Preliminary results from using a back-projected robot head in uncanny valley research

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***Abstract*— Masahiro Mori found that increasing the human-likeness of a robot can cause a decrease in its likability. The so called uncanny valley effect was studied in robots and virtual characters quite extensively, but the underlying cause is still controversial. One main limitation in the related work is the lack of available robot platforms to easily alter cues in the robot's appearance. Back-projected robotic heads are promising as they allow to easily vary visual cues of the robot in order to investigate its perception in a live interaction. In this paper, we discuss how the back-projected robot head Furhat can be used for researching the feeling of uncanniness and present preliminary results and challenges from a conducted experiment.**

I. Introduction

An important part of building social robot companions is to ensure that humans do not feel uncomfortable around them or perceive them as *uncanny*. Masahiro Mori [1] first described the uncanny valley as a non-linear function between the likability of a robot and it's human-likeness. When approaching a very human-like appearance the perception of the robot can drop rapidly, leading to the feeling of uncanniness. One explanation for this effect is the *category uncertainty*. In this theory it is claimed that the feeling of uncanniness arises at every category boundary where the category ambiguity is highest [2][3]. However, the review of empirical studies [4] supports the *perceptual mismatch* theory, where perceptual mismatch refers to any mismatch in perception of realism in a character. A limitation in most of the related empirical work is the usage of still images instead of live robot interactions, which is caused by the difficulty of altering visual cues in robotic embodiments.

With the emergence of back-projected heads [5] it became not only possible to accurately control facial expressions of a robot, but also to easily change visual features in the face. This opens up a variety of possibilities to bridge the research on virtual agents and physical robots, as well as to study the influence of the robot's appearance on its perception. However, back-projected heads still have some limitations, for example, the physical shape of the head, which might be a potential source of uncanniness if it does not match the projected face. To use such robots in social situations, e.g. as tutors or social companion in child or elderly care, we need to investigate how their appearance and interactions can make them likable companions. In this paper, we report first results on the perception of uncanniness in the back-projected robot head Furhat [5] with a male and a female projected face.

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II. The Furhat robot platform

The back-projected robot head *Furhat* [5] is equipped with a firm mask of an adult face. A virtual face is projected onto the mask, which allows for the eyes, lips and various other muscles in the face to be controlled. The mask is flattened around the lips and eyes to minimize the mismatch between the physical shape and the projection.

The perceived appearance of the robot is compound by both the physical shape and the projection of the virtual face. In contrast to the physical shape, the face texture can be easily changed to influence the perception of the appearance. In a pilot study we asked 40 participants ($f = 35\%$) to rate 34 different 2D face textures exported from *FaceGen Modeller* [6] in terms of *gender*, *dominance*, *trustworthiness*, *strangeness* and *attractiveness*.

We selected a male and a female face with significant difference in perceived masculinity and femininity of the face, but without significant difference in terms of perceived *strength of the gender*, trustworthiness and strangeness. The face textures projected on the robot are depicted in Figure 1.

III. Method

A between-subject experiment with the independent variable *robot gender* and 24 subjects ($f = 16.67\%$; age: $M = 23.58$, $SD = 1.85$) from a graduate course was conducted. Nearly all students had a background in Computer Science or a related subject and at least advanced English language skills. Course credits were awarded for the participation.

The Furhat robot was covered by a blanket and placed on a table approximately at the eye level of the participant. The first time the robot was uncovered, it displayed a neutral face with an average face color between the male and female condition and only indicated eyes and lips. This condition provided a baseline of the face shape perception without a gendered face texture applied. Participants were asked to rate their first impression of the robot on 7-point Likert scales of gender, dominance, trustworthiness, strangeness and attractiveness. We did not control for the time participants looked at the robot, but they were told to judge based on their first impression. When the robot was uncovered for the second time, it displayed either the female or the male face texture and participants were asked to rate it on the same five scales described above. Once the first task was completed,

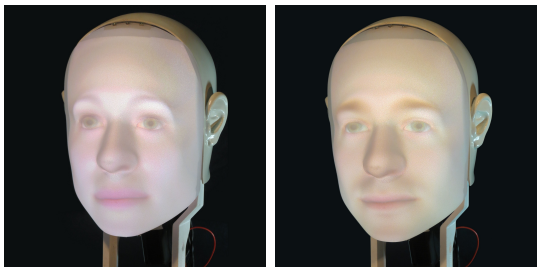

Fig. 1. Furhat with the female texture (left) and the male texture (right).

the robot started a one minute demonstration including facial expressions and head movements. Afterwards, participants answered a post-survey containing 33 questions about the perception of the robot. The perception questionnaire is mainly based on the Godspeed questionnaire by Bartneck et al. [7] and covers the *anthropomorphism*, *likability*, *familiarity* and *trustworthiness* as well as some basic questions regarding the robot's personality.

IV. Results

When not seeing any animation in the face, the physical mask of the robot displaying a neutral face is perceived to be very masculine ($M = 1.63$, $SD = 0.12$). The male face texture shares this gender perception ($M = 1.67$, $SD = 0.22$). A One-way ANOVA showed no significant difference to the neutral face, $F(1, 22) = 0$, $p = 1$, while the female robot is significantly more female ($M = 4.42$, $SD = 0.23$) than both the neutral, $F(1, 22) = 89.55$, $p < .001$, and the masculine face texture, $F(1, 22) = 73.49$, $p < .001$.

The perception of the 3D faces differs significantly from the 2D FaceGen images in many dimensions. The male face is comparable in the perceived masculinity, $F(1, 50) = 0.13$, $p = .717$, but the female face is perceived as significantly less feminine in the 3D embodiment, $F(1, 50) = 46.91$, $p < .001$. Both faces are perceived as less dominant in the 3D condition, $F(1, 50) = 12.25$, $p < .001$ (male) and $F(1, 50) = 14.26$, $p < .001$ (female), and the male face texture is more trustworthy in the 3D version compared to the 2D image, $F(1, 50) = 6.89$, $p = .012$.

The perception questionnaire after the short interaction of the robot revealed that both faces are perceived as medium human-like (Male: $M = 3.42$, $SD = 0.31$; Female: $M = 2.83$, $SD = 0.366$), a little strange (Male: $M = 3.08$, $SD = 0.36$; Female: $M = 3.5$, $SD = 0.29$), but not threatening (Male: $M = 1.2$, $SD = 0.13$; Female: $M = 1.41$, $SD = 0.19$). The likability of the robot is above average (Male: $M = 4.0$, $SD = 0.28$; Female: $M = 3.42$, $SD = 0.26$). While there is no significant difference between the male and female face in these dimensions, the male face texture is perceived as significantly more familiar (Male: $M = 3.17$, $SD = 0.39$; Female: $M = 2.0$, $SD = 0.3$), $F(1, 22) = 5.67$, $p = .026$, and trustworthy (Male: $M = 3.83$, $SD = 0.3$; Female: $M = 2.91$, $SD = 0.29$), $F(1, 22) = 4.91$, $p < .037$, than the female face texture. All other dimensions showed no significant difference between the gender.

V. Discussion and Future Work

The results gained in the perception questionnaire give confidence that back-projected heads like Furhat can be used as a platform to study the uncanny valley effect. The head without specific uncanny related modifications is already perceived as average human-like and we believe that this can easily be improved, for example, by adding artificial hair to create a more complete human-like perception of the robot. Furhat is both considered as likable and a little strange, which seems a good starting point for adding mismatching cues and investigate their influence on the perception. Our findings suggest that we cannot only alter cues related to the robot's realism, but also in other dimensions like gender, which could give helpful insights in the underlying cause behind the uncanny valley effect.

However, the results also show two major limitations of back-projected heads. One limitation is given by the shape of the physical mask. We see that it is not possible to create a congruent female appearance of the robot without changing the physical mask. The second limitations is the difference in perception between the 2D virtual face and the 3D projection on the Furhat face. Even though the results were not obtained under the exact same conditions (one online and one in a lab environment), we believe that the perception should still give comparable results. One explanation for the perceptual difference might be the very bright color display of the projected face.

Our preliminary findings suggest that there is a stronger perception of uncanniness in the female robot, which would oppose previous findings in virtual characters [8]. However, further experiments with stronger gender cues are necessary to confirm this hypothesis. For future work, it would also be interesting to study whether even more opposing gender cues, such as a mismatch between the voice and face, can increase the perceived uncanniness of the robot.

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