On the Role of Personality and Empathy in Human-Human, Human-Agent, and Human-Robot Mimicry

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Abstract. Facial mimicry is crucial in social interactions as it communicates the intent to bond with another person. While human-human mimicry has been extensively studied, human-agent and human-robot mimicry have been addressed only recently, and the individual characteristics that affect them are still unknown. This paper explores whether the humanlikeness and embodiment of an agent affect human facial mimicry and which personality and empathy traits are related to facial mimicry of human and artificial agents. We exposed 46 participants to the six basic emotions displayed by a video-recorded human and three artificial agents (a physical robot, a video-recorded robot, and a virtual agent) differing in humanlikeness (humanlike, characterlike, and a morph between the two). We asked participants to recognize the facial expressions performed by each agent and measured their facial mimicry using automatic detection of facial action unit activation. Results showed that mimicry was affected by the agents' embodiment, but not by their humanlikeness, and that it correlated both with individual traits denoting sociability and sympathy and with traits advantageous for emotion recognition.

Keywords: Facial mimicry · Social robots · Virtual agents

1 Introduction

Facial mimicry is an interesting social cue as it communicates rapport, liking, and social affiliation [19]. It refers to the spontaneous activation of congruent facial muscles in response to the observation of a facial expression from another individual (e.g., smile to a smile) [8]. The mimicry-liking relation is extremely compelling for Human-Robot and Human-Agent Interaction (HRI and HAI). Indeed, human facial mimicry could be used to measure affiliation attitudes towards artificial agents during first encounters, but also to gauge the quality of interaction in prolonged and repeated encounters.

Spontaneous facial mimicry has been mostly studied in Human-Human Interaction (HHI), and has only recently been investigated in HRI and HAI [20,21,26,31]. The majority of research on facial mimicry focuses on whether emotional expressions are mimicked [20], under which circumstances [21], and

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which are the characteristics of the expresser that elicit more intense mimicry [20,30]. For example, an artificial agent that is physically present and humanlike seems to elicit stronger mimicry than its virtual non-humanlike counterpart [20,31]. From other work on human-human mimicry, we also know that the individual traits of a person influence their mimicking response. For instance, people high in empathy mimic emotional expressions already at an automatic level of information processing (56 ms) [37]. What we do not know, however, is whether empathy and personality traits affect human-agent and human-robot mimicry and if the embodiment of an agent causes certain traits to be more salient than others for the sake of mimicry. This paper thus *explores whether the humanlikeness and embodiment of an agent affect facial mimicry and which personality and empathy traits are related to facial mimicry of human and artificial agents.*

In the study presented in this paper, we exposed participants to the six basic emotions [14] displayed by a human agent and three artificial agents differing in embodiment and humanlikeness. We asked participants to recognize the facial expressions performed by each agent and measured their facial mimicry using a computer vision technique. We then assessed whether their empathy and personality traits correlated with facial mimicry. The results highlight that embodiment is more crucial than humanlikeness to determine facial mimicry and that different embodiments correspond to different patterns of correlations between individual traits and facial mimicry.

2 Related Work

Human-Human Facial Mimicry. From Social Psychology and Psychophysiology, we know that observing pictures of happy and angry faces spontaneously elicits the activation of congruent facial muscles, respectively the zygomaticus major (i.e., smiling), and corrugator supercilii (i.e., frowning) [10]. This phenomenon occurs within 300–400 ms of exposure and is largely uncontrolled and subperceptual [11]. Facial mimicry is crucial in social interactions as it promotes liking and social affiliation [6]. Not only does it signal higher rapport when the relation between mimicker and expresser is already established [18], but it is also used to pursue affiliation between new acquaintances [6]. Indeed, the literature highlights that initial liking increases facial mimicry in first encounters [27] and the mere goal to affiliate intensifies people's mimicking response [25].

Human-Agent and Human-Robot Facial Mimicry. Due to the difficulty of studying face-to-face mimicry with human subjects, human-human mimicry has been mostly studied with static images and videos. The use of virtual and robotic agents gives the unique possibility to examine dynamic facial expressions occurring when the expresser and the observer are co-present. In spite of this advantage, the literature has only recently addressed facial mimicry in HAI and HRI. This is probably due to the fact that robotic platforms enabling a proper manipulation of facial expressions became available only recently.

Related work on facial mimicry in HAI and HRI found similar results to those highlighted by human-human studies. Mattheij et al. (2013) revealed that people mimic all facial expressions displayed by virtual agents with a slight preference towards happiness and surprise [26]. Philip et al. (2018) discovered that expressions of joy, anger, and sadness are all congruently mimicked, but joy and anger cause stronger activation when the agent's face is dynamic, rather than static, and displays a real human character, rather than a virtual one [31]. Hofree et al. (2014) discovered that people mimic the facial expressions of happiness and anger displayed by a highly realistic android robot only when it is physically present in the same room with them [20]. By compiling the results from HAI and HRI, it becomes evident that differences in mimicking responses point to differences in salience between real human faces and virtual faces, and between physically co-present agents and video-recorded ones. However, to the best of our knowledge, *no research has studied facial mimicry covering the four types of embodiment described by Philip et al.* [31] *and Hofree et al.* [20], namely a video-recording of a human, a physical robot, a video-recording of the physical robot, and a virtual agent. Moreover, *no study has verified the salience of humanlikeness for facial mimicry within these embodiments.*

Influence of Empathy Traits on Facial Mimicry. A non-negligible feature of facial mimicry is its relationship with emotion recognition and emotional contagion, which are respectively linked to cognitive empathy (i.e., the ability to infer the mental states of others [3]) and emotional empathy (i.e., a person's response to another person's emotional state [13]). Niedenthal et al. (2010) theorized that facial mimicry is the embodied motor simulation of an observed emotion that serves the purpose of emotion recognition [29], a theory that has been proven only for ambiguous, subtle facial expressions [15]. Regarding emotional contagion, there is extant evidence that facial mimicry elicits congruent emotional experiences. Dimberg (1988) found that people exposed to happy faces show congruent mimicry and also report an increased experience of happiness [9].

Facial mimicry is not only connected with emotion recognition and emotional contagion, but is also influenced by people's empathy traits. Sonnby-Borgström et al. (2003) found out that subjects high in empathy show mimicry responses to facial expressions of happiness and anger already at an automatic level of information processing (56 ms), while subjects low in empathy do not, even at a more controlled level of information processing (2350 ms). Moreover, Drimalla et al. (2019) and Rymarczyk et al. (2019) found a strong positive association between people's scores of emotional empathy and their level of facial mimicry, both for positive [12] and negative emotions [35]. In spite of the strong tie between empathy and human-human mimicry, *the influence of empathy traits on human-agent and human-robot mimicry has, to our knowledge, never been studied. Hence, it is still to discover whether empathy traits influence facial mimicry both in interactions with virtual agents and with physical robots.*

Influence of Personality Traits on Facial Mimicry. Personality is an individual trait that has been found to strongly correlate with (and sometimes even predict) rapport in HAI and HRI, but whose connection with facial mimicry is understudied. Cerekovic et al. (2016) revealed that people who score high in extraversion and agreeableness report higher rapport with virtual agents [5]. Along this line, Rosenthal-von der Pütten et al. (2010) found participants high in extraversion to be more talkative during interactions with a virtual agent and participants high in agreeableness to report more positive emotions after the interaction [34]. This result was confirmed by Ivaldi et al. (2016) in the context of HRI [24]. Although facial mimicry serves a social affiliative function that is strictly connected with rapport building, the extent to which facial mimicry is affected by personality traits is unknown. The literature on human-human mimicry overlooked the importance of personality traits in healthy subjects. Similarly, HAI and HRI never studied the link between personality traits and facial mimicry. In fact, *it is yet to discover whether the same personality traits that predict rapport in HAI and HRI, namely extraversion and agreeableness, predict facial mimicry towards human, virtual, and robotic agents.*

3 Research Questions

To study facial mimicry, we employed all embodiments described by Philip et al. (2018) [31] and Hofree et al. (2014) [20]: a video-recorded human, a physical robot, a video-recorded physical robot, and a virtual agent. Furthermore, to verify the salience of humanlikeness for facial mimicry, we varied the appearance of the artificial agents and made them humanlike, characterlike, or a morph between the humanlike and the characterlike. This manipulation served to answer the following research question: **(RQ1)** *Does the humanlikeness and embodiment of an agent affect the mimicking responses of participants?*

In order to disclose whether a tie between facial mimicry and individual traits exists not just in HHI, but also in HAI and HRI, we assessed participants' empathy and personality traits at the beginning of the experimental session, and correlated them with their mimicking responses. This way, we could answer a further research question: **(RQ2)** *Are empathy and personality traits correlated with participants' mimicry? Do these correlations differ across embodiments?*

4 Method and Material

We chose a mixed experimental design with two independent variables: (1) *type of embodiment* (within-subject) with four levels: a physical robot, a video-recording of the physical robot, a virtual agent, and a human video (Fig. 1 (a)) and (2) *level of humanlikeness* (between-subject) with three levels: characterlike, humanlike, and morph (Fig. 1 (b)). Participants were randomly assigned to one level of humanlikeness and observed the humanlike, characterlike, or morph agent displaying facial expressions of the six basic emotions [14] in each embodiment. While the artificial agents varied in terms of humanlikeness, the video-recorded

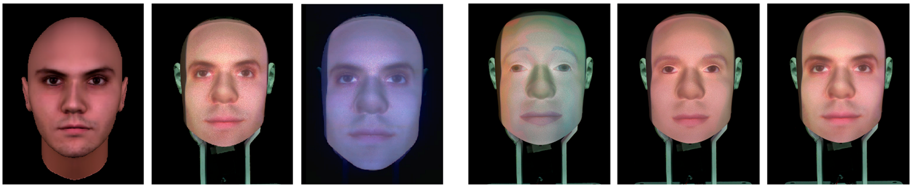

Fig. 1. (a) Embodiments left to right - virtual agent, physical robot, video-recorded robot; (b) facial textures left to right - characterlike, morph, humanlike agent.

human was the same across conditions. The emotional expressions were presented twice for each embodiment in randomized order. The order of presentation of the embodiments was randomized with a Latin Squares technique.

4.1 Participants

Forty-six participants were recruited from a study program at Uppsala University to take part in the study. We excluded two participants due to occlusions in their video recordings and technical issues. The final sample of participants was composed of 44 people (10 female; M = 26.39, SD = 4.31) randomly divided into the three conditions representing the levels of humanlikeness: characterlike (N = 15; 4 female; M = 25.00, SD = 4.09), humanlike (N = 14; 3 female; age M = 26.36, SD = 2.98) and morph (N = 15; 3 female; age M = 27.80, SD = 5.28). None of the participants had previously interacted with the Furhat robot.

4.2 Embodiment and Synthesis of Facial Expressions

The experiment was conducted using three artificial embodiments (Fig. 1) and a video-recording of a human subject. For the physically co-present robot, we chose Furhat as a robotic platform [2]. Furhat is a blended embodiment consisting of a rigid mask on which a facial texture is projected from within.

We designed three facial textures to apply to both the virtual agent and the Furhat robot. The humanlike texture was based on a picture of a real human face (Fig. 1 (b) right). The characterlike texture was Furhat's default facial texture with sketched eyebrows, lips, and eyes (Fig. 1 (b) left). The morph texture was created by blending the humanlike and characterlike textures (Fig. 1 (b) center). The video of the human subject was taken from the MUG database [1].

The human subject in the MUG database was video-recorded while performing the six basic emotions by moving the specific AUs described by Ekman [16]. His facial dynamics were used as reference to synthesize the dynamics of facial expressions for the artificial agents. A researcher trained in the Facial Action Coding System (FACS) remodelled the dynamics of the human expressions as closely as possible by using the facial animation tool provided by the IrisTK framework [36]. Since the IrisTK gesture editor did not allow to control all AUs separately, the facial expressions displayed by the artificial agents and by the human agent were slightly different. However, an online study conducted on Amazon Mechanical Turk revealed no systematic difference in emotion recognition between the artificial and human stimuli.

4.3 Measures

During the experiment, participants were recorded with two LOGITECH C920 HD PRO webcams (30 fps), one positioned on their side, the other in front of them (focusing on their face). We collected questionnaires at four different points in time during the experiment. The first questionnaire (Q1) was filled out at the beginning of the experiment. It included a demographic questionnaire (10 questions), the short version of the *Big Five Personality Traits* [33] (sub-scales: Extraversion, Agreeableness, Conscientiousness, Emotional Stability, and Openness to Experience), and the *Interpersonal Reactivity Index* (IRI, sub-scales: Fantasy, Empathic Concern, and Perspective-Taking [7]). The second questionnaire (Q2) was completed after each facial expression and was meant to assess whether participants correctly recognized the observed emotion and how confident they were about the selected emotion. The third questionnaire (Q3) was filled out after each embodiment to measure participant's perception of the agents. It was composed of excerpts of the *Godspeed questionnaire* [4], the *Social presence* questionnaire [17], and the *Uncanniness* questionnaire [32]. At the end of the session, the experimenter carried out a short semi-structured interview with the participants (Q4). This paper is part of a larger research project. In it, we focus on Q1 and leave aside Q2, Q3 and Q4. These latter questionnaires are used to answer a different set of research questions.

4.4 Experimental Set-Up and Procedure

The experiment was carried out in a laboratory at Uppsala University (Sweden). The area where the experiment took place was separated from the rest of the laboratory by a curtain. Participants were seated at a table 100 cm from the Furhat robot or from the monitor displaying the agent. The size of the agents on the screen was adjusted to match the size of the Furhat robot.

Upon arrival of the participant, the experimenter explained the study procedure. Subsequently, s/he asked the participant to read and sign the consent form. Participants then filled out Q1 on the iPad. After that, they were told that their task was to watch the facial expressions performed by the agents, which lasted each 5 s, and indicate which emotion they observed by filling out Q2 on an iPad. Once Q2 was completed, the next facial expression was automatically generated after 2 s. This procedure was repeated until all six emotional expressions were displayed twice for the same embodiment. Once participants completed an embodiment, they filled out Q3. At the end of the session, the experimenter interviewed the participants following Q4 and debriefed them.

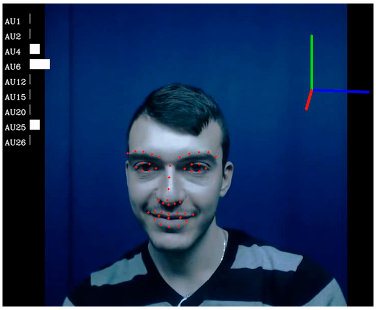

Fig. 2. A facial expression analyzed with the AU intensity detector.

Table 1. AUs extracted for each emotion.

Emotion	Action Units (AUs)
Anger	AU4
Disgust	AU4 + AU25
Fear	AU20, AU1 + AU2 + AU4
Happiness	AU6, AU12, AU6 + AU12
Sadness	AU1, AU15, AU1 + AU4
Surprise	AU26, AU1 + AU2

5 Analysis of Facial Mimicry

We considered two time intervals for facial mimicry: 0–1000 and 1000–5000 ms. The first is based on Moody et al. (2007) [28] and Dimberg and Thunberg (1998) [10]. It refers to quick mimicry responses (also called Rapid Facial Reactions; RFR) that occur at a subperceptual level [11]. The second takes into account a more controlled level of processing, at which mimicry responses can be considered conscious [37]. We call these reactions Controlled Facial Reactions (CFR).

To properly cut and automatically analyze the videos in correspondence of each emotional expression of the agent, we manually segmented each video using ELAN 5.4. In case the face of the participant was occluded, we coded it as missing. Each video snippet was then processed with an AU intensity detector (Fig. 2) [22]. This tool detects the activation and intensity of nine AUs, namely AU1, AU2, AU4, AU6, AU12, AU15, AU20, AU25, and AU26, with an overall Intraclass Correlation Coefficient $ICC(3,1)$ of 0.73, which is within state-of-the-art performance. We performed a frame-by-frame detection of the intensity of each AU on all snippets. In order to consider an emotion mimicked at a given time interval, we checked whether the target AU or combination of AUs (see Table 1) was active for at least 3 consecutive frames (100 ms). Ito et al. (2004) define this as the shortest duration of a facial expression [23]. As the AU intensity detector was not able to detect the AU activation for some of the snippets (RFR = 142; CFR = 86), we excluded them from the final analyses. The final mimicry score for each participant and time interval was then calculated as the percentage of mimicked emotions per embodiment given the available video snippets. This calculation was performed only if we had 6 or more valid snippets. Our dataset thus featured 21 missing values for RFR (12.3%) and 16 for CFR (9.4%).

6 Results

6.1 RQ1: Salience of Humanlikeness

We performed a factorial ANOVA with *level of humanlikeness* as between-subject factor and *type of embodiment* as within-subject factor. Results showed that the level of humanlikeness of the agents did not affect frequency of mimicry for RFR ($F(2, 28) = .888, p = .423$) and CFR ($F(2, 31) = .345, p = .771$). However, the embodiment of the agents did affect frequency of mimicry both for RFR ($F(3, 26) = 5.565, p = .001$), and CFR ($F(3, 29) = 5.800, p = .003$). Post-hoc analyses with a Bonferroni correction revealed a significant difference in frequency of mimicry for RFR between the virtual agent ($M = .559$, $SD = .161$) and the video-recording of the robot ($M = .669$, $SD = .150$, $p = .005$), and between the physical robot ($M = .550$, $SD = .173$) and the video-recorded one ($p = .006$). With regards to mimicry for CFR, they showed a significant difference in frequency of mimicry between the physical robot ($M = .669$, $SD = .204$) and the human ($M = .780$, $SD = .157$, $p = .001$).

6.2 RQ2: Patterns of Correlation Between Individual Traits and Facial Mimicry (Overall and per Embodiment)

As a first step, we ran a Pearson Product-Moment Correlation (two-tailed) between personality and empathy traits and frequency of mimicry for RFR and CFR considering all embodiments (see Table 2). The results showed a significant positive correlation between frequency of mimicry for RFR and the personality traits *agreeableness* ($r(148) = .210$, $p = .010$), *openness to experience* ($r(148) = .171$, $p = .036$) and *fantasy* ($r(148) = .305$, $p < .001$), and between frequency of mimicry for CFR and *extraversion* ($r(153) = .169$, $p = .035$), *openness to experience* ($r(153) = .274$, $p = .001$), and *fantasy* ($r(153) = .310$, $p < .001$).

To find correlation more specific to each embodiment, we performed a Pearson Product-Moment correlation separately for the video-recorded human, the physical robot, the video-recorded robot, and the virtual agent (see Table 2). For the video-recorded human, we found a significant positive correlation between frequency of mimicry for RFR and *agreeableness* ($r(33) = .424$, $p = .011$) and *fantasy* ($r(33) = .413$, $p = .014$), and a significant positive correlation between frequency of mimicry for CFR and *fantasy* ($r(36) = .331$, $p = .043$). While the same analysis did not yield any significant result for the physical robot, it showed a significant positive correlation between frequency of mimicry for RFR and *fantasy* ($r(37) = .434$, $p = .006$), and a significant positive correlation between frequency of mimicry for CFR and *openness to experience* ($r(39) = .410$, $p = .008$) and *fantasy* ($r(39) = .383$, $p = .014$) for the video-recorded robot. Moreover, it disclosed a significant positive correlation between frequency of mimicry for RFR and *empathic concern* ($r(37) = .349$, $p = .030$), and between frequency of mimicry for CFR and *openness to experience* ($r(36) = .349$, $p = .032$) and *fantasy* ($r(36) = .366$, $p = .024$) for the virtual agent.

7 Discussion

RQ1. *Embodiment, But Not Humanlikeness, Affected Facial Mimicry.* The studies of Hofree et al. (2014) and Philip et al. (2018) seemed to suggest that humanlikeness could be the most salient feature for mimicry. However, in our study, we did not find a main effect of humanlikeness on facial mimicry. As Hofree et al. (2014) and Philip et al. (2018) focused on highly realistic android

Table 2. Summary of Significant Correlations

CORRELATIONS		
EMBODIMENT	RFR	CFR
All Embodiments	A(+) O(+) F(+)	E(+) O(+) F(+)
Human Video	A(+) F(+)	F(+)
Physical Robot	none	none
Robot Video	F(+)	O(+) F(+)
Virtual Agent	EC(+)	O(+) F(+)

O: Openness to Experience, **C**: Conscientiousness,
E: Extraversion, **A**: Agreeableness, **N**: Neuroticism;
F: Fantasy, **EC**: Empathic Concern, **PT**: Perspective Taking

robots and real human agents in their studies, the lack of a significant effect of humanlikeness in our study might point to the salience of "realism", rather than anthropomorphism for the sake of mimicry. Future studies should tackle this hypothesis by testing whether differences in facial mimicry occur between humanlike agents varying in their degree of realism.

With regards to embodiment, our results are not aligned with the extant literature either. In stark contrast with Hofree et al. (2014) [20], who found people to mimic an android robot when physically co-present but not when video-recorded, we found participants to mimic the video-recorded robot more than its physically co-present counterpart. This result might be due to the task at hand, where the physical instantiation of the robot could distract participants from the end goal of emotion recognition. Finally, we discovered that the physically co-present robot was mimicked significantly less than the video-recorded human for CFR. However, when comparing the video-recording of the human and the video-recording of the robot, which have the same level of co-presence, we did not find a significant difference in terms of mimicry both for RFR and CFR. This is a novel and interesting result, which seems to point to similarities between HHI and HRI in terms of mimicry, especially when co-presence is kept constant.

RQ2. ***Personality and Empathy Traits were Correlated with Participants' Mimicking Responses and the Patterns of Correlations Differed Across Agents' Embodiments for RFR.*** When taking into account all embodiments, we found agreeableness and extraversion to positively correlate with mimicry, respectively for RFR and CFR. This result is in line with the related work on the relationship between personality traits and rapport [5,34] and substantiates our hypothesis of a connection between facial mimicry and rapport. We also found a positive correlation between facial mimicry and openness to experience and fantasy, both for RFR and CFR. Fantasy is the ability to imaginatively transpose oneself into the feelings and actions of fictitious characters. Openness to experience refers to people high in imagination, curiosity, and artistry. Although openness to experience is a personality trait, in this study, it seems to be core to cognitive empathy (the ability to infer the mental states of others [3]), as much as fantasy. The key role of fantasy and openness to experience for the sake of mimicry might be due to the task the participants were asked to carry out and might indicate a relationship between mimicry and emotion recognition.

By observing the correlations for the single embodiments, what catches the attention is the lack of significant correlations between individual traits and facial mimicry for the physical robot. As already suggested, the physical presence of the robot might have been perceived as an obstacle to emotion recognition. We hypothesize that this concealed the relations between individual traits and facial mimicry for this specific embodiment. Beyond this result, or lack thereof, we can find three clearcut patterns of correlation between facial mimicry and individual traits for RFR corresponding to the three embodiments: video-recorded human, video-recorded robot, and virtual agent. These patterns of correlation become more blurred when moving to CFR. In general, it seems that traits denoting sociability and sympathy, such as agreeableness and empathic concern, are meaningful for mimicry, but at less controlled levels of emotion processing and when it comes to more familiar agents (e.g., the human and the virtual agent). However, at more controlled levels of emotion processing, individual traits denoting identification with others and imagination, such as fantasy and openness to experience, become more crucial for the sake of mimicry, regardless of the familiarity with the agent. This seems to suggest that in this study mimicry is initially modulated by a social drive that gets lost in favor of cognitive empathy at later stages of processing, probably because the objective of the emotion recognition task kicks in. To further support this, it is interesting to note that the significant correlation between the most socially-charged personality trait, extraversion, and mimicry is lost when taking into account CFR for the single embodiments. In future work, it would be interesting to compare our task-based findings to mimicry in a more social context and to specifically take the gender of participants and the genderlikeness of the robot into consideration.

8 Conclusions

In this paper, we presented the results of a study exploring the relationship between individual traits and facial mimicry towards human, virtual, and robotic agents. Results showed that an agent's embodiment, but not its level of human-likeness, influences facial mimicry and that mimicry is correlated with personality and empathy traits key to both rapport building and cognitive empathy. When analyzing the patterns of correlation for the single embodiments, we noticed that the individual traits correlating with facial mimicry denoted sociability and sympathy at early stages of emotion processing, and identification with others and imagination at later stages. This change in significance might be due to the emotion recognition task participants were asked to perform. Future research should study the relation between individual traits and mimicry in real interactions and with larger samples to check whether these findings still hold.

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