

A Multidimensional Perspective on the Uncanny Valley Effect: Studying the Interplay Between a Robot's Appearance and Interaction Strategy

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ABSTRACT

When investigating uncanny feelings towards robots, most researchers focus solely on the dimension of human-likeness as a potential cause. In our research, we aim to broaden the understanding of the so-called uncanny valley effect by exploring the potential multidimensionality of the phenomenon: By using a mixed-embodied robot head, we are able to alter visual and auditory cues in the robot and study the influence and interplay with the robot's interaction strategies and the perceived uncanny feelings in different age groups.

CCS Concepts

•Human-centered computing → Empirical studies in HCI; •Computing methodologies → Intelligent agents;

Keywords

Uncanny valley; Human-robot interaction; Appearance.

1. INTRODUCTION

With the aim of multi-purpose robots in home environments in mind, it is important to study when and why people feel comfortable around robots. One popular focus of study is the feeling of uncanny people potentially develop towards robots. While the major cause of uncanny feelings discussed in the literature so far has been the human-likeness of a robot [5], other researchers suggest that the problem involves different dimensions simultaneously [2].

In our research project, we aim to broaden empirical investigations behind the uncanny in robots. In the related work, studies have been mostly carried out (i) by studying the sole appearance of a character (ii) in the narrow domain of human-likeness and (iii) in virtual characters or still images of robots. We extend the existing literature and theories by considering the uncanny as a multidimensional problem and address gaps in the literature by (i) considering multimodal interactions of a robot with a special focus

on the interplay between a robot's appearance and interaction strategy (ii) using different dimensions, like robot gender, (iii) in the mixed-embodied robot platform Furhat that combines a virtual projected face with a 3D embodiment. Using a mixed-embodiment enables us to easily alter visual cues in the face and combine them with other modalities, like voice or interaction strategies.

Up to date, our research project has been mainly focused on studying the perception of gender during a pre-scripted short introduction of the Furhat robot [1]. In the future, we want to implement a real interaction scenario between a human and a robot and investigate the influence of interaction strategy, appearance and the interplay between the two of them on the perception of the uncanny.

2. RELATED WORK

Since Masahiro Mori [5] described the non-linear correlation between a robot's human-likeness and its perceived likability, researchers tried to empirically understand the underlying cause of the so-called uncanny valley effect. Today, there are two main competing theories: The *perceptual mismatch theory* explains the feeling of eeriness towards a robot by a mismatch in the perception of realism, while the *categorization ambiguity theory* claims this mismatch only leads to uncanny feelings if it pushes the perception to the categorization border between a human and a machine [3]. While Kätsyri et al. [3] recently found more empirical research supporting the perceptual mismatch theory, Moore [4] developed a Bayesian model which replicates the original function proposed by Mori. In his work, Moore describes that conflicting cues give rise to a perceptual tension at any category boundary. This suggests that uncanny feelings are a rather multidimensional problem, with different causalities in the robot's appearance or interaction strategy [2].

3. RESEARCH QUESTIONS

To investigate the multidimensionality of the uncanny valley effect, we aim to understand the influence of the robot's interaction strategy and the interplay between the interaction strategy and the robot's appearance. We state the main research question as follows:

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

The perception of the uncanny is not only caused by the robot's appearance, but is rather a result of the overall perception of the robot, including its movement and interaction [2]. We believe that a robot's appearance and movements will still face limitations for some years. Under this circum-

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stance, the interaction can play an important role in overcoming initial uncanny feelings towards robots. Research in this area also involves studying interactions between people and robots over a longer period of time to analyze how uncanny feelings change after multiple encounters.

In addition to the main research question, the PhD project involves some subordinate questions that are considered relevant for the main project. First, the use of a mixed-embodied robot head is novel in uncanny valley related research. Since this type of platform combines virtual 2D and physical 3D aspects, we consider it important to *study the relation between full 2D, mixed and full 3D embodiment* to ensure the transferability of our findings to other platforms. Different age groups interact differently with robots and the *influence of age on the perception of uncanny* is under-explored as well. With our research, we aim to add empirical insights in this relation, with a focus on the differences in perception between children and adults. In addition, we aim to *investigate potential triggers of uncanny in other dimensions than the robot's human-likeness*. In our previous research projects, the dimension of *gender* was the focus of investigation. However, other dimensions might be used in future work to ensure the transferability of the findings.

4. RESULTS TO DATE

In the first year of this ongoing PhD work, the main focus was to explore the influence of gender on the uncanny valley effect. As a preparation, we selected two face textures and voices to create the impression of a male and female version of the Furhat robot in two pilot studies [6].

In our first study [6], we aimed to investigate the relation between the robot's gender and the perception of the uncanny using the two gendered versions of the Furhat robot designed in the pilot studies. In a between-subject experiment with the two independent variables robot gender and interaction modality we found that *not the gender itself, but the congruency of the gender cues influence the perception of the uncanny in adults*. Specifically, we found the male shape of the Furhat's face and the female texture applied to it lead to an uncanny feeling when no voice was applied to the robot. This gives support to the categorization ambiguity theory, because the uncanny of the robot was perceived higher when participants rated the robot to be more towards the border between being masculine and feminine.

For the second experiment [7], we pushed the perception of the robot's gender even more towards the border by applying a female voice to the male appearance and vice versa. We found that this *multimodal opposing gender cues did not trigger the feeling of the uncanny in children*. In ongoing work, we compare these findings in children to those in adults in the same study. Apart from the age, a potential influence factor could be the fact that the incongruence of the gender cues was less subtle, which might influence the cognitive processes during the interaction.

5. FUTURE WORK

As a continuation of the first experiment [6], we are in the process of designing a female mask for the Furhat robot with a feminine shape perception. With the new mask, we want to be able to conduct experiments with a more congruent gender perception as a baseline and eventually use a deliberate gender incongruency as an independent variable.

In the future, the focus of the project shall shift from fully scripted behaviors as used in the first year of the project to real interactions with a robot. In particular, we want to deepen our knowledge about what in the behavior of a robot can cause an uncanny feeling in humans and how the appearance of the robot can increase or decrease this feeling. In two different scenarios (one related to a game and one to an information task) we aim to design interactions that are interesting even in repeated encounters. In those scenarios, we want to study how the initial perception of a robot is influenced by repeated interactions. Based on initial observations we hypothesize that overcoming initial uncanny feelings towards a robot can potentially lead to strong positive and encouraging feeling in humans.

With robots that are specifically designed to (not) be perceived as uncanny, different aspects of interaction strategies shall be addressed. For example, the robot could (i) explicitly, (ii) implicitly or (iii) not address subtle cues in its appearance that have shown to be uncanny in pre-experiments. With this study, we can further investigate the idea that the uncanny in the perceptual mismatch is weakened if people consciously understand what the perceptual mismatch is caused by. In another project, we aim to understand how the amount of information the robot has about the interaction partner or the collaborative task influences its likability.

So far we only used questionnaires about the robot's likability to measure uncanny feelings towards it. In an ongoing project we try to establish another, more objective measures to assess the robots likability by investing the link between the uncanny and the ability of humans to mimic a robot.

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