discomfort, $F(3, 132) = 5.706, p = .001$, and social presence, $F(3, 132) = 6.073, p < .001$. The warmth of the robot is the only trait which was not significantly influenced by the robot's embodiment, $F(3, 132) = 2.001, p = .185$.

Interestingly, the humanlike facial texture was perceived as the least humanlike among the textures tested ($M = 2.69$, $SD = 0.14$). It was seen as significantly less humanlike than both the machinelike version ($M = 3.2$, $SD = 0.15$), $p = .031$, and the morph ($M = 3.27$, $SD = 0.12$), $p = .013$. No significant difference was observed towards the sick version of the humanlike face ($M = 3.13$, $SD = 0.14$). Similarly, we found the humanlike version ($M = 3.92$, $SD = 0.2$) to be perceived as the least competent compared to the machinelike texture ($M = 4.66$, $SD = 0.23$), $p = .037$, and the morph ($M = 4.84$, $SD = 0.16$), $p = .005$. The difference between the humanlike texture and the sick version of the same texture ($M = 4.61$, $SD = 0.21$) was not significantly different. However, the social presence of the humanlike face ($M = 5.71$, $SD = 0.32$) was perceived lower than the one of the sick version ($M = 6.85$, $SD = 0.3$), $p = .019$, and the morph ($M = 7.3$, $SD = 0.26$), $p < .001$. Even though the social presence of the machinelike texture ($M = 6.66$, $SD = 0.37$) was rated higher than the humanlike one, the trend is not significant.

While we found the morph of the face to receive comparable ratings to the machinelike and sick texture, it stands out when rating discomfort with the robot: People feel significantly more uncomfortable when interacting with the morphed texture ($M = 2.77$, $SD = 0.23$) than with the humanlike texture ($M = 2.08$, $SD = 0.18$), $p = .013$, the machinelike texture ($M = 2.01$, $SD = 0.15$), $p = .005$, and sick texture ($M = 1.96$, $SD = 0.12$), $p = .002$.

Our ANOVA analysis showed no significant interaction between the robot's embodiment and the level of exposure. However, it is interesting to note that after the first impression the morph was rated 0.71 points more uncomfortable compared to the machinelike version (which received the highest rating of discomfort among the three other textures). After the interaction phase, participants were only 0.4 points more uncomfortable with the morph compared to the humanlike texture (which now received the highest rating of discomfort among the three other textures).

In summary, creating a sick version of the humanlike face does not seem to elicit uncanny feelings towards the robot. Thus H1.2 cannot be confirmed with our experiment. However, participants expressed significantly more uncanny feelings towards the morph, which confirms H1.1. Figure 3 visualizes the perception of the four different textures over the course of the interaction with the robot.

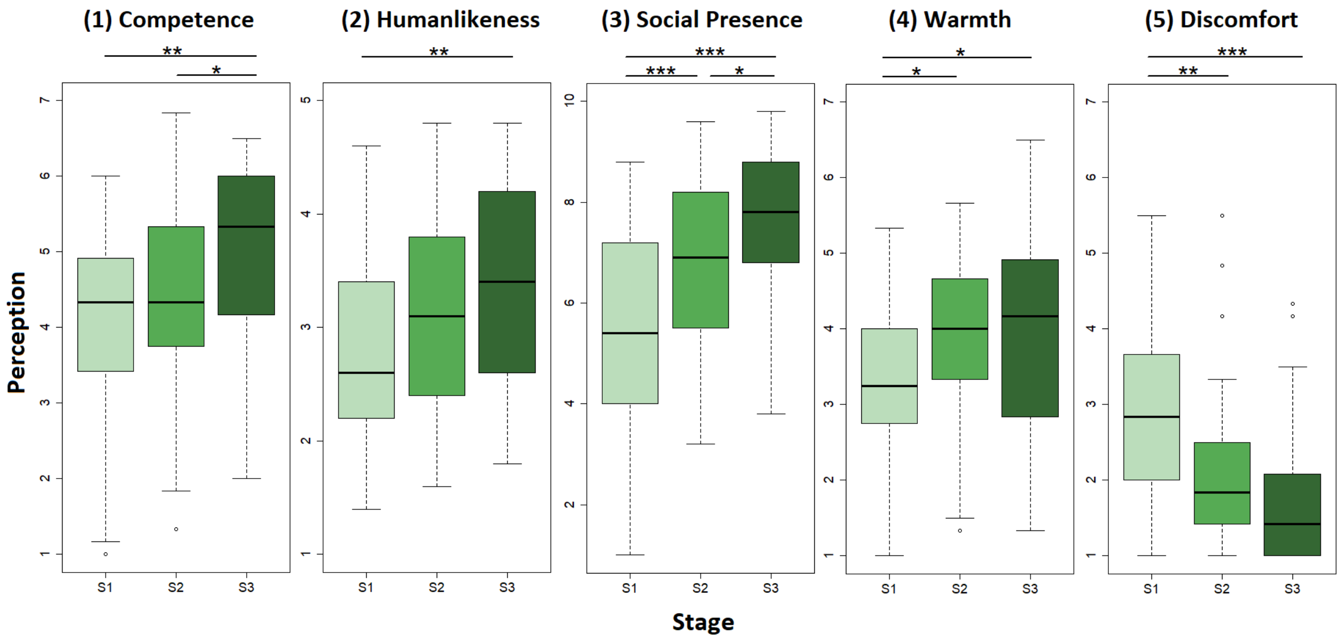

Figure 4: Change of perception of the robot's (1) competence, (2) humanlikeness, (3) social presence, (4) warmth and (5) discomfort over the three stages of interaction. Significant differences are indicated by * ($p < .05$), ** ($p < .01$), and * ($p < .001$).**

5.2 The Influence of the Level of Exposure

In the following section, we present how the perception of the robot changes from the first impression (S1) over the introduction of the robot (S2) to after having a real interaction with it (S3). Figure 4 visualizes the findings which are discussed in detail below.

H2.1 - Competence

The interaction stage has a significant influence on people's perception of the robot's competence, $F(2, 132) = 6.741, p = .002$. A Tukey's PostHoc analysis revealed that participants considered the robot to be significantly more competent after the interaction with it (S3, $M = 4.99$, $SD = 0.17$), both compared to after the first impression (S1, $M = 4.14$, $SD = 0.17$), $p = .001$, and after the introduction of the robot (S2, $M = 4.4$, $SD = 0.17$), $p = .038$. The difference between stage 1 and stage 2 was not significant, $p = .51$. These findings partially confirm H2.1.

H2.2 - Humanlikeness

The interaction stage has a significant influence on people's perception of the robot's humanlikeness, $F(2, 132) = 5.414, p = .006$. A Tukey's PostHoc analysis revealed that people considered the robot to be significantly more humanlike after interacting with it (S3, $M = 3.33$, $SD = 0.13$) compared to after the first impression (S1, $M = 2.8$, $SD = 0.11$), $p = .004$. There was no significant difference between the perception after the robot's introduction (S2, $M = 3.09$, $SD = 0.11$) and the first impression, $p = .18$, as well as between the robot's introduction (S2) and the actual interaction with the robot (S3), $p = .29$. H2.2 was thus partially confirmed.

H2.3 - Social Presence

The interaction stage has a significant influence on people's perception of the robot's social presence, $F(2, 132) = 25.103, p < .001$. A Tukey's PostHoc analysis revealed a significant difference between all three stages of exposure to the robot: After the introduction (S2, $M = 6.82$, $SD = .23$) the robot was considered significantly more socially present than after the first impression (S1, $M = 5.37$, $SD = .29$), $p < .001$. Similarly, the robot was considered significantly more socially present after the interaction (S3, $M = 7.7$, $SD = 0.22$), both compared to the first stage, $p < .001$, and the second stage, $p = .024$. These findings confirm H2.3.

H2.4 - Uncanniness

The interaction stage has a significant influence on the perceived warmth, $F(2, 132) = 5.104, p = .007$, and discomfort towards the robot, $F(2, 132) = 14.424, p < .001$. A Tukey's PostHoc analysis revealed that people were significantly less uncomfortable around the robot after the introduction of the robot (S2, $M = 2.07$, $SD = 0.14$) compared to the first impression (S1, $M = 2.78$, $SD = 0.16$), $p = .001$. The difference in perceived discomfort between the interaction with the robot (S3, $M = 1.76$, $SD = 0.13$) and the first impression (S1) was significant as well, $p < .001$. There was no significant difference between the second and third stage, $p = .25$.

The same effect can be observed regarding the perceived warmth of the robot. The robot was perceived significantly more warm after the introduction of the robot (S2, $M = 3.95$, $SD = 0.15$) compared to the first impression (S1, $M = 3.34$, $SD = 0.14$), $p = .022$. After the interaction with the robot, the perceived warmth slightly increased (S3, $M = 4.0$, $SD = 0.18$). The change in warmth after the interaction (S3) was significant in comparison to the first impression (S1),

p = .014, but not compared to after the introduction of the robot (S2), p = .99. This partially confirms H2.4.

In summary, the results suggest that exposing the robot's abilities by giving a short introduction increases the perceived social presence of the robot and reduces the uncanny feeling (measured with the items warmth and discomfort) towards it. Moreover, they show that by allowing participants to interact with the robot, the humanlikeness and competence of the robot is also likely to increase.

6 DISCUSSION

Participants felt mostly positive about their overall experience with the robot. Many commented on the impressive technology of the robot platform and its high level of realism. The robot was quite successful in playing the 20 Questions Game. Only for eight participants the robot was unable to guess the character. Many were quite surprised when the robot made the correct guess, especially when they tried to challenge it by selecting a less well known character.

The voice of the robot, its sense of humour and the "pauses [as if it] is actually thinking about the question" have been mentioned by many participants when asked what they liked about the robot. By far the most negative comments were made regarding the robot's face tracking behavior. Because the eyes in the projection are slightly off center, it always gives the impression of trying but not succeeding to make eye contact.

In the following, we will discuss the findings regarding the influence of the embodiment and stage of interaction, the limitations of the study presented in this paper and suggestions for future work in more detail.

6.1 The Influence of Embodiment

Related work on virtual characters has shown promising results when using morphing to create uncanny perceptions towards agents [15]. However, the effect was explained with the categorization ambiguity which left people uncertain whether they were looking at a real human or at a computer animated image. By projecting a morphed face on a blended robot platform, this categorization ambiguity dissolves since the nature of the stimulus is undoubtedly mechanical. Consequently, in our previous work we were unsuccessful in eliciting the same uncanny feelings towards the blended embodiment that we had observed in response to a virtual agent, even if we used the exact same facial texture [18]. The morph we used in this study was purposefully created so that features of both the humanlike and mechanical texture would be visible. Our results suggest that *a morph between a humanlike and machinelike texture with clearly visible morphing features is perceived as significantly more uncanny than either the humanlike or machinelike textures.*

We believe that by designing a morph containing obvious features from both the humanlike and machinelike texture we did, in fact, create a perceptual mismatch. However, the uncertainty may likely not lay in whether or not the stimulus is human or mechanical. Instead, it may reside in *whether the impression that the agent is trying to communicate is humanlike or machinelike.* From the literature we know that people base their perception of a robot's capabilities heavily on the robots appearance [7]. By creating a stimulus that contains both humanlike and machinelike features, the cues about how to approach the robot are ambiguous and could hence lead to an eerie feeling. Further support for this theory is given by observing participants' uncanny feelings over time: After the robot has introduced itself and has clearly communicated very humanlike features, the discomfort towards it drops significantly. This may be because participants were given enough cues to resolve the perceptual mismatch and clearly sort the robot into a more humanlike category. *While this explanation is speculative and further research is necessary to confirm it, it may extend the traditional definition of the perceptual mismatch theory to include expectations regarding the robot's interactive capabilities.*

Interestingly, we found the facial texture that was created based on the photograph of a real human to be perceived as the least humanlike among our stimuli. This is contrary to previous findings in which we found the exact same texture on the robot to be rated above average on the scale of humanlikeness (M= 3.40 SD= 0.11) [18]. In the related experiment, people were asked to label the robot's facial expressions, which is a task very different in nature to the one presented here. Since we only measured the robot's humanlikeness after the task was completed in the previous experiment, the task may have had a significant influence on the rating of the robot.

Despite the difference in perception from previous work, it is still interesting that the texture resembling a real human was rated the least humanlike in comparison so the other textures presented. A possible explanation for our finding is that people apply different standards when judging the appearance of the robot. When being presented with a very humanlike face, participants may compare the robot to humanlike virtual characters or even real humans. One participant who interacted with the humanlike robot version reflected on this part explicitly: "I mean I think it would be less strange if it wouldn't try to look as human [...]. It doesn't succeed well enough in looking as [a] human." Thus, the hypothetical maximum of the scale they judge the robot on shifts towards a more humanlike impression. Multiple participants mentioned the robot's realism and its attempt to mimic a human face for all robot textures. However, the less humanlike textures may have still subconsciously been compared to more mechanical robots, which led to a more favourable rating overall. In other words, participants may have been more critical with the face that tried the hardest to create a humanlike appearance. This may also explain why the sick version of the humanlike texture was not perceived as more uncanny: People may have been forgiving towards the imperfect facial features because they assumed this was due to the technical limitations of the platform. To further investigate this, a within-subject experiment would be necessary in which participants are presented with all different facial textures of the robot.

An important takeaway from our experiment is that *blended embodiments are indeed a suitable platform to conduct uncanny valley related research as the same physical robot can be perceived as more or less eerie depending on which facial texture is exposed.* One limitation of the stimuli presented in this study is that even the discomfort with the morphed texture was only rated as 3.43 on a scale from 1 to 7. Thus, it can still be considered to only elicit slightly uncanny feelings. However, we also see that we barely reach ratings higher than average on the scale of perceived warmth. Thus, in future work it would be interesting to find some facial textures that increase the uncanny feelings towards the platform and others that increase the likability of it. Creating morphs that show the mechanical structure of the face even more clearly on an otherwise humanlike face may be one interesting approach to follow up on.

Another possible explanation for the low ratings in discomfort towards the robot may be the demographics of our participants. Almost all participants had a background in Computer Science, which likely makes them more exposed to (other) robot platforms and knowledgeable regarding the capabilities and limitations of artificial agents. In the future, it would be interesting to compare our results to the perception of participants with more diverse demographics.

6.2 The Influence of the Level of Exposure

The main goal of our experiment was to investigate whether getting to know a robot would help overcoming initial uncanny feelings towards it. Indeed, *we found that initial discomfort with the platform significantly decreased after the robot introduced itself.* However, we found that the uncanny feelings towards the robot did not further decrease after interacting with it. This may be due to the fact that the interaction with the robot in our study was quite simple. As multiple participants mentioned, the agent's understanding was very limited to a certain set of utterances, the interaction became quickly repetitive and it was not possible to ask the agent any questions in return. Even though we saw that the perceived competence and social presence of the agent significantly increased due to the interaction, this might have not been sophisticated or social enough to further lower the discomfort towards the agent. For future work, it would be interesting to include an interaction that is more social in nature and allow participants to interact with the robot more freely. Another interesting approach would be to include an interaction strategy that is more eerie and compare whether the uncanny feelings towards the robot persist and can even be increased by such a multimodal interaction with it.

The results presented in this paper highlight the *importance of using real interaction scenarios when investigating uncanny feelings towards robots.* When participants were asked whether their perception of the robot changed over the course of the experiment, almost all reported it did. One participant described his feeling about the robot as follows: "[When] you haven't talked to it, then it's just dead. It's just nothing. It's kind of not even a robot before it moved." Another participant expressed that "it feels like [the robot] is just there" when you first see it and it only becomes real when it starts talking. Many participants also mentioned the robot's capabilities exceeded their expectations, for example, by being more interactive than they anticipated. However, few also experienced the interaction to stay behind their expectations. Often they imagined the task they would do with the robot to be more sophisticated. One, however, also mentioned that he believed the robot would be more emotional, but when he started interacting and playing the game he found the robot was "too serious".

The finding that uncanny feelings decrease over time will probably not be influential on the design of social and entertainment robots for home environments. If the first impression of a robot is uncanny, it will negatively influence the decision to buy it. However, before robots will enter personal homes on a larger scale, they will likely first become more present in public spaces. Our findings give an initial indication that, if people are encouraged to interact with an agent, they may likely overcome their initial reluctance towards it. We hope that the need to worry less about the uncanny valley in human-robot interaction settings will eventually lower the bar for companies to use robots in public spaces.

Our work builds upon and extends the experiment conducted by Zlotowski et al. [22]. While they found repeated interactions with a robot to significantly lower uncanny feelings towards it, our work shows that even one interaction suffices to decrease perceived uncanniness. A main limitation of the work presented in this paper is that the interaction with the agent was quite short. In total, people were exposed to the robot for an average of about 20 minutes. In future work, we would like to further investigate how uncanny feelings towards a robot evolve over the course of multiple interactions. The trend seen in Figure 3 is quite encouraging as it seems to suggest that initial differences in discomfort might converge over time. This could mean that the robot's interactive capabilities have a much higher influence on its overall perception than its mere appearance. However, future work is necessary to confirm this hypothesis. As already pointed out in the previous subsection, the significance of findings could increase when including stimuli that are rated as more uncomfortable than 3.43 on a scale from 1 to 7. Even though our findings are in line with Zlotowski et al. [22] who used a different robot platform than ours, additional research is necessary to ensure our findings generalize to traditional robot platforms as well as virtual agents.

7 CONCLUSION

This paper presents a study in which people are gradually exposed to the blended robot platform Furhat. The robot was equipped with one of four different facial textures. We could show that the different textures could significantly alter the robots perceived humanlikeness, social presence and competence. Our findings further suggest that creating a morph between a humanlike and mechanical texture with visual features from both underlying stimuli can be used to elicit uncanny feelings towards the robot platform. While the creation of humanlike robots is still limited by the available mechanics, blended embodiments may be a promising intermediate option for conducting research on uncanny feelings towards physically present robots.

The results presented in this paper further suggest that initial eerie impressions of a robot may be overcome when people get to know the robot better. We found that people did not just perceive the robot as more competent, humanlike and socially present after interacting with it. Their level of discomfort with the robot also decreased significantly when the robot introduced itself. This highlights the importance of investigating uncanny feelings in human-robot interaction scenarios and the persistence of the uncanny valley effect in general.

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