# Congruency Matters - How Ambiguous Gender Cues Increase a Robot's Uncanniness

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**Abstract.** Most research on the uncanny valley effect is concerned with the influence of human-likeness and realism as a trigger of an uncanny feeling in humans. There has been a lack of investigation on the effect of other dimensions, for example, gender. Back-projected robotic heads allow us to alter visual cues in the appearance of the robot in order to investigate how the perception of it changes. In this paper, we study the influence of gender on the perceived uncanniness. We conducted an experiment with 48 participants in which we used different modalities of interaction to change the strength of the gender cues in the robot. Results show that incongruence in the gender cues of the robot, and not its specific gender, influences the uncanniness of the back-projected robotic head. This finding has potential implications for both the perceptual mismatch and categorization ambiguity theory as a general explanation of the uncanny valley effect.

**Keywords:** Uncanny valley · Robot gender · Back-projected robotic head

## 1 Introduction

Building robots which can serve as social companions, for example, in child or elderly care applications, is one of the main goals of social robotics research. An important aspect in building likable companions is to ensure that humans do not feel uncomfortable during the interaction or perceive the robot as *uncanny*. Masahiro Mori [14] first described the uncanny valley effect in 1970, suggesting that making the robot more humanlike leads to a drop in the likability of the robot at some point in the interaction. The underlying cause of the uncanny valley effect is still controversial, with different competing explanations such as the *perceptual mismatch* and *categorization ambiguity theory* [6,8,9]. Both theories agree in the proposed explanation that uncanniness is triggered by a mismatch in perceptual cues, but differ in the argumentation if this mismatch leads to an ambiguity in assigning related categories. While empirical research


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to date has been primarily concerned with the dimension of realism, the impact of other dimensions, like gender, requires further investigation.

With the emergence of back-projected heads [4] it has become not only possible to accurately control facial expressions of a robot, but also to easily change visual features in the face in a cost-effective manner. 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 gender on its perception.

Using the Furhat robot platform [4] (Fig. 1), we investigated the influence of the robot's gender on perceived uncanniness by varying visual and auditory gender cues in different modalities in a between-subject experiment involving 48 participants. We found that the congruency of the gender cues, and not the robot's specific gender, influence the robot's uncanniness, potentially supporting the categorization ambiguity theory of uncanniness [6,11].

## 2 Background

Although not numerous, some previous studies have investigated the perception of gender in robots. Eyssel et al. [7] used the hair style of the robot to change its visual gender perception. This proved to be very successful as it was shown that human gender stereotypes are assigned to robots. Siegel et al. [15] found that the rating of credibility, trust and engagement of a robot has a cross-gender effect with the participant's gender. However, they argue that one limitation of their work is given by the fact that they varied the gender only by changing the robot's voice. One possible explanation as to why research related to robot's gender and its perception is still somewhat rare is that changing the gender of a robot is not trivial. In this study, the back-projected robot head *Furhat* has been used in the experiments [4]. Although there are limitations in matching the projected face texture to the physical shape of the mask, they provide an efficient and cost-effective route for investigating the impact of varying cues on perception. While we were unable to find other research relating the robot's gender to uncanniness, Tinwell et al. [16] found that male virtual characters are perceived as significantly more uncanny than female characters and related this finding to the perception of psychopathic behavior.

In contrast to the theory by Tinwell et al., another explanation of uncanniness in robots suggests that uncanniness does not follow the dimension of human-likeness as Mori originally described [14]. It rather occurs at category boundaries where the category ambiguity is highest [6]. This was supported by Moore [13], who developed a Bayesian explanation of the uncanny valley, in which conflicting cues give rise to a perceptual tension at category boundaries.

Kätsyri et al. [8] recently reviewed the empirical research related to the uncanny valley effect and found more support overall for the *perceptual mismatch theory*. According to this theory, any mismatch in the perception of realism in robots and virtual characters increases the sense of eeriness. For example, disproportional facial parts [10] may result in an increase in uncanniness. However, this mismatch does not necessarily lead to an ambiguity in the related category, which distinguishes this theory from the *categorization ambiguity theory* [9].

Here, we explore whether the perception of uncanniness in robots can be expanded to the category of gender, which has potential implications for supporting the categorization ambiguity theory of uncanniness.

### 2.1 Hypothesis

We state the following hypothesis:

**H1:** *The gender of the robot has an influence on its perceived uncanniness.*

Similar research in the field of virtual characters suggests that male characters are perceived as significantly more uncanny than female characters [16], but it has not yet been studied if these findings apply to robots.

While most robots can only vary the gender by changing the voice, back-projected heads allow to assign visual gender cues on the face. As it has not been studied so far how well the texture on back-projected heads can convey gender information, we explore our hypothesis using two different modalities. Although we believe that the gender of the robot can be controlled by unimodal visual gender cues in the face texture, the combination of multimodal visual and auditory gender cues were expected to lead to stronger impressions of perceived masculinity and femininity. Testing both unimodal and multimodal cues therefore helps us to better understand the link between visual and auditory gender cues, perceived gender and the perceived uncanniness of the robot.

## 3 Experiment

This study investigates how the gender of a robot influence its uncanniness through two pilot studies (Sects. 3.1 and 3.2) and a main study (Sect. 3.3).

### 3.1 Pilot-Study 1: Visual Gender Cues

The first pilot study was conducted to select one female and one male face texture with clear gender cues in order to control the robot's visual gender cues in further experiments.

**Participants.** We conducted a within-subject online experiment with 40 participants ($m = 60\,\%$, $f = 35\,\%$, participants were allowed to withhold this information). All participants were over 18 ($M = 26.15$, $SD = 6.9$) and had at least an advanced English language ability. Recruitment was done entirely on the Internet on a voluntary basis and participating subjects were mostly from Germany (85 %) and the USA (12.5 %).

**Stimulus and Independent Variables.** *FaceGen Modeller* [3] was used to create a variety of different face textures in the 2D shape of the Furhat mask. Independent variables for generating the faces were the gender (17 steps in the FaceGen gender slider between very male and very female) and the level of caricature (*the average* and *attractive* on the FaceGen slider), leading to 34 different faces in total.

**Procedure and Dependent Variables.** Image exports from FaceGen were presented to the participants one at a time (cf. Fig. 1, left). Latin square was used to determine the image sequence to avoid ordering effects. For every image, participants were asked to rate the face on a 7-point Likert scale on the dimensions *gender*, *dominance*, *trustworthiness*, *strangeness*, and *attractiveness*. There was no time limit for rating an image and the image remained on the screen while participants were rating it. Three test images were inserted and used to discount the results of participants who answered randomly or were not paying attention to the task, in a similar manner to the approach in [11].

**Fig. 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.

**Results.** In order to obtain an equal strength in terms of gender perception, we selected a male and female face that were rated equally by participants. The most masculine rated image was 0.33 Likert points less masculine than the theoretic optimum, while the most feminine face was 1.02 Likert points away from the theoretic optimum. Therefore, a less masculine face was chosen in order to be paired with the feminine face. As the research presented in this paper aims to investigate the perception of uncanniness, we also controlled the selected images so they had no significant difference in terms of trustworthiness and strangeness. The selected face textures are depicted in Fig. 1 to the left.

### 3.2 Pilot-Study 2: Auditory Gender Cues

The second pilot study was conducted to select one female and one male voice synthesizer with clear gender cues in order to control the robot's auditory gender cues in further experiments.

**Participants** 52 participants were recruited to take part in the online between-subject experiment. All participants were over 18 ($M = 25.06$, $SD = 5.16$) and had at least an advanced English language ability. 61.5 % of the participants were female. Recruitment was done entirely on the Internet on a voluntary basis and subjects were mostly from Germany (76.9 %) and the USA (7.7 %).

**Stimulus and Independent Variables** Independent variables for generating the voices were the gender and the level of anthropomorphism, leading to 4 different voices in total. The anthropomorphism was varied using the commercial

software *CereProc* [1] (male: *William*, female: *Sarah*) and the OpenSource software *espeak* [2] (male: *en* with speech rate 150, female: *en+f1* with speech rate 150 and pitch 70).

**Procedure and Dependent Variables.** Participants were asked to listen to a two minute audio clip in which an artificial character introduced itself. The text was identical between all conditions, apart from laughter and a filled pause which appeared only for the CereProc voices, as espeak has no support for it. Participants had to listen to the entire audio clip at least once before they could continue to the perception questionnaire, in which they were asked to answer 33 questions about the perceived anthropomorphism, gender, likability, intelligence, personality traits and uncanniness of the voice.

**Results.** In general, participant responses show a clear preference towards the CereProc voices compared to the espeak voices in a One-way ANOVA analyses: the speed and flow of communication was rated better, $F(1, 50) = 24.29$, $p < .001$, the voice was perceived as more friendly, $F(1, 50) = 7.59$, $p = .008$, and pleasant, $F(1, 50) = 25.42$, $p < .001$, and overall liked better, $F(1, 50) = 17.16$, $p < .001$. We therefore decided on using the CereProc synthesizer in the main experiment. There was no significant difference between the male and the female CereProc voice in all dimensions except perceived masculinity and femininity.

### 3.3 Main Study

The main study involved a between-subject experiment in which subjects watched a short demonstration of Furhat in a lab at Uppsala University and answered a questionnaire about their perception of the robot.

**Participants.** 48 subjects from a graduate course participated in the experiment. All subjects had at least advanced English language skills and most had a background in Computer Science or a related subject. Course credits were awarded for the participation. From self-disclosure of the participants, 14.6 % were female and all were over 18 ($M = 23.96, SD = 0.41$).

**Stimulus.** *Furhat* was used for the main experiments [4]. It is equipped with a firm mask designed as an adult face. The projected face is animated, which allows for the eyes, lips and various other muscles in the face to be controlled. Furhat is equipped with two motors to move the jaw and pitch of the head. The voice and face texture were selected as discussed in Sects. 3.1 and 3.2. The head with the female and male face is depicted in Fig. 1 to the right.

**Procedure.** Each experiment session took about 20 min and involved one subject. The experiment room was set up to control for the vertical and horizontal distance between participant and robot as well as for the lightning condition.

At the beginning of the experiment, while the participant was being informed about the experiment task, the robot was still covered by a blanket. The experiment started with uncovering the robot. The participants were asked to rate their first impression of the robot on 7-point Likert scales of gender, dominance,

trustworthiness, strangeness and attractiveness on a sheet of paper. Participants were instructed to judge based on their first impressions. 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 for face shape perception without a gendered face texture applied. The robot was then covered again. When it was uncovered a second time, it displayed either the female or the male face. Participants rated it on the same five scales described above. The gender of the robot was assigned randomly.

Once the first task was completed, the demonstration of the robot started. The participants were asked to watch either the unimodal or multimodal pre-recorded behavior and answer a questionnaire including basic demographic questions as well as 33 questions concerning the perception of the robot.

**Independent Variables.** The experiment had the two independent variables *modality* and *gender*. In the *unimodal condition*, the robot performed a set of facial expressions, which took about one minute in total. The gender cues were varied between the *male face texture* and the *female face texture* described in Sect. 3.1. The *multimodal version* consisted of a combination of speech and facial expressions. The order of the facial expressions was the same as in the unimodal condition, but the pauses were longer due to the talking in between. The voice and speech was the same as used in the pilot-study 2 (cf. Sect. 3.2). Both *male voice and male face texture* respectively *female voice and female face texture* were combined to change the gender of the robot.

**Dependent Variables.** The perception questionnaire consists of 33 questions about the perceived human-likeness, gender, uncanniness, personality traits and sociability of the robot and is mainly based on the Godspeed questionnaire by Bartneck et al. [5]. All questions are rated on a 5-point Likert scale. For the first part of the questionnaire, participants are asked to rate their agreement with a postulated statement and, for the second part, to rate the robot in different dimensions, e.g. *unintelligent* vs. *intelligent*.

The feeling of uncanniness is rather complex and multidimensional and the exact measurement of the y-axis of the uncanny valley effect is a topic of ongoing discussion in the research community. Most common are the measures *familiarity* and *likability*, which are both included in our questionnaire. To cover the

**Table 1.** Excerpt from the scales used in the experiment questionnaire.

| Category | Scales |
|---|---|
| Anthropomorphism | fake/natural, machinelike/humanlike, unconscious/conscious, artificial/lifelike |
| Familiarity | familiar, strange |
| Likeability | unfriendly/friendly, pleasant/unpleasant, dislike/like, like to have a conversation with |
| Trust | trustworthy, reliable |

feeling of uncanniness as extensively as possible, we also add *trustworthiness* and *reliability* as an indicator for the likability of a robot [12]. An excerpt of the scales used in the data collection is shown in Table 1.

We explicitly ask participants to decide on the gender of the robot between *female*, *male*, and *neutral*. In addition, we ask for a separate rating of masculinity and femininity and how easy it is to determine the gender.

As gender is commonly associated with certain personality traits and Walters et al. [17] suggested that the personality traits assigned to a robot are also related to its likability, we include questions on the perceived personality of the robot.

## 4 Results

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 shows no significant difference to the neutral face, $F(1, 22) \approx 0$, $p \approx 1$, 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, $F(1, 22) = 73.49$, $p < .001$. All reported significance results are based on One-way ANOVA with alpha level of .05 and Type III sum of squares.

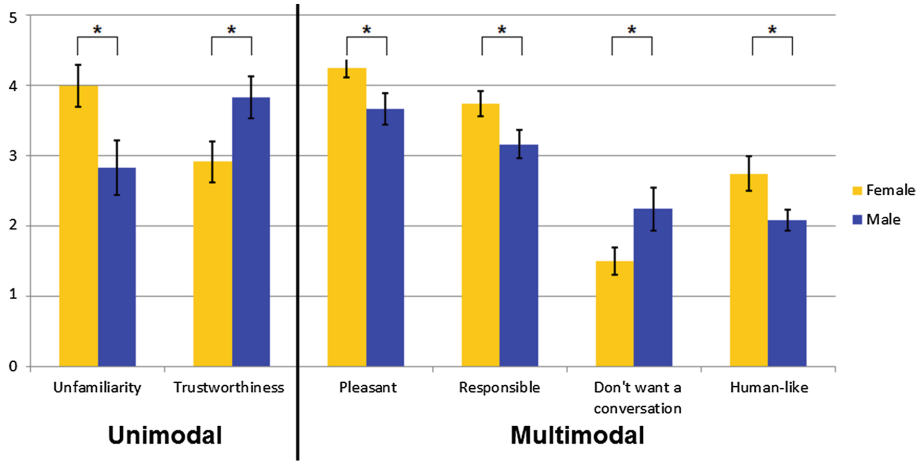


**Fig. 2.** Differences in the responses between the genders per condition (M and SE). Significant differences in One-way ANOVA are indicated by * ($p < .05$)

Within the unimodal condition, the male face texture is perceived as significantly more familiar, $F(1, 22) = 5.67$, $p = .026$, and trustworthy, $F(1, 22) = 4.91$, $p = .037$, than the female face texture. This difference cannot be confirmed in the multimodal condition, where both familiarity, $F(1, 22) = 0.96$, $p = .338$,

and trustworthiness, $F(1, 22) \approx 0$, $p \approx 1$, show no significant difference between the genders. However, the female face texture is perceived as more pleasant, $F(1, 22) = 5.04$, $p = .035$, and more responsible, $F(1, 22) = 4.53$, $p = .045$, than the male face texture in the multimodal condition. Subjects also reported they would like to have a conversation with the female character significantly more, $F(1, 22) = 4.3$, $p = .05$. At the same time, the male character is perceived as more machinelike than the female character, $F(1, 22) = 5.25$, $p = .031$. The results are depicted in Fig. 2. *They show that the general trend in the perception of traits related to uncanniness is flipped by adding a voice to the face only.*

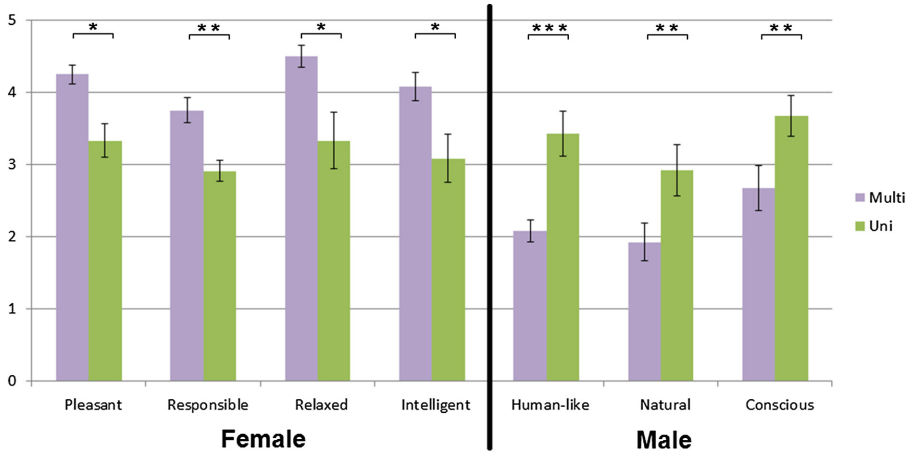


**Fig. 3.** Differences in the responses between the conditions per gender (M and SE). Significant differences in One-way ANOVA indicated by * ($p < .05$), ** ($p < .01$), *** ($p < .001$)

Comparing the two versions of modality with the female texture, we see that the perception of it changes when we add a voice to the face (cf. Fig. 3). It becomes significantly more pleasant, $F(1, 22) = 7.44$, $p = .012$, responsible, $F(1, 22) = 12.79$, $p = .002$, relaxed and content, $F(1, 22) = 7.59$, $p = .012$, and intelligent, $F(1, 22) = 6.66$, $p = .017$. We do not see any of these changes in the perception of the male robot when changing from unimodal to multimodal condition. However, we see that the male robot is perceived much more machine-like, $F(1, 22) = 14.82$, $p < .001$, artificial, $F(1, 22) = 5.11$, $p = .034$, and less conscious, $F(1, 22) = 5.66$, $p = .027$, than in the unimodal condition (Fig. 3).

A Randomized Block Design ANOVA with the modality as blocking factor showed no significant influence of the participant's gender in any dimension.

## 5 Discussion

In the unimodal condition, the male character has a higher likability and a higher trustworthiness, which could lead to the conclusion that female characters are

more uncanny. However, this explanation does not hold for the multimodal condition. Here, the female robot is perceived as more pleasant and participants reported that they would like to have a conversation with the female character significantly more. In addition, the more positive rating in other personality traits, e.g. perceived relaxation and intelligence, can be an indicator of a decreased uncanniness [17]. Therefore, we found no indication that the specific gender of the robot influences the perceived uncanniness across modalities.

In general, we observed a difference in the gender perception between the male and the female condition. The perception of the male face is clearly on the masculine side of the scale and all participants assigned the male gender in both unimodal and multimodal condition. Voting for the female face is only marginally on the feminine side of the scale, but still significantly more feminine than the male face. After watching the unimodal condition, seven out of twelve participants assigned a female, four assigned a male and one a neutral gender.

In the unimodal condition, participants reported significantly more difficulties in assigning a gender for the female face compared to the male face. Adding the voice to the face helps to resolve uncertainty about the gender. Ten out of twelve participants assigned a female gender in the multimodal condition, the other two a neutral gender. The gender uncertainty that subjects experienced after interacting with the female face can most likely be explained by the discrepancy between the shape and texture of the face. From the perception questionnaire of the neutral face, we know that the shape of the face is masculine and dominant. It appears that the *conflicting gender cues between the shape and the texture of the face lead to difficulties in assigning a gender to the robot.*

In addition, this finding suggests that *uncanniness is caused by an incongruence of gender cues rather than a specific gender.* This might give support to the categorization ambiguity theory of uncanniness, as the perceived masculinity and femininity of the female character was more towards the boundary between the two extremes, while the male character's ratings were clearly on the masculine side. Future work with a questionnaire more tailored towards the categorization of the robot might facilitate a deeper interpretation of this finding.

The preference for the female character in the multimodal condition can be explained by a general preference for female characters, a cross-gender preference [15], or by the perception of the male version as significantly more artificial. The lack of facial hair or participant's cultural background could have an influence as well. Again, future work could give further insights in the underlying causes.

## 6 Conclusion and Future Work

In this paper, we studied the influence of gender in different modalities on the perceived uncanniness of a back-projected robotic head. We found that *incongruent gender cues varied using different modalities lead to a decreased likability of the robot, rather than its specific gender.*

For future work, it would be interesting to study whether we can find support for *H1* in a study without conflicting gender cues. In addition, it would be

insightful to investigate if 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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