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The Influence of robot personality on the development of uncanny feelings

Maike Paetzel-Prüsmann[a,b,*], Giulia Perugia[a], Ginevra Castellano[a]

[a] Uppsala Social Robotics Lab, Division of Visual Information and Interaction, Department of Information Technology, Uppsala, Box 337, 75105, Sweden
[b] Computational Linguistics, Department of Linguistics, University of Potsdam, Potsdam, Karl-Liebknecht-Straße 24-25, 14476, Germany

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ABSTRACT

Empirical investigations on the uncanny valley have almost solely focused on the analysis of people's non-interactive perception of a robot at first sight. Recent studies suggest, however, that these uncanny first impressions may be significantly altered over an interaction. What is yet to discover is whether certain interaction patterns can lead to a faster decline in uncanny feelings. In this paper, we present a study in which participants with limited expertise in Computer Science played a collaborative geography game with a Furhat robot. During the game, Furhat displayed one of two personalities, which corresponded to two different interaction strategies. The robot was either optimistic and encouraging, or impatient and provocative. We performed the study in a science museum and recruited participants among the visitors. Our findings suggest that a robot that is rated high on agreeableness, emotional stability, and conscientiousness can indeed weaken uncanny feelings. This study has important implications for human-robot interaction design as it further highlights that a first impression, merely based on a robot's appearance, is not indicative of the affinity people might develop towards it throughout an interaction. We thus argue that future work should emphasize investigations on exact interaction patterns that can help to overcome uncanny feelings.

1. Introduction

In 1970, Masahiro Mori hypothesized that a robot's human-likeness is positively correlated with the affinity people feel towards it (Mori et al. (2012)). He noted, however, that this positive relation between human-likeness and affinity only holds until the robot's appearance becomes almost indistinguishable from that of a human being. In this situation, people's positive feelings towards the robot drop drastically and affinity turns into eeriness. Mori called this flip in people's perception of a human-like robot the *uncanny valley*. In his work, he further presumed that the uncanny valley effect could intensify if observers were exposed to a moving robot instead of a still version of it. While empirical investigations on the uncanny valley mostly confirmed Mori's theory (Kätsyri et al. (2015); Mende et al. (2019)), related studies almost exclusively focused on the appearance of a robot, and the effect of movement on people's perception of uncanny robots has rarely been studied (Bartneck, Kanda, et al. (2009); Saygin et al. (2012)). What adds complexity to the picture is that the abilities of modern robots go beyond the simple movements Mori discussed in his original work: today's robots can utilize conversational strategies and enrich them with voice tone (Mitchell et al. (2011); Sundar et al. (2017); Dou et al. (2019)), gestures (Salem et al. (2013); Venture and Kulić (2019)) and facial expressions (Breazeal (2003)). Moreover, these robots are often envisioned to perform tasks that are social in nature (e.g., receptionist (Johanson et al. (2020); Hwang et al. (2020)) or bartender (Petrick and Foster (2020); Rossi et al. (2020))). Hence, we consider it crucial *to extend the study of the uncanny valley to social interactions with robots that encompass the interactive capabilities they might have in real-life applications*.

So far, few studies included face-to-face interactions between humans and robots when studying uncanny feelings (e.g., Bartneck, Kanda, et al. (2009); Broadbent et al. (2013); Koschate et al. (2016); Rosenthal-von der Pütten et al. (2014); Williams et al. (2014); Złotowski et al. (2015)). In our previous work, we did so and extended the body of knowledge on the effect of robot's interactive capabilities on the uncanny valley by gradually exposing participants to the robot's behavioral modalities and measuring whether this affected the perception of uncanniness over time Paetzel & Castellano (2019); Paetzel, Perugia, & Castellano (2020); Perugia, Paetzel-Prüsmann, Alanenpää, & Castellano (2021). Our results suggest that perceptual dimensions, particularly those related to the uncanny valley (i.e., perceived threat, likability and

* Corresponding author. Uppsala Social Robotics Lab, Division of Visual Information and Interaction, Department of Information Technology, Uppsala, Box 337, 75105, Sweden.
E-mail addresses: paetzel-pruesmann@uni-potsdam.de (M. Paetzel-Prüsmann), giulia.perugia@it.uu.se (G. Perugia), ginevra.castellano@it.uu.se (G. Castellano).

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discomfort), are positively influenced by allowing people to interact with a robot for a time exceeding that of a first impression (i.e., 5 min, as defined by Ambady et al. (2000)).

As people do not interpret the robot's actions separately but tend to see patterns in them, allowing people to interact with a robot for an extended period might have helped them to form a more complete image of the robot's behavioral patterns, thus counterbalancing initial uncanny feelings. In human-human interactions, behavioral patterns are important to infer personality (Gifford (1994)). Personality is used to describe the underlying characteristics of a person that are stable over time and allows us to predict how an individual will behave even if we have not interacted with that specific person before (Matthews et al. (2003)). Due to people's inherent tendency to anthropomorphize robots (Reeves and Nass (1996)), it is likely that they make similar inferences when observing the behavior of a robot. While we already know that interactions might help overcome initial uncanny feelings, *we still have to understand whether different robot personalities leading to more variable behavioral patterns can affect the perception of uncanniness and how exactly they can help overcome uncanny feelings.*

In a recent review on personality in human-robot interaction (HRI), Robert et al. (2020) identified only 17 papers that manipulated or measured the perceived personality of a social robot. While these studies covered many perceptual concepts like intelligence, friendliness, trust or enjoyment, and discussed their relation to the perceived personality traits, only two included explicit measures that captured uncanny feelings. Broadbent et al. (2013) did not manipulate the personality of the robot directly, but measured the personality traits people assigned to a Peoplebot displaying different versions of a virtual face and analyzed how these traits correlated to their uncanny feelings towards the robot. They found that the robot was perceived as more eerie the less sociable, amiable and trustworthy its personality was rated. Sundar et al. (2017) specifically manipulated the robot's personality by making its behavior more playful or serious. Based on their results, they noted that the task the robot was envisioned to perform had more influence on people's uncanny feelings than its behavioral patterns. This is in contrast with findings by Złotowski et al. (2015), who were the first to consider the effect of robot behavior on uncanny feelings over three consecutive interaction sessions. In their experiment, they found that the robot's negative attitude intensified uncanny feelings even when the robot's appearance characteristics were not uncanny. *Our work extends the existing literature by developing and empirically testing two distinct personalities that use believable interaction strategies to engage a person in a joint task.*

Related work focusing on the influence of the robot's embodiment in general, and the level of human-likeness in particular, has shown that more human-like robots are overall associated with more positive personality traits (Broadbent et al. (2013); Chee et al. (2012)). As human-likeness also plays a core role in the original uncanny valley hypothesis (Mori et al. (2012)), *it is important to study whether the interplay between the robot's personality-driven behavioral patterns and its level of human-likeness influence people's perceptions of uncanniness*.

In this paper, we present a study in which participants with limited expertise in Computer Science coming from diverse geographic backgrounds played a collaborative geography game with a social robot. To manipulate the level of human-likeness, we used the blended robot head Furhat and applied two facial textures to it, one human-like texture and one containing additional mechanical features. Furthermore, to elicit different personality-driven behavioral patterns, we designed two personalities, one *optimistic and encouraging*, and the other *impatient and provocative*. Participants in our experiment were randomly assigned to one of four conditions, each corresponding to a possible combination of robot personality and level of human-likeness. To extend our previous findings and *understand whether a robot's personality-driven behavioral patterns influenced people's uncanny feelings over the course of an interaction*, we measured people's perception of the robot at three different times throughout the interaction: (1) a few seconds after they were first exposed to the robot and before having any interaction with it, (2) after 2 min of social chat, and (3) after 10 min of game interaction and two additional minutes of post-game social chat.

The personality-driven behavior developed for our robot was multimodal and consisted of crowd-authored conversations and facial expressions animated by an expert. The two robot personalities were specifically designed to be coherent and to not have inconsistencies in their behavioral patterns (Reeves and Nass (1996)). We achieved consistency by introducing and empirically testing a *novel semi-autonomous dialogue management system that tracks the current affective state of the robot and relies on semi-situated affective ratings of the crowd-authored dialogue lines to select the next line best fitting the conversational content and the current affective state*. The resulting conversational strategies applied by the robot led to a complex and believable personality-driven behavior fitting the context. They hence allowed us to gain novel insights into people's perception of robot behavior which go beyond the simplistic behaviors utilized in the related work on uncanny feelings towards humanoid robots.

2. Related work

2.1. Robot appearance & the uncanny valley

Since the publication of the uncanny valley theory in 1970, researchers did not only try to find evidence for its existence but also aimed to identify its potential causes. In a recent review, Kätsyri et al. (2015) identified two explanatory theories that gained substantial empirical support in the literature: the *categorization ambiguity theory* and the *perceptual mismatch theory*. The first theory posits that uncanny feelings arise when an observer is unsure about the exact nature of a stimulus due to its conflicting perceptual cues. Such categorical ambiguity can, for example, arise if an observer cannot identify whether a picture shows a computer-generated or a natural human face. The second theory, the perceptual mismatch theory, postulates that any perceptual mismatch can lead to uncanny feelings, even if the categorical affiliation of the stimulus is not into question. For example, it was found that eyes containing conflicting cues (Meah and Moore (2014)), disproportional facial parts (MacDorman et al. (2009)), or a lack of movement in parts of the face increase the feeling of uncanniness when observing an artificial agent (Tinwell et al. (2013)). The perceptual mismatch theory could also explain why the related work did not only find androids, a class of very human-like robots (Ho and MacDorman (2010, 2017); Lischetzke et al. (2017); MacDorman and Entezari (2015); Nakane et al. (2014); Reuten et al. (2018); Rosenthal-von der Pütten and Krämer (2014); Strait et al. (2017)), but also some clearly mechanical robots to elicit uncanny feelings (Łupkowski and Gierszewska (2019); Rosenthal-von der Pütten and Krämer (2014); Stroessner (2020)).

While most experiments on the uncanny valley focused on perceptual cues related to the robot's embodiment, introducing multimodal cues could increase the potential for a perceptual mismatch to arise. Hence, Bartneck, Kanda, et al. (2009) suggested that uncanny feelings may be too complex to be mapped into Mori's simple two-dimensional graphical representation of the uncanny valley theory. They argue that the robot's level of anthropomorphism in itself is influenced by many different factors that go beyond the mere embodiment of a robot. For example, a sophisticated and human-like behavior of a robot could lead to a higher level of perceived anthropomorphism independent of its embodiment features. Such human-like behavior could possibly cause a perceptual mismatch to arise if paired with a mechanical robot body. However, there are more ways in which the behavior of a robot could contribute to the elicitation of uncanny feelings: It is possible that it is not a mismatch between behavior and appearance but an incongruence within the robot's behavioral patterns that lead to a perceptual mismatch and consequently to uncanny feelings. This is in line with Reeves and Nass (1996), who hypothesized that discomfort with an artificial agent could be raised by inconsistencies in personality-driven behavior, often originating from several developers being involved in implementing the behavior. However, it is also possible that uncanny feelings go beyond an incongruence and certain types of universally undesirable behaviors in robots exist that generally make people feel threatened by them. Złotowski et al. (2015) designed a positive and friendly behavior and tested it against a negative and antagonistic one. Their findings indeed suggest that the uncanny valley intensifies for robots with an overall negative attitude.

2.2. Robot personality

Human personality is generally complex and early work from social psychology has identified as many as 18,000 relevant terms in the English language to describe a person's nuances in personality (Matthews et al. (2003)). Over the years, however, taxonomies evolved to facilitate "more effective theories of the development, structure, and functioning of personality" (Norman (1963)). The most common descriptor for personality used in social psychology today, the Big Five model, consists of five distinct dimensions: openness to experience, conscientiousness, extroversion, agreeableness, and neuroticism (Reeves and Nass (1996)).

People tend to anthropomorphize computers and robots and use terminology from human-human interaction even if a device is not inherently human-like (Ball and Breese (2000); Reeves and Nass (1996)). For example, Sirkin et al. (2015) has shown that people assign intention to inanimate objects like a mechanical footstool. The tendency to anthropomorphize also shows when people assign personality traits to robots, even to those as basic as autonomous vacuum cleaners (Hendriks et al. (2011)). Robot designers utilize this tendency and explicitly manipulate the perceived personality to create more enjoyable interactions. Robots displaying personality have, for example, been found to engage users in tasks across several different domains, like post-stroke rehabilitation therapy (Tapus et al. (2008)), or restaurant recommendations (Aly and Tapus (2013)).

In social robotics, personality is often used to distinguish the behavior of similar agents, but also to explain the range of emotional states a character can display (Oliveira and Sarmento (2002)). In a recent review on robot personalities utilized in HRI, Robert et al. (2020) found the majority of papers to define personality descriptors based on established taxonomies from social psychology. Among the 17 papers included in their review, nine measured and/or manipulated personality using the Big Five personality descriptors, and four Wiggins Personality Test. Among these 13 papers, a strong focus on the personality trait extroversion became apparent and only few took additional dimensions like a combination of extroversion, agreeableness and conscientiousness into consideration (Meerbeek et al. (2008)).

In addition to personality descriptors common in social psychology, researchers in HRI have used a variety of further terms to distinguish agents' personality-driven behavior. For example, Sundar et al. (2017) described the robot's personality as *playful* or *serious*, while Yamashita et al. (2016) used the terms *likable*, *mighty* and *vital*. Grollman (2016) manipulated the personality of the comparably simplistic and mechanical robot Marz along the dimensions *friendliness*, *cautiousness*, *laziness* and *gluttony*. While some of these overlap with the traditional factors used in social psychology, the majority differs substantially and a mapping between these and commonly utilized personality dimensions is not easy to infer.

2.3. The relationship between personality and robot perception

The relationship between personality and robot perception can be studied in two directions: One can either investigate what perceptual cues in a robot lead people to attribute certain personality traits to a robot, or one can assess how perceived personality traits influence other perceptual dimensions of the robot. Interestingly, research studies examining the former have mostly focused on embodiment features of the robot and little work has taken robot behavior into account. It was found that a robot's appearance influences how people perceive its personality even if the robot did not show any behavior at all. Groom et al. (2009) found that a humanoid robot was ascribed a more malicious personality, while an autonomous car was perceived as more friendly. These findings are in stark contrast to most of the empirical evidence suggesting that human-like robots are perceived as having a more favourable personality. For example, Chee et al. (2012) found that the robot's human-likeness, its color and surface material influenced the personality attributes people ascribed to it. More specifically, their data suggest that robots with more human-like features were perceived as more friendly than mechanical robots. They hypothesized that a higher familiarity with humans could have led to assigning more favourable personality traits to the more human-like robots. These findings are in line with Broadbent et al. (2013), who manipulated the virtual face displayed on a Peoplebot and found that the more human-like version was perceived as more sociable and amiable. Yamashita et al. (2016) extended this work by including perceptual cues from touch sensations of the robot's skin. They found that a robot which felt natural improved the likability of its personality. However, robots with more mechanical features made of rigid, and hard covering materials were ascribed a more mighty personality.

Only a few studies have focused on how the personality traits of a robot influence people's perception of it, specifically on perceptual dimensions related to the uncanny valley. Fong et al. (2003) hypothesized that a "compelling personality" will increase a robot's likability. Conversely, if this hypothesis holds, less compelling personality traits could have the potential to cause an uncanny sensation in humans. First empirical evidence for this hypothesis was found by Hwang et al. (2013) and Broadbent et al. (2013). Hwang et al. (2013) found that all of a robot's perceived personality traits (neuroticism was coded as emotional stability) were negatively correlated with the feeling of concern, and some were positively correlated with a favourable and enjoyable feeling towards it. Results by Broadbent et al. (2013) show a similar trend despite not using the same personality descriptors in their work. They found that the perceived eeriness of a robot was correlated with a less sociable, amiable and trustworthy personality. While both studies make an important observation about a correlation between uncanny feelings and less favourable personality traits, they both did merely observe people's personality attribution to the robot without actively manipulating the personality.

2.4. The effect of matching personality traits in HRI

In social psychology, it has been shown that the level of attraction felt towards people with different personality characteristics is not necessarily universal, but depends on a match or mismatch in personality traits between two people (McPherson et al. (2001)). In HRI, most empirical investigations have found a similar trend, showing a preference for a robot that matched the personality of participants (Park et al. (2012); Tapus et al. (2008)). Andrist et al. (2015) showed that people even comply more with a robot matching their own personality. The work by Joosse et al. (2013), however, suggests that the preference for similar or complimentary personality might be context dependent and specifically rely on the task the robot is performing. Similar observations were made by Goetz et al. (2003), who found that it was not the playful personality in itself that was liked better by participants in their study, but that the task context had a strong influence on what personality traits were favored by the human interaction partner. This is contrary to work by Sundar et al. (2017), who found that more eerie feelings instead of affection were elicited by robots with a match between the assigned task and personality traits. People rated a companion robot more uncanny when it behaved playful than when it was serious, while assistant robots were perceived as more eerie when being serious. They suggested that the task description may have played a more important role in the elicitation of uncanny feelings, and that the robot's personality description had little influence on the overall perception. However, interaction with the robot in their experiment was limited and they only varied the robot's personality by manipulating its voice pitch. Their findings may thus not translate to robots displaying stronger personality-driven behavioral patterns over a longer period of time.

2.5. The development of personality perception over time

Even though it was shown in social psychology that a judgement of someone's personality can be made after a few seconds, the time of exposure was still found to influence the accuracy of the impression (Calvo-Barajas et al. (2020); Carney et al. (2007)). In spite of this, only a few studies in HRI have explicitly investigated the influence of time on the perception of a robot's personality. Groom et al. (2009) found a potential effect of previous exposure to a robot on how favourable its personality was rated. More specifically, participants in their experiment generally preferred the personality of a robot they had assembled before instead of one that they believed to be assembled by someone else. The study design by Złotowski et al. (2015) included three consecutive interaction session that lasted for an hour in total. In each session, the human participant had a job interview with a robot interviewer that had a positive or negative attitude towards them. Their results show that uncanny feelings towards the robots declined over the three sessions regardless of the robot's attitude. Moshkina and Arkin (2005) did a longitudinal study involving four 20–60 min interaction sessions with an AIBO robot. They found no general influence of displaying personality driven-behavior on how pleasant people rated their interaction with the robot. Nevertheless, they discovered that people who believed the robot to have a personality found the interaction to be more pleasant independent of whether the robot was programmed to actually show personality or not.

3. Research questions

This work aims to deepen our understanding on how a robot's appearance and personality-driven behavioral patterns influence people's perception of it over time, particularly in dimensions related to the uncanny valley.

Our first research question is concerned with the general perception of robots with different combinations of human-likeness and personality. The aim is to understand whether certain personality traits in a robot are favored independent of the personality of the observer. In other words, are there personality traits that are universally perceived as more uncanny and others that are favored and can hence lower uncanny feelings in humans.

RQ1 To what extent does robot personality influence people's perception of robots with different levels of human-likeness?

From social psychology, we know that a preference for certain personality traits often depends on the personality of the observer and a match in personality traits often leads to a positive perception overall (McPherson et al. (2001)). Related work in HRI has confirmed that robots displaying a level of extroversion matching their human conversation partner are preferred over those with opposite traits (Park et al. (2012); Tapus et al. (2008)). Whether these findings transfer to other personality traits has not been investigated so far. In our work, we do not alter the robot's level of extroversion, but attempt to manipulate its agreeableness and neuroticism instead. We are thus interested in understanding whether a match in these traits is also preferred and can lower uncanny feelings, or whether the level of likability and threat is independent of the similarity in personality.

RQ2 To what extent does a match in personality between a robot and a human interlocutor influence the human's perception of the robot?

The personality of the robot potentially alters more than people's perception of it – it can also influence how they perform in and engage with a joint task or perceive their engagement with the robot. To deepen the understanding of the impact a robot's personality has in human-robot interaction, we specifically analyze people's performance and their self-reported engagement in such an interactive scenario.

RQ3 How do robot personality characteristics influence people's engagement and task performance?

In previous work, we have shown that people's first impressions of robots are not stable and can be altered when exposing people to a robot's behavior for longer Paetzel & Castellano (2019); Paetzel, Perugia, & Castellano (2020); Perugia, Paetzel-Prüsmann, Alanenpää, & Castellano (2021). In this work, we aim to extend our previous findings by understanding what role robot personality plays in changing people's perception over time. More specifically, we aim to investigate whether one personality allows the perception of the robot to stabilize faster, while another make it fluctuate over the course of the interaction.

RQ4 To what extent does the personality of the robot influence how people's perception of it develops over time?

4. Scenario and robot interaction design

To study the influence of personality on people's perception of a robot, we asked participants to play an interactive collaborative game, the Rapid Dialogue Map Game (RDG-Map), with a Furhat V1 robot (Al Moubayed et al. (2012)). Furhat is a blended embodiment consisting of a firm mask on which a virtual face texture is projected from within. The robot's head is mounted on a white box containing the processor, speaker and two motors. These motors allow the robot to shake the head and nod. The virtual texture can be animated to direct the robot's gaze, perform facial expressions and achieve lip synchrony when talking.

We designed two distinct but believable personality-driven interaction strategies for the robot within the game: one *lighthearted, optimistic, and determined to engage and encourage others in every situation* (optimistic personality [OPT]), the other *snarky, with little patience for life's imperfections and people's mistakes and receiving pleasure from challenging others* (impatient personality [IMP]). Thus, just like a human game partner, the robot could either be fun and engaged in the game, eager to learn, but very forgiving of mistakes, or impatient, overly invested in winning the game and thus trying to challenge the human game partner to constantly improve the performance. The personalities designed for the robot were mainly expressed through affective conversational content, which was occasionally enriched by emotional facial expressions, and were shown both while the participants were playing the game with it, and in a short social chat occurring before and after the game.

4.1. The RDG-Map scenario

In the RDG-Map game Paetzel & Manuvinakurike (2019), a human player helps a robot to correctly identify as many countries as possible on the world map in a given time of 10 min. The human player acts as the *Director* in the game and is provided with a tablet on which a map of the world is displayed and one country, the *target country*, is highlighted in green (cf. Fig. 1 bottom left). The goal of the Director is to verbally describe the target country to the robot by means of a free conversation and help it to identify it as quickly as possible. In the RDG-Map game, the robot player thus takes the role of the *Matcher* and its goal is to correctly select the target country on a shared screen, which is visible to the Director. The robot has two opportunities per target country to make a guess. If the first guess is correct, the team receives two points. If it is incorrect, the Director can continue describing the country and the team can earn one point if the robot correctly selects the target country at the second attempt. In case the second guess is also wrong, the team does not receive any points.

4.2. Robot appearance and control

Based on previous studies, we selected two face textures for the robot representing two different levels of human-likeness Paetzel & Castellano (2019). The *human-like* version was created using a photograph of a real human (cf. Fig. 2 left). The *morph* version was designed by blending the

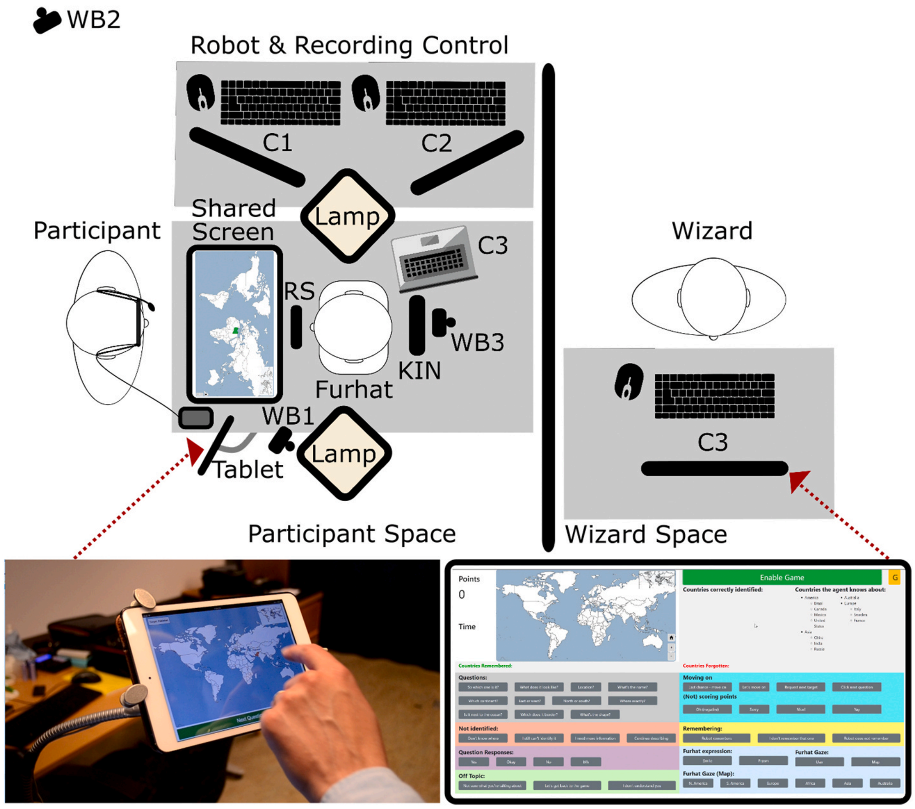

Fig. 1. Schematics of the experimental setup. On the bottom left, the tablet displaying the Director's screen during the game interaction is shown. To the bottom right, a screenshot from the robot control interface during the game interaction is visualized.

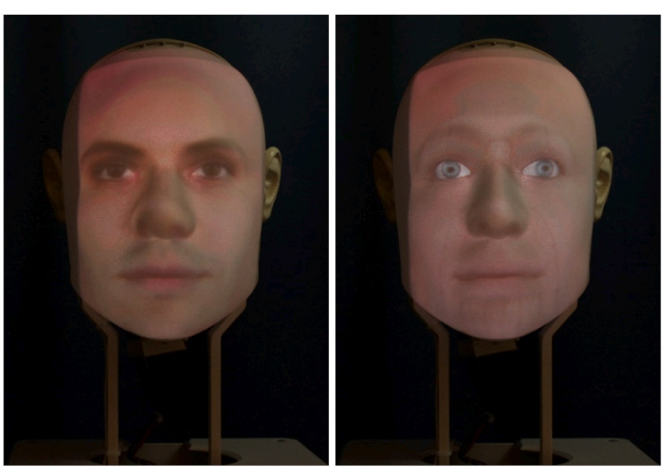

Fig. 2. The Furhat robot with the humanlike (left), and morph (right) facial texture applied.

human-like texture with the texture of a mechanical robot (cf. Fig. 2 right). Both human-like as well as mechanical features were clearly visible in this face texture, but less pronounced than in the original textures. Hence, to further strengthen the mechanical features of the morph robot, we used the eyes of the mechanical version of the robot.

Since the RDG-Map game is a challenging game from a language processing perspective, we used a researcher to remotely control parts of the agent's functionalities (cf. Fig. 1 bottom right). The researcher was trained to operate the robot during 50 online game interactions and over 150 in-person interactions and followed strict guidelines when making decisions. For instance, in the pre- and post-game chat, (s)he followed a predefined order of conversational topics. Within a conversational strand, the controller merely replaced the language understanding unit of the system. Each button on the control interface was related to a potential response that the human could give, so, for instance, when the robot started to talk about the upcoming task by saying: "Well, I guess we get to play a game with each other. That sounds nice, don't you think?", the controller could sort the response of the human partner into one of three possible categories: The human was excited to play the game, not excited, or unsure about it.

During the game, most of the robot's responses were designed to be neutral and were targeted at scoring points by guessing the country correctly. The controller was tasked with making a guess on the target country for the robot only upon receiving enough information. In case more details about the target country were needed, the controller could select one of several questions. On top of the more neutral game actions, after certain pre-determined events of the interaction (e.g., scoring points, or making a wrong selection), the controller could select in-personality comments.

The human controller was additionally tasked with directing the gaze of the robot. During the game, the robot's gaze was mostly focused on the shared screen positioned in between itself and the human. However, whenever a continent, country or region known to the robot was mentioned, the controller could direct the robot's gaze towards it and, when the human director took very long breaks for thinking about a cue or searching on the tablet, the controller could bring the robot's gaze up, directing it to the human. These gaze cues were supposed to give the human partner a feedback on the game actions, and communicate an overall understanding of the context. In the pre- and post-game social chat, Furhat autonomously tracked people's head using a Kinect camera mounted atop its head and held eye contact with participants as precisely as possible. On top of this default behavior, the controller could move the robot's gaze downward to the left or to the right for a short period of time to simulate thinking.

4.3. Design of the robot personalities

4.3.1. Conversational content

Traditionally, personality-driven behavior in robots has been handcrafted by researchers and interaction designers (Robert et al. (2020)). This approach is, however, infeasible when designing longer interactive scenarios which require a stream of coherent behavior for a given personality. For this reason, the interest has recently shifted from expert-authored dialogue lines to designing systems that can autonomously generate such conversational content (Mairesse and Walker (2011)). Another approach that gained popularity in recent years to overcome the authoring bottleneck is crowd-sourcing conversational content (Kriegel (2015)), as well as emotional expression generation (Ravenet et al. (2013)).

In previous work, we showed that crowd-authoring can be used to create personality-driven conversational content for a robot playing a cooperative game Mota et al. (2018). We designed two personalities similar to those presented in this paper: one that was quick to overreact and had little patience for life's imperfections, the other that was lighthearted, optimistic, and determined to find the fun in every situation. When evaluating our proof-of-concept implementation, we found that the two personalities were indeed perceived as significantly different in agreeableness and neuroticism, but did not differ in the enjoyment participant felt while playing with them. However, we also discovered that the affective states of the two personalities were not developing naturally over time, but had sudden changes in emotion intensity. This was likely caused by a shortcoming in our crowd-authoring technique. Indeed, as we provided crowd-workers with a description of the context of the conversation, but did not inform them about the current emotional state of the robot, their interpretation of how a certain personality would react to a given situation differed substantially. In later work, we developed an extension to our crowd-authoring pipeline by giving authors the affective state of the robot (excited or frustrated) instead of its personalityPaetzel, Kennedy, Castellano, & Lehman (2018). This approach allowed us to collect a variety of affective responses useable in multiple situations for both of our original personalities.

In the experiment presented in this paper, we implemented a fully-functioning pipeline further extending our previous work. The affective states we chose described the robot as being (a) excited and encouraging, (b) impatient and provocative, or (c) indifferent. The two robot personalities were designed so that the development of their affective states over time differed: The robot with the optimistic personality was supposed to get easily excited whenever a human partner scored a point or responded positively to its question, but to be more indifferent to failures in the game. On the contrary, the robot with the impatient personality was supposed to get more impatient and provocative if less favourable responses were given, but to not be affected by positive events in the game that were equally strong (e.g., scoring a point). It is important to note that both the optimistic and the impatient personality could potentially adopt the full range of affective states and that there were certain overly positive or negative responses of the interaction partner that triggered both personalities in a comparable way.

Crowd-Authoring content Following the approach introduced in our previous research (Mota et al., 2018; Paetzel, Kennedy, Castellano, & Lehman, 2018), we asked crowd-workers on Amazon Mechanical Turk to author affective content for our robot. The crowd-sourcing pipeline consisted of three stages. In stage one (*authoring stage*), crowd-workers were provided with one of 61 situational description corresponding to conversational strands in the pre-and post-game interaction or events in the game. The descriptions were occasionally accompanied by a previous dialogue excerpt, and crowd-authors were asked to write one utterance the robot could say for the given context and affective state. For each scenario and affective state, five crowd-workers were asked to write an utterance. In the second stage (*situational evaluation*), each authored line was shown to five crowd-workers. These were asked to judge how (a) typical and ordinary, and (b) offensive the line was on a five-point Likert scale. A line could also be flagged as non-sensical. Finally, in stage 3 (*affective evaluation*), another five crowd-workers were asked to evaluate whether they perceived the authored lines as excited and encouraging, frustrated and provocative, or indifferent, and to rate the intensity of the excited and encouraging or frustrated and provocative affect on a four-point scale.

Lines rated as non-sensical more than twice or receiving an average rating of less than 2.6 on typicality were excluded from the corpus. Utterances that were rated as 2.66 or higher on offensiveness were flagged and manually checked by a researcher involved in the experiment. In case the researcher agreed that the line was offensive, it was excluded from the corpus. In total, crowd-workers contributed a total of 1512 lines in 61 scenarios to the final corpus of the robot's conversational content. 24.9% of pre-game, 29.7% of in-game and 24.3% of post-game lines were rejected and excluded from the corpus, leaving a final set of 1121 conversational lines for the robot.

Situational use of the dialogue content To make use of the personality-driven affective content in a coherent manner, each button of the robot's control interface corresponding to a potential response of the human was annotated with one affective specification (+, - or *o*) per robot personality. These indicated how the given response of the human would influence the affective state of the robot in its current personality. The label + indicated that the response made the robot more excited and encouraging (maximum of $+0.25$ on a scale from -4 to 4), the label - that the response made it more impatient and provocative (maximum of -0.25), the label *o* that the response left the robot indifferent and thus kept the robot's affective state as stable as possible (ideally in the range of -0.1 and $+0.1$).

To pick the most fitting response in a given context, the robot first extracted all utterances that were authored for the specific situation. Then, it filtered these utterances, keeping only those in the range of the target affect for the next line. In case this list returned empty, the search criteria were relaxed to ensure the robot would always be able to say a line in every situation. To relax the search criteria, the system considered lines that would correspond to a stronger development in the intended direction (e.g., updating the current level of affect for more than $+0.25$ given a +). Among the list of potential lines, the robot would first pick the utterance that was used in the same conversation the longest ago. This rule was relevant for the game, as the robot could encounter situations like scoring or not scoring points multiple times. In case multiple lines qualified, the one that was rated most typical for the given situation was selected.

4.3.2. Facial expressions

Once a line was selected, the robot autonomously decided whether to say the line with a neutral face, or perform a facial expression with the utterance. Based on previous work Mota et al. (2018), we selected eight facial expressions for the RDG-Map game: four that were evaluated as frustrated (brow frowning and shaking the head, among others) and four that were perceived as excited (smile and raising eyebrows, among others). The expressions are visualized in Fig. 3. We evaluated the expressions on Amazon Mechanical Turk by randomly selecting nine scenarios, three each from the pre- and post-game social chat and from the game interaction. Crowd-workers were shown a video of a virtual agent with a human-like face texture which said the crowd-authored line with an accompanying facial expression. Five crowed-workers per expression and situation were asked to rate how typical and ordinary the expression was perceived in the given scenario on a five-point Likert scale, and how excited and encouraging or impatient and provocative the virtual human appeared on a four-point Likert scale. In addition to the eight videos showing the different facial expressions, a ninth video was included as a baseline that showed the robot saying a line without an accompanying expression.

To decide which expression to use in a given situation, the average

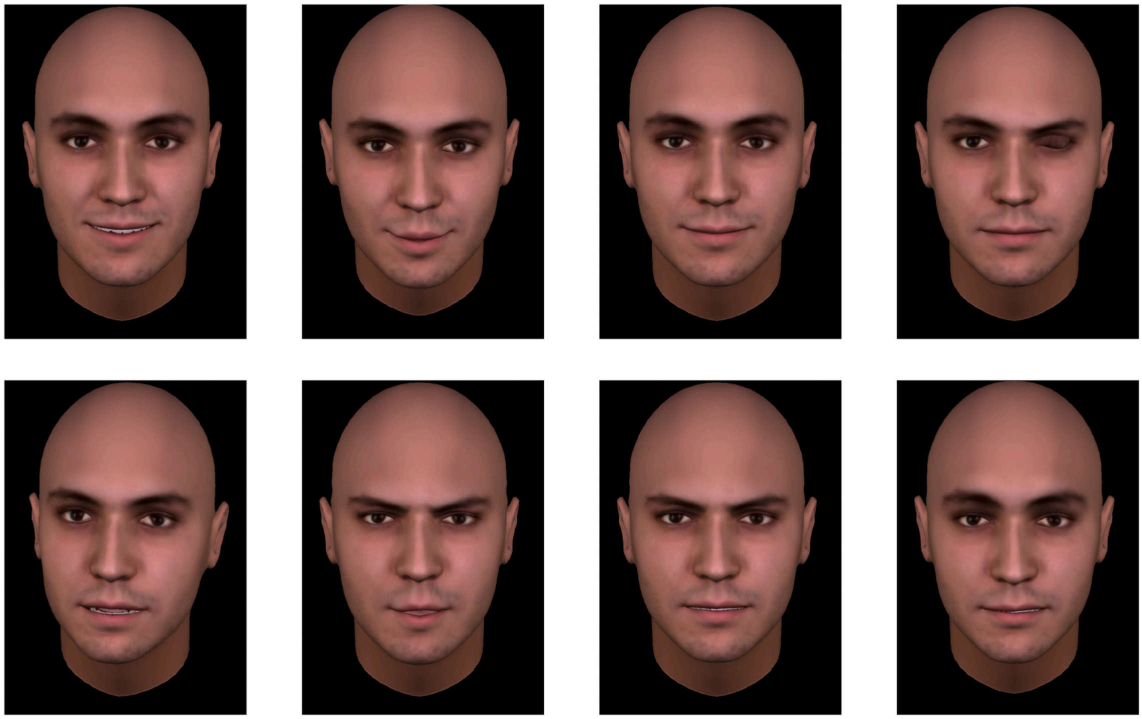

Fig. 3. Face of a virtual human showing the four excited (top row) and four impatient facial expressions (bottom row). Top row left to right: Smile, nodding, slight smile with raised eyebrows, wink. Bottom row: shaking head, strong frown, slight frown, slightly disgusted mouth shape with raised eyebrows.

typicality score of an expression was calculated separately over all three scenarios for the pre-game, post-game and in-game situations. In addition, it was calculated how performing this expression changed the affective state compared to not performing any expression (baseline video):

$$a_{expression} = a_{raw-baseline} - a_{raw-expression} \quad (1)$$

This calculation was used to inform the situational development of the robot's affect when performing a facial expression even for lines not explicitly rated by crowd-workers.

In the actual interaction, the decision to perform a facial expression was made in two steps. First, the dialogue manager decided whether to perform a facial expression with the selected utterance or not. Then, it selected the exact facial expression to perform. The decision to perform a facial expression was made randomly with a custom adjustment to the random factor based on the amount of time that elapsed since the last facial expression was shown, the strength in effect of the selected utterance on the current affective state of the robot, and how close to the extreme (extremely excited or extremely impatient) the robot's affective state was. Generally, the more lines were uttered without an accompanying facial expression, the smaller the difference in affect for the selected utterance was, and the closer the affect to the extreme ends of the scale, the more likely a facial expression was to be performed. An exception was made for response categories which were not supposed to change the affective state of the robot (labelled *o*). In this case, performing a facial expression was given a low probability by default.

If the function evaluating whether to perform a facial expression came to a positive result, the facial expression was picked among the four corresponding to the current affective state of the robot. In other words, as long as the robot's affective state was on the impatient end of the scale, only the impatient facial expressions could be performed. The exact expression to display was chosen randomly, weighted by how typical and ordinary each expression was perceived for scenarios in pre-game, post-game or in-game situations.

After the utterance and the expression were selected, the affective state of the robot was updated accordingly:

$$S_{new} = S + a_{utterance} + a_{expression} \quad (2)$$

where S_{new} is the affective state of the robot after the next line is uttered, S the current affective state, and a the affective ratings derived from the crowd-workers.

5. Experiment and data analysis

To answer our four research questions as stated in Section 3, namely the influence of personality (RQ1), and a match in personality between a human and a robot (RQ2) on people's perception of robots with different levels of human-likeness, the interplay between robot personality and engagement (RQ3) and the development of robot personality and related perceptions over time (RQ4), we designed a 2×2 between-subject experiment with robot *appearance* (human-like and morph) and *personality* (optimistic and impatient) as independent variables. The experiment was conducted over the period of 12 days at a science museum in Stockholm. Ethical clearance for the study was provided by the local ethical review board (Regionala etikprovningsnamnden i Uppsala, reference number 2018/503).

5.1. Participants

73 participants were recruited among the visitors of the Tekniska museet Stockholm. They could sign up for the experiment upon entry to the museum. 12 participants needed to be excluded from the study due to technical failures of the system, interruptions during the study or because they suspected that the robot was remote-controlled. The remaining 61 participants were evenly distributed into four experimental conditions corresponding to all possible combinations of the robot's appearance and personality: 16 people interacted with the human-like optimistic (HUM-OPT) robot and 15 with the human-like impatient (HUM-IMP), morph impatient (MOR-IMP) and morph optimistic (MOR-OPT) robot.

Due to a problem we encountered in storing the results of the demographic questionnaire for 7 participants, we can only report the demographic information of 54 people. Visitors at the museum and hence participants in our study had a very heterogeneous background. On average, participants were 35.4 years old ($SD = 14.13$) with the youngest participant being 19 years and the oldest 73. We had slightly more male (59.26%) than female participants (40.74%), with none describing their gender as "other" or abstaining to answer the question. Slightly over half of the participants (53.7%) had a University degree, but only 9 (16.67%) had a background in Computer Science or related subjects. Even though the majority of participants was from Sweden (59.26%), international visitors from 17 different countries took part in our study as well.

5.2. Experimental setup

The experiment space was divided into the participant's and wizard's area as visualized in Fig. 1. The participant's area was visually separated from the wizard's area by three exhibition walls covered by black fabric. The Furhat robot was placed in front of the walls so the fabric provided an even background for the experiment. The participant was standing in front of the table. Between the robot and the participant, a shared touch screen displaying the robot's country selection and a RealSense (RS) camera recording participant's facial expressions were placed. At the side of the table a tablet was attached on a bendable arm. The tablet was aimed at guiding the participant through the experimental procedure, was used to show the director screen and to fill out the questionnaires. We ensured that the robot was roughly on participant's eye level by installing it on an additional small table on top of the main experiment table. Behind the robot, a tripod with a Kinect (KIN) for face and skeleton tracking was placed. A webcam (WB3) was attached above the Kinect to provide a video stream to the robot operator behind the wall. Two further webcams (WB1 & WB2) provided frontal and lateral recording of the experiment at 30 fps. Participants were asked to wear a close-range Sennheiser microphone and Tobii eye-tracking glasses during the experiment. The light in the participant's area was switched off, except for a professional light system that was used to provide even light for the video recordings. As the robot was placed behind the light system, the light did not impair the visibility of its facial features.

To the left of the robot, a table with three computers was installed to control the game interface, robot behavior and recordings. Computer C1 recorded videos from two webcams (WB1 & WB2) and the microphone using EyesWeb,[1] as well as skeleton data from the Microsoft Kinect. C1 was also running the scripts for the game and questionnaire as well as the robot control system. All interactions with the game, the robot speech as well as its gaze and facial expressions were written to a log file on C1. C2 ran a custom developed software connected to the Tobii eyetracker that autonomously analyzed the incoming video stream and provided information to the robot controller behind the wall on what object the participant was paying attention to. The third computer (C3) recorded the RealSense video. It was also connected to the shared touch screen and displayed the respective game interface on the screen.

The wizard controlled the robot from the wizard's area on computer C4. This computer was connected to webcam WB3 and the stream of the camera was visible to the robot controller in real-time and recorded for later analysis. The wizard was never seen by nor interacted directly with the participants. Different researchers (R1, R2) monitored the experiment: they recruited the participants for the study, asked them to sign the consent form and fill out questionnaires before and after the interaction and debriefed them after the experiment had finished.

5.3. Measures

The analyses provided in this paper are based on three different questionnaires: Q1 was filled out before the experiment started, Q2 at three different times throughout the interaction with the robot and Q3 after the interaction with the robot had finished.

Questionnaire Q1 was provided to participants outside the experiment room before the experiment started. It included demographic questions capturing participants age, gender, nationality and highest level of education, a short version of the Big Five personality questionnaire by Rammstedt and John (2007) as well as the Negative Attitude Towards Robots (NARS) scale by Nomura et al. (2006). Questionnaire Q2 was designed to capture the perception of the robot in different dimensions during the interaction with the robot. It consisted of questions related to the robot's perceived anthropomorphism based on the Godspeed questionnaire developed by Bartneck, Kulić, et al. (2009) (reliability between $\alpha = .929$ and $\alpha = .856$), perceived threat ($\alpha = .91$) and likability ($\alpha = .827$) as introduced by Rosenthal-von der Pütten and Krämer (2014), as well as warmth ($\alpha = .91$), discomfort ($\alpha = .82$) and competence ($\alpha = .84$) from the RoSAS scale (Carpinella et al. (2017)).

The final questionnaire (Q3) was filled out at the end of the session outside the participant area. In it, participants were first asked to report their overall satisfaction with the game (e.g., how satisfied they were with the score, or whether they felt they learned new things playing the game) and the interaction with the robot (e.g., whether they understood what the robot was saying, and whether they believed the robot understood them) on ten different scales. Participants were then prompted to rate their involvement with both the game and the robot separately, as well as to report their focused attention throughout the game (O'Brien and Toms (2010)). The final set of questions regarded the perceived personality of the robot: Participants rated the robot's personality using the short version of the Big Five personality questionnaire by Rammstedt and John (2007) and on several scales capturing how coherent they perceived the interaction with the robot to be (e.g., whether the personality developed smoothly over the interaction and whether the mood of the robot was fluctuating). They were also prompted to describe the robot they had met in three words. In the end, they indicated whether they had seen the Furhat robot or interacted with it before. In case participants had interacted with a Furhat prior to the study, their data were excluded from the analyses.

5.4. Procedure

Participants were recruited at the entrance of the museum by R1 and were brought to a waiting area in front of the experiment space. R1 further explained the purpose of the experiment and the experimental procedure to participants, handed them the consent form to sign, the rules of the game and questionnaire Q1 on a laptop. During this period, R2 and the wizard prepared the experiment space and covered the Furhat robot with a blanket.

Once the participant finished Q1, R2 took them to the experiment space, set up and calibrated the eye-tracker and the microphone and started the camera recording. R2 then uncovered the robot and left the experiment space. While participants were led to believe they were alone in the experiment room throughout the experiment, the shared screen had an alarm button that could be pressed in case they needed assistance or had any further question. R2 was seated outside the experiment space and received the alarm on a laptop.

The first instance of Q2 was based on participant's first impression of the robot and they were instructed to look at the robot for a few seconds before starting to respond to the questionnaire. After participants filled out Q2 for the first time, the robot woke up and autonomously started the pre-game interaction, after which it asked participants to fill out Q2 again. They then played the game with the robot for 10 min and had the post-game social chat without a break. Thereafter, participants responded to Q2 once more inside the experiment space. As soon as the questionnaire was completed, R2 was notified outside the experiment space by the system. R2 entered the experiment space, stopped the recordings and walked the participant back to the waiting area. R1 took

[1] http://www.infomus.org/eyesweb_ita.php.

over outside the experiment space again, handing them a laptop to fill out Q3 before debriefing the participant on the experiment and handing over a free ticket to the museum as compensation.

5.5. Data analysis

To answer our research questions, several statistical analyses were executed in IBM SPSS 26. In order to perform the manipulation checks and answer RQ1 and RQ3, we ran a number of 2×2 ANOVA using robot appearance (human-like and morph) and personality (impatient and optimistic) as between-subject factors. Responses from questionnaire Q2 filled out after the post-game social chat were used for the manipulation check and the analysis regarding RQ1, while responses to questionnaire Q3 were used to reply to RQ3.

To respond to RQ2 and understand the influence of a match in personality traits between the robot and the human observer, we first analyzed which personality traits people perceived as different between the impatient and optimistic version of the robot (based on Q3). For each of the personality traits where the difference between conditions reached significance, a 2×2 ANCOVA was performed with the robot's personality (impatient and optimistic) and participant's level on that particular personality trait (low and high) as between-subject variables and the robot's appearance (human-like or morph) as co-variate. In order to divide participants into low and high on a certain personality trait, we calculated the median scores of the respective trait based on participants' responses to Q1 and attributed the value low to those participants whose rating was lower than the median, and the value high to those participants whose rating was equal or higher than the median. The analysis was performed on participants' responses to Q2 filled out after the post-game social chat.

Finally, to answer RQ4 and understand the influence of time on the perception of personality, we performed a series of 2×2 x 3 factorial ANOVA using appearance (human-like and morph) and the robot's personality (impatient and optimistic) as between-subject factors and time (first impression, social chat, and game interaction) as within-subject factor. To perform this analysis, we used the Q2 filled out after the first impression, Q2 collected after the 2-min of pre-game social chat, and the Q2 completed after the game interaction and the post-game social chat. All post-hoc analyses were performed with a Bonferroni correction.

6. Results

When checking the equality of variance and normality of the dependent variables, we realized that the item discomfort of the RoSAS scale (Q2), the majority of the items of the satisfaction questionnaire (Q3) and two of the questions about the coherence of the robot's personality (Q3; i.e., *the robot lost temper easily* and *the robot was supportive*) did not meet the assumptions. When performing the manipulation checks and the analyses for RQ1 and RQ3 on these dependent measures, we ran two separate Mann-Whitney U tests with appearance and personality as between-subject factors. When performing the analyses for RQ2 and RQ4, which were focused on interaction effects, the respective scales were excluded from the analysis, as interaction effects cannot be calculated with parametric statistics.

6.1. Manipulation check

We performed two manipulation checks. The first was to understand whether the appearance of the robot was perceived as significantly different across the two levels of human-likeness. The second was to check whether the personalities that we created for the robot were perceived as distinct and coherent. In the case of appearance, we were particularly interested in variations in the perception of anthropomorphism and uncanniness (i.e., perceived threat, likability, and discomfort). In the case of personality, we were interested in understanding whether the robot's personality had an effect on the Big Five traits attributed to it by the participants and whether the personalities we created were perceived as coherent and were captured correctly by the participants. In the following sub-sections, we only report the main effects of appearance and personality on the dependent variables. For a comprehensive overview of the results and their observed power, please refer to Tables 1 and 3. The descriptive statistics are reported in Tables 2 and 4.

6.1.1. Appearance

The results disclosed a main effect of appearance on perceived anthropomorphism ($F(1,57) = 5.024$, $p = .029$, $\eta p^2 = .081$) and a trend main effect of appearance on perceived threat ($F(1,57) = 3.155$, $p = .081$, $\eta p^2 = .052$). Interestingly, the morph robot was perceived as more anthropomorphic ($M = 3.187$, $SD = .914$) than the human-like version ($M = 2.658$, $SD = .896$), but also as more threatening (MOR: $M = 2.067$, $SD = .611$; HUM: $M = 1.748$, $SD = .561$). We did not find any significant main effect of appearance on the perceived likability ($F(1,57) = .615, p = .436$, $\eta p^2 = .011$), warmth ($F(1,57) = 1.649, p = .204$, $\eta p^2 = .028$), competence ($F(1,57) = .037$, $p = .847$, $\eta p^2 = .001$), and discomfort ($U = 445.0$, $z = -.289$, $p = .772$) elicited by the robot.

6.1.2. Personality

Distinct Personalities. The results of the 2×2 ANOVA revealed a significant main effect of the robot's personality on its perceived agreeableness ($F(1,57) = 34.731$, $p < .001$, $\eta p^2 = .379$), conscientiousness ($F(1,57) = 4.746$, $p = .034$, $\eta p^2 = .077$), and neuroticism ($F(1,57) = 4.033$, $p = .049$, $\eta p^2 = .066$). The optimistic robot was perceived as significantly more agreeable ($M = 4.016$, $SD = .664$) and conscientious ($M = 4.032$, $SD = .482$) than the impatient one (agreeableness: $M = 2.883$, $SD = .827$; conscientiousness: $M = 3.733$, $SD = .583$), while the impatient robot was perceived as more neurotic ($M = 2.083$, $SD = .671$) than the optimistic one ($M = 1.774$, $SD = .530$).

Coherent Personalities. We did not find a significant difference in coherence between the different robot's personalities ($F(1,57) = .391$, $p = .534$, $\eta p^2 = .007$). In both cases, the coherence of the robot personality was good (IMP: $M = 3.617$, $SD = .499$; OPT: $M = 3.702$, $SD = .572$). However, we found a significant main effect of personality on the perception of the robot as losing temper easily ($U = 160.500$, $z = -4.710$, $p < .001$), on the perception of the robot as supportive ($U = 180.500$, $z = -4.379$, $p < .001$), on its perception as indifferent ($F(1,57) = 6.034, p = .017$, $\eta p^2 = .096$), and on the abruptness of the robot's changes in behavior ($F(1,57) = 6.054, p = .017$, $\eta p^2 = .096$). Overall, the optimistic robot was perceived as more supportive ($M = 4.065$, $Mdn = 4.00$, $IRQ = 0.00$) than the impatient one ($M = 2.933$, $Mdn = 3.00$, $IRQ = 2.00$), while the impatient robot was perceived as losing temper more easily ($M = 2.600$, $Mdn = 2.50$, $IRQ = 2.00$), as more indifferent ($M = 2.833$, $SD = .986$), and as more abrupt in its reactions ($M = 2.333$, $SD = .711$) than the optimistic one (loss of temper: $M = 1.290$, $Mdn = 1.00$, $IRQ = 1.00$; indifference: $M = 2.226$, $SD = .921$; abruptness: $M = 1.887$, $SD = .680$).

6.1.3. Summary of manipulation check results

The results presented so far suggest that we were indeed able to develop two distinct and coherent personalities that significantly differed in three of the Big Five personality traits. Our findings on the robot appearance, on the contrary, are not entirely in line with our expectations and previous work. While we intended the human-like face texture to be perceived as more anthropomorphic, participants rated the morph between the human-like and a mechanical face as more anthropomorphic. Our main reasoning to manipulate the human-likeness of the face texture was, however, not the manipulation of anthropomorphism itself, but the elicitation of different levels of uncanny feelings

Table 1
2 × 2 ANOVA results for manipulation check, RQ1, and RQ3. Bold: significant results ($p < .05$); Italics: trend results ($p < .10$); the abbreviation pow. stands for observed power.

	Appearance				Personality				Interaction Effect			
	F	p	ηp^2	pow.	F	p	ηp^2	pow.	F	p	ηp^2	pow.
Extraversion	.002	.967	<.001	.050	.084	.773	.001	.059	.139	.711	.002	.066
Agreeableness	1.451	.233	.025	.220	**34.731**	**<.001**	**.379**	**1.000**	.498	.483	.009	.107
Open. Exper.	.022	.822	<.000	.052	.022	.882	<.001	.052	.354	.554	.006	.090
Conscient.	*2.848*	*.097*	*.048*	*.382*	**4.746**	**.034**	**.077**	**.572**	.076	.783	.001	.058
Neuroticism	.083	.774	.001	.059	**4.033**	**.049**	**.066**	**.506**	1.478	.229	.025	.223
Coherence	.099	.926	< .001	.051	.391	.534	.007	.094	.660	.420	.011	.126
Indifference	.092	.763	.002	.060	**6.034**	**.017**	**.096**	**.675**	.255	.616	.004	.079
Abruptness	.629	.431	.011	.122	**6.054**	**.017**	**.096**	**.677**	.179	.674	.003	.070
Anthropo.	**5.024**	**.029**	**.081**	**.596**	.038	.846	.001	.054	.235	.629	.004	.076
Threat	*3.155*	*.081*	*.052*	*.415*	**5.718**	**.020**	**.091**	**.652**	.897	.348	.015	.154
Likability	.615	.436	.011	.120	1.464	.231	.025	.221	1.602	.211	.027	.238
Warmth	1.649	.204	.028	.243	.166	.685	.003	.069	.416	.522	.007	.097
Competence	.037	.847	.001	.054	.243	.624	.004	.077	**4.430**	**.040**	**.072**	**.544**
Involv. robot	2.455	.123	.041	.337	.084	.773	.001	.059	**5.898**	**.018**	**.094**	**.665**
Involv. game	.002	.969	¡.001	.050	.440	.510	.008	.100	.002	.969	<.001	.050
Foc. attention	.580	.449	.010	.116	.178	.674	.003	.070	.586	.447	.010	.117
Game Score	.023	.879	<.001	.053	1.728	.194	.029	.253	.508	.479	.009	.108

Table 2
Descriptive statistics for the 2 × 2 ANOVA results reported in Table 2.

	Appearance				Personality			
	human-like		Morph		impatient		optimistic	
	M	SD	M	SD	M	SD	M	SD
Extraversion	3.258	.784	3.267	.763	3.233	.716	3.290	.824
Agreeableness	3.580	.932	3.333	.941	2.883	.827	4.016	.664
Openness to Experience	2.919	.895	2.883	.827	2.883	.751	2.919	.958
Conscientiousness	4.000	.563	3.767	.521	3.733	.583	4.032	.482
Neuroticism	1.903	.555	1.950	.687	2.083	.671	1.774	.530
Coherence	3.653	.486	3.667	.588	3.617	.499	3.702	.572
Indifference	2.484	1.061	2.567	.935	2.833	.986	2.226	.921
Abruptness	2.032	.752	2.183	.701	2.333	.711	1.887	.680
Anthropomorphism	2.658	.914	3.187	.896	2.900	.975	2.936	.913
Threat	1.794	.619	2.067	.611	2.113	.643	1.748	.561
Likability	2.568	.802	2.720	.721	2.527	.696	2.755	.814
Warmth	2.919	1.144	3.300	1.135	3.050	1.245	3.161	1.060
Competence	4.425	1.285	4.494	1.068	4.539	1.157	4.382	1.204
Involvement robot	3.624	.802	3.911	.637	3.744	.544	3.785	.888
Involvement game	4.118	.597	4.111	.490	4.067	.521	4.161	.570
Focused attention	3.894	.684	3.767	.614	3.795	.625	3.866	.678
Game Score	26.387	.7442	26.600	6.360	25.300	7.539	27.645	6.064

Table 3
Mann-Whitney U results for the manipulation check, RQ1 and RQ3. Bold: significant results ($p < .05$); Italics: trend results ($p < .10$).

	Appearance			Personality		
	U	Z	p	U	z	p
Discomfort	445.0	-.289	.772	403.0	-.897	.370
Losing temper	396.5	−1.06	.289	**160.5**	**−4.710**	**<.001**
Supportiveness	429.5	-.546	.585	**180.5**	**−4.379**	**<.001**
Robot understood me	464.0	-.017	.987	438.0	-.451	.652
Robot played efficiently	431.0	-.573	.567	396.0	−1.163	.245
I understood what the robot was saying	426.0	-.710	.478	**336.0**	**−2.348**	**.019**
I knew what to say to the robot	455.5	-.144	.885	**252.0**	**−3.238**	**.001**

towards the embodiment. Despite only finding a trend in significance, our data give confidence that the manipulation worked as intended and people felt more threatened by the morph compared to the human-like texture. While these conflicting results need to be taken into account when interpreting the main results of our paper and are more thoroughly discussed in Section 8.1, we still consider the manipulation of the appearance successful and hence continue to the analysis of our research questions.

6.2. Analyses of the research questions

6.2.1. Influence of Robot's personality on its perception [RQ1]

Given that the manipulation of the robot's personality proved to be successful, we proceeded to analyze whether the two personalities elicited different perceptions in the participants. The results revealed a significant main effect of personality on participants' perception of the robot as threatening ($F(1,57) = 5.718, p = .020, \eta p^2 = .091$) and a significant interaction effect of appearance and personality on the participants' perception of the robot as competent ($F(1,57) = 4.430$, $p = .040$, $\eta p^2 = .072$). In detail, the impatient robot was perceived as more threatening ($M = 2.113$, $SD = .643$) than the optimistic robot ($M = 1.748$, $SD = .561$). Moreover, the human-like impatient robot was perceived as more competent ($M = 4.822$, $SD = 1.196$) than the human-like optimistic one ($M = 4.052$, $SD = 1.189$), and the morph optimistic robot was perceived as more competent ($M = 4.733$, $SD = 1.035$) than the morph impatient one ($M = 4.256$, $SD = 1.082$, see Fig. 4 left). Overall, the human-like impatient and the morph optimistic robots achieved similar scores in terms of competence. Interestingly,

Table 4
Descriptive statistics for the Mann-Whitney U results reported in Table 4.

	Appearance						Personality					
	human-like			morph			impatient			optimistic		
	M	*Mdn*	*IRQ*	*M*	*Mdn*	*IRQ*	*M*	*Mdn*	*IRQ*	*M*	*Mdn*	*IRQ*
Discomfort	2.20	2.00	1.33	2.14	2.00	.92	2.27	2.08	.92	2.08	2.00	1.33
Losing temper	1.81	1.00	1.00	2.07	2.00	2.00	2.60	2.50	2.00	1.29	1.00	1.00
Supportiveness	3.42	4.00	1.00	3.60	4.00	1.00	2.93	3.00	2.00	4.06	4.00	.00
Robot understood me	4.19	4.00	1.00	4.23	4.00	1.00	4.20	4.00	1.00	4.23	4.00	1.00
Robot played efficiently	4.23	4.00	1.00	4.17	4.00	1.00	4.13	4.00	.00	4.26	4.00	1.00
I understood what robot was saying	3.29	4.00	2.00	3.33	3.00	1.25	4.53	5.00	1.00	4.84	5.00	.00
I knew what to say to the robot	4.74	5.00	1.00	4.63	5.00	1.00	2.90	3.00	2.00	3.71	4.00	1.00

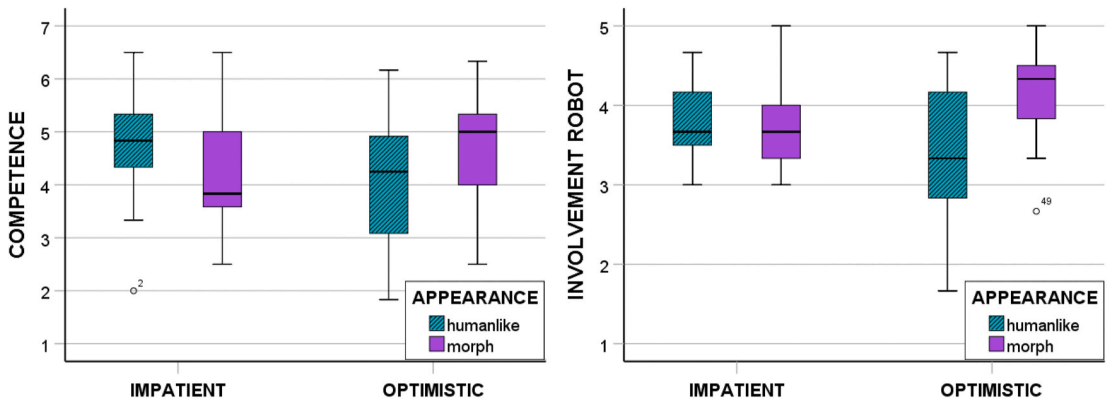

Fig. 4. Boxplots of the significant interaction effects of robot's appearance and personality on the perception of competence and the involvement with the robot.

while differing in terms of perceived threat, the two personalities were not perceived as significantly different in terms of likability ($F(1,57) = 1.464$, $p = .231$, $\eta p^2 = .025$), and discomfort ($U = 403.0$, $z = -.897$, $p = .370$). Further results and details (especially on the observed power) are presented in Tables 1–4.

6.2.2. *Influence of human-robot matching personality of Robot's perception [RQ2]*

The purpose of this analysis was to assess if a match between the robot's and the participant's personality affected the perception of the robot's uncanniness. As the two personalities displayed by the robot were found to differ in terms of agreeableness, conscientiousness, and neuroticism, we focus only on these traits to analyze the interaction effects between the robot's personality and the participant's level of the same traits. Furthermore, we focus on the dependent variables denoting participants' perception of the robot's uncanniness which meet the assumption of normality, namely perceived threat and likability.

The results of the 2 × 2 ANCOVA did not disclose any significant interaction effect of the robot's personality and the participant's level of agreeableness and neuroticism on the perception of the robot (see Table 5). However, they showed a significant interaction effect between the robot's personality and the participant's level of conscientiousness on perceived threat ($F(1,50) = 4.511$, $p = .039$, $\eta p^2 = .084$) with participant's low in conscientiousness perceiving the impatient robot (the robot matching their personality) as more threatening ($M = 2.160$, $SD = .515$) than the optimistic robot (the robot not matching their personality; $M = 1.467$, $SD = .400$), and participants high in conscientiousness perceiving the impatient robot (the non-matching robot) and the optimistic robot (the matching one) as similarly threatening (IMP: $M = 1.925$, $SD = .505$; OPT: $M = 1.884$, $SD = .627$) as visible in Fig. 5.

Table 5
2 × 2 ANCOVA results for RQ2. Bold: significant results ($p < .05$); Italics: trend results ($p < .10$); the abbreviation pow. stands for observed power.

	Robot Personality				**Human Agreeableness**				**Interaction Effect**			
	F	*p*	ηp^2	pow.	*F*	*p*	ηp^2	pow.	*F*	*p*	ηp^2	pow.
Threat	*3.013*	*.089*	*.058*	*.398*	.039	.844	.001	.054	.375	.543	.008	.092
Likability	.526	.472	.011	.110	.191	.664	.004	.071	1.599	.212	.032	.236
	Robot Personality				**Human Conscientiousness**				**Interaction Effect**			
	F	*p*	ηp^2	pow.	*F*	*p*	ηp^2	pow.	*F*	*p*	ηp^2	pow.
Threat	**5.453**	**.024**	**.100**	**.629**	.108	.744	.002	.062	**4.511**	**.039**	**.084**	**.549**
Likability	1.901	.174	.037	.272	.034	.855	.001	.054	2.075	.156	.041	.292
	Robot Personality				**Human Neuroticism**				**Interaction Effect**			
	F	*p*	ηp^2	pow.	*F*	*p*	ηp^2	pow.	*F*	*p*	ηp^2	pow.
Threat	2.563	.116	.050	.348	.456	.503	.009	.102	.239	.627	.005	.077
Likability	1.159	.287	.023	.184	1.799	.186	.035	.260	.191	.664	.004	.071

Table 6
2 × 2 x 3 ANOVA results for RQ4. Bold: significant results ($p < .05$); Italics: trend results ($p < .10$); the abbreviation pow. stands for observed power.

	Appearance				Personality				Time			
	F	p	ηp^2	pow.	F	p	ηp^2	pow.	F	p	ηp^2	pow.
Anthropomorphism	1.459	.232	.025	.221	.002	.965	<.001	.050	.912	.407	.032	.200
Threat	2.599	.113	.044	.354	1.977	.165	.034	.282	**3.285**	**.045**	**.107**	**.601**
Likability	.071	.791	.001	.058	.896	.348	.015	.154	**3.294**	**.044**	**.105**	**.602**
Warmth	*3.368*	*.072*	*.056*	*.438*	.077	.782	.001	.059	.823	.444	.029	.184
Competence	.740	.393	.013	.135	.279	.599	.005	.081	**6.376**	**.003**	**.185**	**.885**

Table 7
Descriptive statistics for the 2 × 2 x 3 ANOVA results reported in Table 7.

	Appearance				Personality				Time					
	human-like		morph		impatient		optimistic		first imp.		social chat		post game	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Anthro.	2.768	.724	2.991	.735	2.876	.723	2.884	.724	2.889	.652	2.826	.878	2.918	.936
Threat	1.915	.501	2.124	.501	2.111	.501	1.929	.501	2.143	.568	1.980	.634	1.917	.624
Likab.	2.534	.618	2.576	.613	2.480	.613	2.629	.618	2.436	.578	2.584	.705	2.643	.761
Warmth	2.810	.947	3.254	.942	2.998	.942	3.065	.947	2.932	.978	3.046	1.107	3.107	1.146
Comp.	4.084	.913	4.285	.915	4.246	.915	4.122	.913	3.924	1.088	4.150	1.044	4.459	1.174

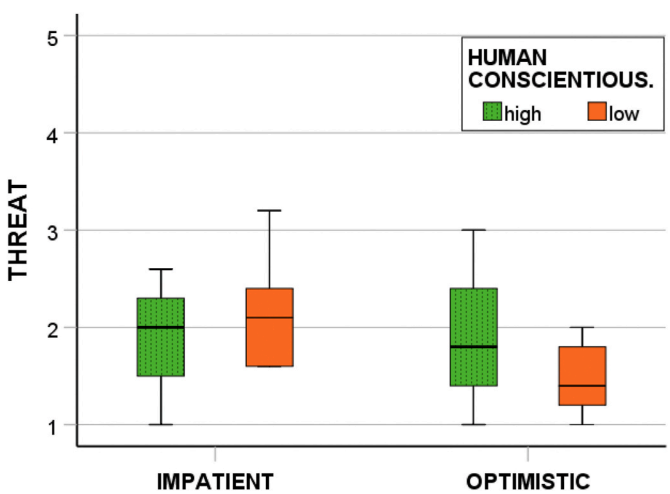

Fig. 5. Boxplot of the significant interaction effect of robot's personality and participant's level of conscientiousness of the perception of threat.

6.2.3. *Influence of personality on involvement, task performance, and satisfaction [RQ3]*

As the robot's personality, and partially also its humanlikeness, affected participants' perceptions of it, we wanted to understand whether they also affected participants' involvement with the robot, involvement with the game, focused attention, score in the game and interaction satisfaction. The results of the analyses and the associated descriptive statistics are displayed in Tables 1–4.

Involvement with the Robot. The results did not show any significant main effect of appearance ($F(1,57) = 2.445, p = .123, \eta p^2 = .041$) and personality on the involvement with the robot ($F(1,57) = .084$, $p = .773$, $\eta p^2 = .001$). However, they disclosed a significant interaction effect of appearance and personality on it ($F(1,57) = 5.898$, $p = .018, \eta p^2 = .094$) as seen in Fig. 4 to the right. In detail, the morph optimistic robot elicited more involvement ($M = 4,156$, $SD = .628$) than the human-like optimistic robot ($M = 3.437$, $SD = .972$), while no major difference was found between the morph impatient ($M = 3.667$, $SD = .563$) and the human-like impatient robot ($M = 3.822$, $SD = .533$).

Involvement with the Game. We did not find a significant effect of the robot's appearance ($F(1,57) = .002, p = .969, \eta p^2 < .000$), personality ($F(1,57) = .440$, $p = .510$, $\eta p^2 = .008$) and interaction between appearance and personality on the involvement with the game ($F(1,57) = .002, p = .969, \eta p^2 < .000$).

Focused Attention and Task Performance. The results for involvement with the game were mirrored by the lack of significant differences across conditions in terms of focused attention (appearance: $F(1,57) = .580$, $p = .449$, $\eta p^2 = .010$; personality: $F(1,57) = .178$, $p = .674$, $\eta p^2 = .003$; appearance and personality: $F(1,57) = .586$, $p = .447$, $\eta p^2 = .010$) and score (appearance ($F(1,57) = .023$, $p = .879$, $\eta p^2 < .000$; personality: $F(1,57) = 1.728$, $p = .194$, $\eta p^2 = .029$; appearance and personality: $F(1,57) = .508$, $p = .479$, $\eta p^2 = .009$). Participants had similar levels of attention across conditions and achieved similar scores at the game regardless of the type of robot they interacted with.

Satisfaction. We did not find significant differences between the two robot's personalities for the items *the robot understood me* ($U = 438$, $z = -.451, p = .652$) and *the robot played the game efficiently* ($U = 396$, $z = -1.163, p = .245$). However, a significant difference between the two could be seen for the item *I understood what the robot was saying* ($U = 336, z = -2.348, p = .019$) - with participants perceiving more difficulty to understand the impatient robot ($M = 4.533$, $Mdn = 5.00$, $IRQ = 1.00$) than the optimistic one ($M = 4.839$, $Mdn = 5.00$, $IRQ = 0.00$) - and the item *I knew what to say to the robot* ($U = 252$, $z = -3.238, p = .001$) - with participants being more knowledgeable about what to say to the optimistic robot ($M = 3.710$, $Mdn = 4.00$, $IRQ = 1.00$) than to the impatient one ($M = 2.900$, $Mdn = 3.00$, $IRQ = 2.00$).

We did not find similar differences across the different levels of appearance (*the robot understood me*: $U = 464, z = -.017, p = .987$; *the robot played the game efficiently*: $U = 431$, $z = -.573$, $p = .567$; *I understood what the robot was saying*: $U = 426, z = -.710, p = .478$; *I knew what to say to the robot*: $U = 455.5, z = -.144, p = .885$).

6.2.4. *Influence of personality on Robot's perception over time [RQ4]*

The main results of the analyses and the associated descriptive statistics are reported in Tables 6 and 7. Due to space limitations, we do not report the results of the multiple interaction effects from this analysis in the tables. None of them was found to be significant. The results showed a significant interaction effect of time and appearance on anthropomorphism ($F(2,56) = 4.833$, $p = .012$, $\eta p^2 = .147$) with the anthropomorphism of the morph robot growing over time (first impression:

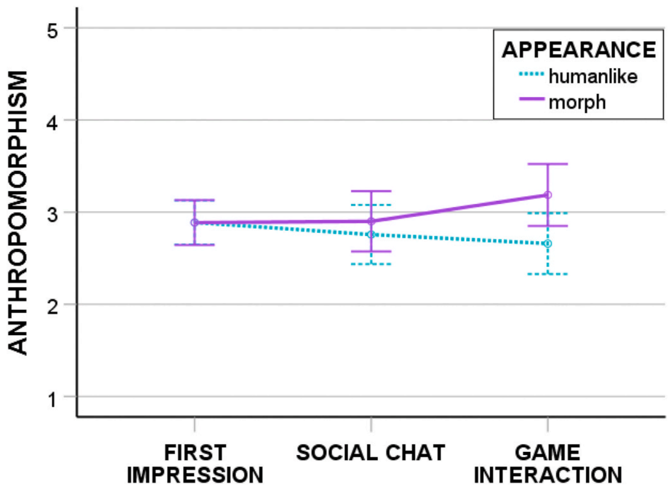

Fig. 6. Line chart of the significant interaction effect of robot's appearance and time on the perception of anthropomorphism.

$M = 2.887$, $SD = .706$, social chat: $M = 2.900$, $SD = .867$, game interaction: $M = 3.187$, $SD = .896$) and the anthropomorphism of the human-like robot slightly decreasing over time (first impression: $M = 2.890$, $SD = .606$, social chat: $M = 2.755$, $SD = .897$, game interaction: $M = 2.658$, $SD = .914$) as shown in Fig. 6. Moreover, a significant main effect of time on perceived threat ($F(2,55) = 3.285$, $p = .045$, $\eta p^2 = .107$), likability ($F(2,56) = 3.294$, $p = .044$, $\eta p^2 = .105$), and competence was observed ($F(2,56) = 6.376$, $p = .003$, $\eta p^2 = .185$). While the perceived threat elicited by the robot decreased over time (first impression: $M = 2.143$, $SD = .568$; social chat: $M = 1.980$, $SD = .634$; game interaction: $M = 1.917$, $SD = .624$), the perceived likability (first impression: $M = 2.436$, $SD = .578$; social chat: $M = 2.584$, $SD = .705$; game interaction: $M = 2.643$, $SD = .761$) and competence increased over time (first impression: $M = 3.924$, $SD = 1.088$; social chat: $M = 4.150$, $SD = 1.044$; game interaction: $M = 4.459$, $SD = 1.174$, see Fig. 7). Post-hoc analyses revealed a significant difference in perceived threat and likability between the first impression and the game interaction (threat: $p = .042$; likability: $p = .040$), and a significant difference in competence between the first impression and the game interaction ($p = .003$) and between the social chat and the game interaction ($p = .019$).

7. General discussion

7.1. Manipulation check

The goal of this work was to expand the extant literature on the uncanny valley effect by understanding how different robot personalities influence uncanny feelings. More specifically, our aim was to create two distinct but overall engaging personalities and study the effect of their behavioral patterns on the development of uncanny feelings during the interaction. Our results show that we were indeed able to create two distinct personalities. In line with our previous work, we found the optimistic and encouraging personality to be perceived as more agreeable and emotionally stable than the impatient and provocative one. However, while in our previous work the difference between the two personalities was limited to agreeableness and neuroticism, in this study, we found the two personalities to also differ in terms of conscientiousness. Although we grounded the description of the impatient personality in the robot's determination to perform well in the game (progress quickly and score high), it seems that many crowd-workers interpreted the robot's impatience as willingness to finish the game quickly and move on, and hence as indifference towards the goal of the game. This led them to author conversational content like "I don't really care if it is wrong or not anyway" when not scoring a point, which clearly suggests the robot's disinterest towards the game performance and is an indicator of lack of conscientiousness. Despite being rated as less agreeable, less conscientious and more neurotic, people still felt the same level of engagement towards the impatient and the optimistic robot. *This suggests that we were indeed able to create two distinct personalities that both led to believable behavioral patterns in the given task.*

When using a crowd-sourcing pipeline to generate conversational content for similar personalities in the past, we found the coherence of the personality-driven behavior to be a main challenge to our approach. For the present study, we developed a semi-autonomous dialogue manager that tracked the robot's affective state and picked the next utterance by prioritizing a coherent development of the target affect over time. Our results show that the two personalities were both perceived as coherent and developing naturally over time and hence signal that we were able to overcome the drawbacks of our previous pipeline. *This finding is important for the human-robot interaction community, as it suggests that crowd-authoring in combination with an affect-driven dialogue management system is a suitable approach to create large conversational corpora for social robots with distinct and coherent personalities.*

The second independent variable we manipulated in our experiment was the appearance of the robot. Based on our previous work on the uncanny valley, we used one human-like face texture and a texture that was a morph between a human-like and a mechanical one. In prior studies, we found these two face textures to differ significantly both in their perceived anthropomorphism and discomfort, with the morph being perceived as less anthropomorphic but eliciting more discomfort. While we still found a trend difference in perceived threat between the two robots, with the morph robot being perceived as more threatening that the human-like one, in this study, it was the morph robot to be perceived as more anthropomorphic. We believe that the difference in technological expertise between the participants of the present study and those of our previous studies had a core influence in the deviation of results. In this work, the majority of people were novices and less than 20% had a background in Computer Science or a related field, while, in our previous work, almost all participants were Computer Science

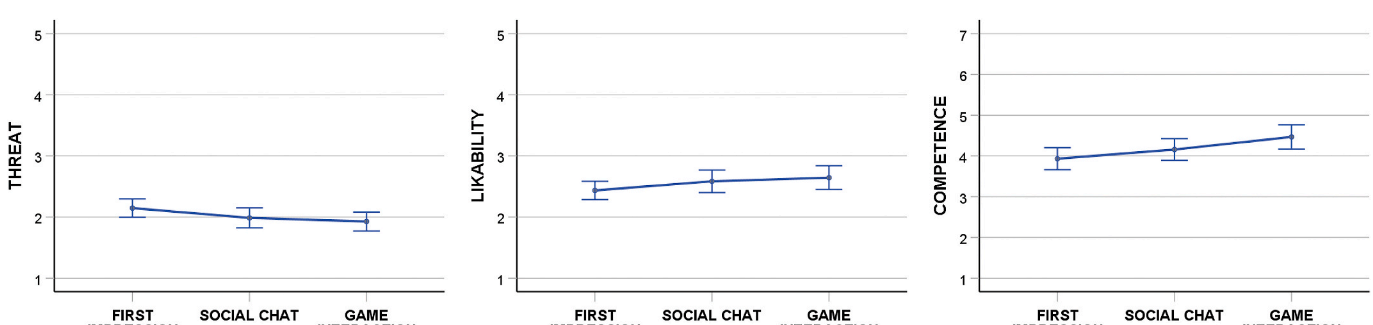

Fig. 7. Line charts of the significant effect of time on the perceived threat, likability and competence of the robot.

students. It is thus possible that the participants of the present study were overall more new to robots and had less knowledge about robotic platforms to properly judge Furhat's anthropomorphism. Moreover, it is also possible that participants interacting with the morph robot assumed the mechanical features in its face to be due to the technical limitations of the platform and hence rated the morph facial texture with more mechanical platforms in mind. Under the same line of thought, it might be that participants that interacted with the human-like robot compared it with a real human being and hence rated its anthropomorphism more critically. It is important to underline that Furhat has a mechanical body and even when projecting a human-like face onto its mask, a dissonance in its anthropomorphism can be perceived which might lead to uncanny feelings.

7.2. Findings

7.2.1. Influence of Robot's personality on its perception [RQ1]

While the two personalities designed as part of this paper were perceived as distinct in their personality traits, people's perception of the two did not differ on most of the other perceptual scales included in our questionnaires. In particular, the two personalities were perceived similar in anthropomorphism, warmth, and competence. However, when examining the perceptual dimensions related to the uncanny valley, we found the robot that behaved impatient and provocative to be perceived as more threatening than the optimistic and encouraging one. This finding is particularly interesting given that the two personalities did not differ in their perceived likability and discomfort, which are also related to uncanny feelings.

We did not design either of the personalities to elicit negative feelings or threat. In fact, to ensure that the personalities were both not offensive, we implemented a two-step process involving a pre-screening of the dialogue content by crowd-workers and a manual check of the lines rated as offensive by one of the authors. It is possible, however, that offensive lines made it to the final corpus due to not being properly flagged by crowd-workers. When checking the overall ratings of the crowd-authored lines, we found that the impatient lines were rated as more offensive than the excited lines, which is only natural given the difference in their affective definition (pre-game: $M = 2.2$ for impatient, $M = 1.6$ for excited; in-game: $M = 2.3$ for impatient, $M = 1.7$ for excited; post-game: $M = 2.3$ for impatient, $M = 1.6$ for excited). It could thus be that participants felt more intimidated when playing with the impatient personality due to its particular reactions to negative events in the game. Instead of being forgiving about mistakes and blaming them on the team, the impatient robot often called out participants for their insufficient descriptions provided. For example, the robot would say: "Took you long enough" after they scored a point, or even: "Can't you do better? Come on" when missing a point. The difference in response to the question whether participants were satisfied with their final score shows that the robot's behavior did indeed affect their perception: Although both robots played equally well and the final score did not differ between the two personalities, participants reported a significantly higher satisfaction with their score after playing with the optimistic personality. Kaniarasu and Steinfeld (2014) found that people trust a robot that frequently blames the human interaction partner for mistakes less in comparison to one that blames the team or itself. Since the impatient personality made use of more lines that attributed blame to the human player than the supportive personality, it might likely be that it came across as more offensive, and hence threatening.

Złotowski et al. (2015) suggested that a robot's negative attitude can intensify uncanny feelings. In their work, the negative attitude was designed as an antagonistic behavior of the robot during a common task. With respect to Złotowski et al. (2015), we did not design our personalities to be perceived as having a positive or negative attitude. This led them to be both evaluated as very engaging and to elicit a similar involvement in the game. Our results thus extend the related work in that they show that *robot behavior, even when not explicitly designed as negative, can still elicit uncanny feelings.* In addition, the specific personality traits assigned by participants to our robot can provide a first insight into what in a robot's personality leads to the feeling of threat. In agreement with Hwang et al. (2013) who found all five personality traits to be negatively correlated with the feeling of concern towards a robot, our impatient robot, which was indeed perceived as less emotionally stable, less agreeable and less conscientious, was perceived as more threatening. We believe that emotional stability might have been of particular importance in this sense. A high emotional stability is likely to lead to predictable behavior and makes it easier to predict the future actions of the robot. *Since the impatient robot was perceived more emotionally unstable, it might have been harder for participants to gain an understanding of its behavioral patterns, and the associated insecurity generated by this unpredictable behavior might have in turn caused a feeling of threat.*

Finally, it is surprising to note that our results show little interaction between the robot's personality and its appearance. As previous research suggested that people generally ascribe more positive personality traits to more human-like robots (Broadbent et al. (2013); Chee et al. (2012); Yamashita et al. (2016)), we would have expected a significant interaction effect of personality and appearance on the perception of the robot. However, we only found an interaction effect of appearance and personality on the perceived competence of the robot. The human-like robot was perceived as more competent when behaving impatient, while the morph was judged as more competent when being optimistic. In our study, it is unclear what contributes to forming a perception of competence, especially because all combinations of personality and appearance scored equally high in the game. There were a variety of aspects in the interaction other than the game score that could potentially affect the assessment of competence and the exact contribution of each one is difficult to disentangle. For future work, it would thus be interesting to examine the concept of competence more closely to gain further insights into the interplay between appearance and personality.

7.2.2. Influence of human-robot matching personality of Robot's perception [RQ2]

Based on the related work, we hypothesized that a match in personality between the human and robot game partners could lead to a more favourable perception of the robot and hence to less uncanny feelings (Park et al. (2012); Tapus et al. (2008)). However, we found that the feelings towards the robot, particularly those related to the uncanny valley, did not change when the participant's personality matched the one of the robot. The only exception to this was found in people low in conscientiousness, who perceived the robot with the impatient personality as more threatening than the optimistic one. As the impatient robot was rated low in conscientiousness, it was thus a match in personality that led to uncanny feelings. This seems counter-intuitive, since people low in conscientiousness should generally be less invested in the outcome of a task and thus less affected by a robot with a similar level of disinterest. It is important to note, however, that we did not manipulate the robot's personality traits separately. Hence, it may be possible that this finding is due to an interaction between agreeableness, neuroticism and conscientiousness, rather than conscientiousness alone. In the future, it will be crucial to design robot personalities that allow for a separate analysis of the effect of the three personality traits on uncanny feelings to see if a match in the level of conscientiousness still produces the same results.

As a last note, we would like to underline that the body of knowledge investigating how a match in personality between a human and a robot affects the robot's perception has exclusively focused on extroversion. Our work extends the existing body of knowledge by suggesting that *a match in personality traits does not lead to a more positive evaluation of the robot across all personality traits.* Joosse et al. (2013) previously suggested that the preference for similar or complimentary personality may depend on the context and the task the robot is performing. It would thus be interesting to understand whether our findings generalize to other contexts, specifically those involving more competitive and serious interactions.

7.2.3. Influence of personality on involvement, task performance, and satisfaction [RQ3]

Overall, participants rated their involvement with the game and the robot very high regardless of the robot's personality. *This suggests that two distinct personalities specifically designed to fit a task can lead to similar levels of involvement.* Interestingly, we found that people meeting the optimistic robot were more involved with it when playing with its morph version than with the human-like one. Even though the same effect was not observable for the impatient robot, this finding suggests that people's involvement was at least partially based on the robot's appearance.

One possible explanation for a lower involvement with the human-like robot with respect to the morph for the optimistic personality could be provided by the *blemishing effect*. According to it, "under specifiable conditions, people will be more favorably disposed towards a product when a small dose of negative information is added to an otherwise positive description" (Ein-Gar et al. (2012)). This is in line with previous research in HRI, which found that robots displaying faulty behaviors were perceived as more likable (Mirnig et al. (2017); Salem et al. (2013)). In this sense, the morph appearance might have acted as a flaw in an overall positive attitude of the optimistic personality, thus making it more engaging.

7.2.4. Influence of personality on Robot's perception over time [RQ4]

In previous work, we found that people's uncanny feelings towards an agent declined over the course of an interaction with it Paetzel & Castellano (2019); Paetzel, Perugia, & Castellano (2020); Perugia, Paetzel-Prüsmann, Alanenpää, & Castellano (2021). The aim of this work was to further our understanding and investigate whether it is just the exposure to any kind of robot behavior that lowers uncanny feelings, or whether the behavior the robot displays also matters. The present study shows that the perceived threat of the robot declines from the first impression to the end of the interaction, which is in line with our previous work, as well as with Złotowski et al. (2015). Even though the interaction effect between time and personality was not significant, looking at the data revealed an interesting trend. The perceived threat elicited by the two different personalities was similar at first sight. However, it started diverging after the 2-min pre-game social chat and it differed significantly after the game interaction and the post-game social chat. The optimistic personality was perceived as increasingly less threatening over time, while the impatient one remained equally threatening over the course of the interaction (cf. Fig. 8). At this point, people had interacted with the robot for about 15 min, a time exceeding that of a first impression (Ambady et al. (2000)). *Our findings thus suggest that behavioral patterns play an important role in overcoming initial uncanny feelings. More specifically, we see that a robot perceived as agreeable, emotionally stable and conscientious is able to progressively lower its perceived threat.*

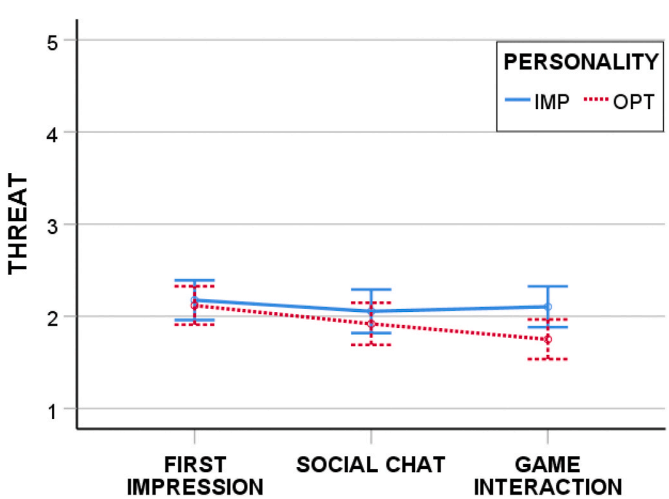

Fig. 8. Line chart of the interaction effect of robot's personality and time on the perceived threat elicited by the robot.

In most of the related work on the uncanny valley, researchers exposed participants to still images or brief videos of a robot and could thus merely capture people's perception of it at first sight. The findings presented in this paper provide further evidence that *initial uncanny feelings towards a robot may not be predictive of people's long-term perception of it.* This has important implications for the human-robot interaction community: Our results show that empirical investigations should focus more on interactive scenarios when measuring uncanny feelings towards a robot. This research could eventually inform the development of guidelines for robot designers aimed at minimizing or weakening the perception of uncanniness in a robot.

7.3. Limitations and future work

In this work, we focused on two personalities that were designed to display two distinct behavioral patterns. In particular, the two personalities varied in three out of five personality traits. This made it difficult to draw conclusions about what particular traits were responsible for lowering or eliciting uncanny feelings. While it is challenging to develop personalities that differ in only one particular trait while staying comparable in the others, doing so would give valuable insights into the causes of uncanny feelings and in ways to overcome them throughout an interaction. Similarly, our work is limited by the use of only one robot platform and by the fact we did not manage to successfully manipulate the robot's human-likeness as envisioned. For future work, it is thus essential to replicate this study with multiple robot platforms to understand whether the findings in this paper generalize across robots.

The interactive behavior of the robot in our experiment was partially controlled by a human operator. While the dialogue management and language generation was performed autonomously, a human replaced the language understanding unit of the system for the personality-driven behavior. Within the game, the controller also handled the country selection for the robot. During the debriefing, all participants were asked whether they suspected the robot to be remote-controlled. Participants who raised suspicion were excluded from the statistical analysis presented in this paper. We thus believe that the remote-controlled nature of the robot interaction had limited influence on people's perception. It is, however, still possible that the excellent language understanding skills of the robot and the very good performance in the game positively influenced people's perception of the robot overall. We are currently working on a fully autonomous version of the robot and aim to confirm our findings using autonomous behavior in the future.

Finally, the time people interacted with the robot was comparably short in the present research. In previous work, we found repeated interactions with multiple days of zero exposure in between to significantly lower uncanny feelings towards a robot beyond the effect a single interaction can have Paetzel, Perugia, & Castellano (2020); Perugia, Paetzel-Prüsmann, Alanenpää, & Castellano (2021). Due to the choice of conducting the experiment in a public space and thus to broaden the demographics of our participants, it was not possible to invite participants to interact with the robot again. For the future, however, it would be important to analyze how repeated interactions influence the perception of personality over time. In particular, it would be interesting to understand whether uncanny feelings towards the impatient personality remain stable over the course of several repeated interactions, or whether they eventually decrease over time. Moreover, a long-term study would further our understanding of whether the two personalities eventually converge in their perceived level of threat, or whether the gap between them persists.

8. Conclusion

In this paper, we examined the influence of a robot's personality and appearance on people's perception of it with a specific focus on feelings related to the uncanny valley. We presented an experiment in which 61 visitors of a science museum were asked to play a cooperative game with a Furhat robot. We manipulated two independent variables in the experiment: The robot's appearance and its personality-driven behavior. The two personalities we developed were found to differ in their perceived agreeableness, emotional stability and conscientiousness. While people's ratings of the robot were comparable for most perceptual dimensions across the four combinations of personality and appearance, we found the robot that acted impatient and provocative to be overall perceived as more threatening. This finding is important since it provides further evidence for the assumption that the behavior of a robot can influence people's perception of its uncanniness. Our data further show that this difference in uncanniness between the two personalities develops over time. It thus seems that the longer people interact with a robot, the more influential its behavioral patterns become and the less significance its embodiment has on the judgment of its uncanniness. These findings contribute to the literature on human-robot interaction by providing an important perspective on the research related to the uncanny valley. While the related work has often studied people's perception of a robot's uncanniness merely based on first impressions, we discovered that the influence of such impressions decreases over time and may play only a limited role in the long-term perception of a robot.

Credit author statement

Maike Paetzel-Prüsmann: Conceptualization, Methodology, Software, Investigation, Resources, Writing – original draft, Visualization, Giulia Perugia: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing – review & editing, Visualization, Project administration, Ginevra Castellano: Supervision, Funding acquisition

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