The Role of Empathic Traits in Emotion Recognition and Emotion Contagion of Cozmo Robots

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***Abstract*— In this online study, we investigated how well people could recognize emotions displayed by video recordings of a Cozmo robot, and the extent to which emotion recognition is shaped by individuals' empathic traits. We also explored whether participants who report more empathic tendencies experienced more emotional contagion when watching Cozmo's emotional displays, since emotion contagion is a core aspect of empathy. We tested participants' perceptions of Cozmo's happiness, anger, sadness, surprise, and neutral displays. Across 103 participants, we report high recognition rates for most emotion categories except neutral animations. Furthermore, the mixed effects modelling revealed that an empathy subtype (the empathic concern subscale from the Interpersonal Reactivity Index) significantly impacted emotional contagion. Contrary to predictions, participants with high empathic concern subscale scores were less likely to find the robot's videos emotionally contagious. The study validates the utility of Cozmo robots to display emotional cues recognizable to human users, and further suggests that empathic traits could shape our affective interactions with robots, though perhaps in a counterintuitive way.**

Keywords*— *Human–robot interaction, Dispositional empathy, Emotion recognition, Emotion contagion

I. Introduction

Accurate recognition of others' emotional cues is a crucial factor that contributes to effective and smooth interpersonal interactions [1]–[3]. Similarly in human—robot interaction (HRI), the capacities for social robots to display appropriate and recognizable emotion cues can be conducive for forming meaningful and socially sophisticated relationships with users [4], [5]. On the other hand, emotion recognition abilities for people to recognize robots' emotional cues might differ by individuals, by robotic platforms, and by emotion types [6]. The current psychology literature has well documented the individual differences in recognizing human facial expressions [1], [7]. In particular, individual differences in empathic traits have been linked with differential performances in emotion recognition. For example, empathic people have been found to perform better in facial expression recognition tasks [8]; emotional empathy (i.e., the ability to feel the emotions others experience) is related to better recognition of facial expressions within a short period of time [7]; and people with autism spectrum conditions who have difficulties with emotion recognition tasks also record low scores in self-report empathy scales [9], [10]. Given the relationship between empathic traits and people's recognition abilities for human emotional expressions, it is important to examine whether similar links exist between dispositional empathy and accurate recognition of robots' emotional displays. Current evidence has suggested that people could correctly recognize about 50% to 60% of embodied robots' emotional displays (based on 43 HRI studies reviewed in [25]), the research here could help explain the individual differences in emotion recognition of robots and set the foundations of bespoke social robots based on users' personality traits.

Empathy, as a multidimensional construct, refers to not only a person's ability to cognitively understand others' perspectives, but also the tendencies of being affectively connected to another person's inner experience [11]. The affective component of empathy is therefore associated with emotional contagion, which is a phenomenon that occurs when we automatically synchronize our own emotional states with others' [12], [13]. Previous studies have found that highly empathic people are more likely to experience emotions from non-human targets like art [14] and music [15]. It is therefore of interest to determine whether people's baseline empathic tendencies might also make them more likely to experience vicarious feelings from robots' emotional displays.

In this study, we used Cozmo entertainment robots (manufactured by Anki Inc., Fig. 1) as the robotic platform to display emotional expressions. Cozmo's affordability, portability and programming flexibility has made this robot a suitable tool for HRI research [16], [17]. Consequently, a better understanding of people's emotion recognition of Cozmo's simple emotional displays stands to benefit future studies aiming to investigate embodied robots' display of human readable emotions. Additionally, the current research could help bridge the gap between psychology and HRI research by raising awareness of a personal factor – empathic traits – in social and affective interactions with robots. Based on psychological evidence [5,16,24,29], we predicted that people who reported

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high empathic traits could more accurately recognize Cozmo's emotional displays, and would be more likely to feel the vicarious feelings from the robot's emotional expressions.

II. Methods

We devised an online experiment via formR [18] to explore the relationships between people's empathic traits and emotion recognition and emotion contagion of the Cozmo robot's emotional displays. The online experiment involved three sections: (1) participants filled out the Interpersonal Reactivity Index (IRI) [19] as a measure of their empathic traits; (2) they watched and rated a series of videos showing Cozmo's different emotional displays (each approximately 10 seconds long) (Fig. 1); (3) they answered demographic questions of their age and gender. The details of the first two sections are explained below.

A. Empathy Measures

The Interpersonal Reactivity Index (IRI) is a widely used empathic trait measure from the psychological literature [7], [19]. The IRI involves four subscales: *perspective taking, fantasy, empathic concern,* and *personal distress*. *Perspective taking (PT)* focuses on the cognitive component of empathy, which is the readiness to see things from others' points of view. *Fantasy (FT)* scale measures whether people tend to imagine themselves as characters in novels or movies, and how easily they become emotionally engage with fictional characters. *Empathic concern (EC)*, ascribed to emotional aspect of empathy, is about how often people experience feelings of others' sufferings. Lastly, *personal distress (PD)* subscale assesses whether observing others' misfortunes usually results in their own anguish. Each subscale contains seven items and items are rated on a five-point Likert scale from 0 (does not describe me well) to 4 (describes me very well).

B. Cozmo Emotion Rating Task

Three experimenters watched all 348 Cozmo animations from the Github repository – https://github.com/cozmo4hri/animations [16]– and independently categorized these animations based on the emotion types perceived by individual experimenters. The final set of animations comprised videos that all three experimenters consistently assigned to the same emotion categories. These emotion categories included happy (animation numbers: 92, 94, 100, 193), angry (73, 74, 136, 137), sad (63, 134, 152, 190), surprising (24, 65, 91, 200), and neutral (25, 99, 160, 208) emotions. In the emotion rating session (Fig. 1), participants watched a video of Cozmo displaying a specific emotion type (around 10 seconds long) and answered what they recognized from the video: "neutral", "happy", "sad", "angry", "surprise", "other" (with a text space for more details), or "I don't know". Furthermore, participants also reported their subjective feeling(s) after watching each video, using the same options provided. The first question was a measure of participants'

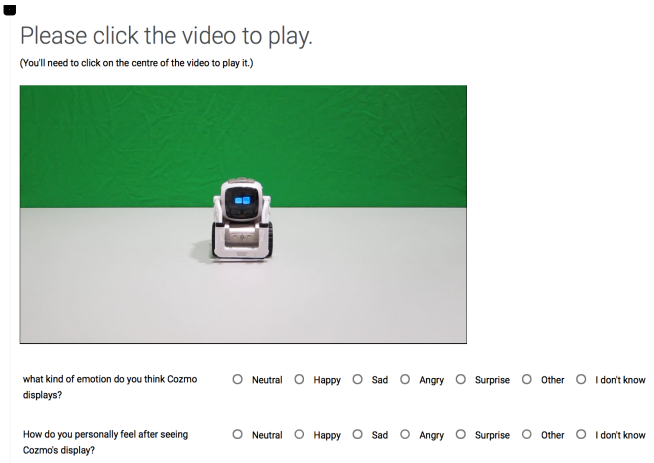

Fig. 1. Screenshot of the online emotion rating task. Participants would report the emotion(s) they recognized from a short video of Cozmo's emotional displays and also the feeling(s) they experienced after watching the video.

emotion recognition accuracy (i.e., that the emotion a person recognized from a Cozmo's video was in line with the emotion the experimenters intended the robot to display). The second question about their personal feelings was to know whether participants' emotional states were influenced by Cozmo's emotional displays (emotion contagion). Participants rated a total of 20 videos (four videos for each category and five emotion categories) and video order was randomized across participants.

III. Results

We report the relevant research materials, anonymous data, and analysis codes on the Open Science Framework (OSF) project page – https://osf.io/p49jv/ – following open science initiatives [20]. All analyses were done with R v4.0.1 [21]. In total, one hundred and three valid samples (average age = 32.3 years old; 43 females, 57 males, one non-binary, and 2 preferring not to report) were collected for the online experiment.

A. Emotion Recognition and Subjective Feelings for Cozmo's emotional displays

We calculated the recognition rates of Cozmo's five emotions and the report rates of subjective feelings after watching the robot's videos (Fig. 2). The emotion type most accurately and consistently recognized by participants was Cozmo's anger (mean recognition rate = 78.40%), followed by Cozmo's sadness (recognition rate = 69.18%), happiness (recognition rate = 62.38%), and surprise (recognition rate = 63.35%). For neutral animations, participants' recognition was less in consensus. On average, only 19.42% of participants perceived the neutral videos as neutral. 18.2% of them reported "I don't know" and 17.48% of participants classified them as "happy".

As for participants' subjective feelings after watching Cozmo's different emotional displays, happy and sad animations were the emotion categories that showed stronger effects of emotional contagion. 46.60% of participants felt happy after the robot's happy displays and 50.49% of them felt sad after the robot's sad displays. For angry, surprising, and neutral videos, participants mostly felt neutral after watching

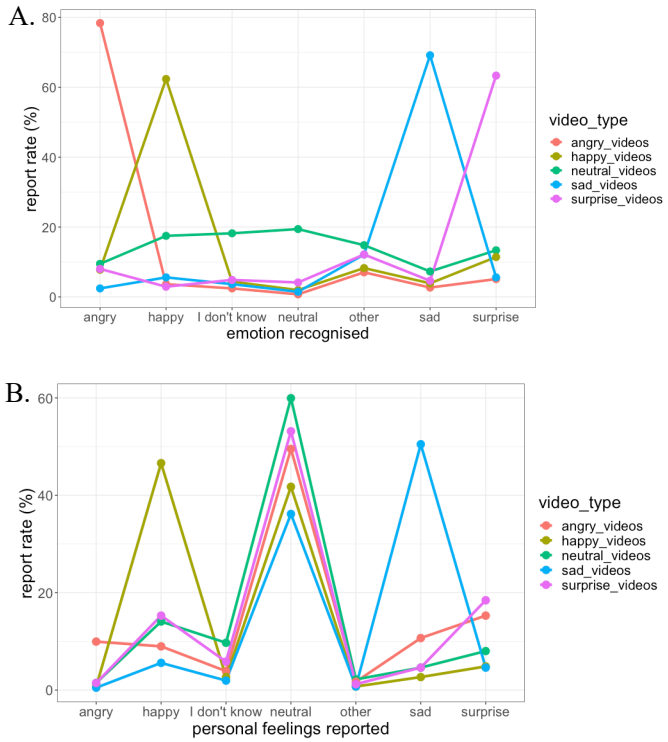

Fig. 2. (A) Recognition rates of Cozmo's emotional displays. (B) Participants' report rates of their subjective feelings after watching the robot's animation videos.

them: 49.52% of them felt neutral after the robot's angry displays (compared to only 9.95% of them feeling angry); 53.16% of them felt neutral after surprising displays (compared to 18.45% of them feeling surprised); 59.95% of them felt neutral after watching neutral displays.

B. Dispositional Empathy and Emotion Recognition of Cozmo

We calculated the mean scores of participants' IRI reports (M = 2.55, SD = 0.43; on a 5-point Likert scale from 0 to 4) and the means of their IRI subscale scores (perspective taking: M = 2.77, SD = 0.7; fantasy: M = 2.66, SD = 0.75; empathic concern: M = 2.98, SD = 0.66; personal distress: M = 1.77, SD = 0.88). Reliability analysis revealed that *Cronbach's alpha* for IRI is .76. We then analyzed the correlations between IRI scores and emotion recognition rates (Fig. 3). None of the Pearson's correlation coefficients between variables was significant. Overall, the relationship between emotion recognition of all emotions and IRI scores was r = -0.14, p = .150.

C. The Influence of Dispositional Empathy on Emotion Recognition and Emotion Contagion

*1) **The Influence of Dispositional Empathy on Emotion Recognition.***

We ran a generalized linear mixed effects model with the lme4 package (v1.1.23) [22] to examine the impact of empathic traits on participants' trial-by-trial emotion recognition (correctly recognizing an emotional display was coded as 1; incorrectly recognizing a display was 0). In the model, we had

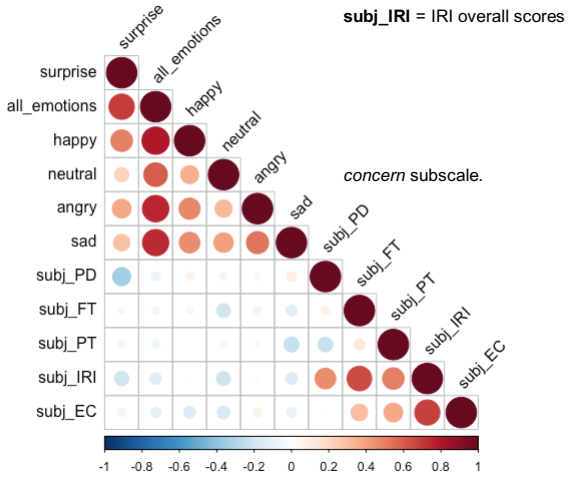

Fig. 3. Correlations between emotion recognition and IRI scores. Redder and bigger dots represent stronger positive correlations, and the bluer and bigger dots show stronger negative correlations.

IRI overall scores as the fixed factor, emotion recognition accuracy as the binary dependent variable, and controlled subject-level and trial-level random effects. In the result, the effect of empathic traits was non-significant on trial-by-trial recognition, β = -0.46, *95% CI* [-1.02, 0.11], p = .116. Considering previous evidence showing that empathy subtypes could differentially impact recognition of human facial expressions [7], we conducted another generalized linear mixed effects model with the four IRI subscales (*PT, PD, FT, EC*) as fixed factors while the rest of model design remained the same. The results showed that none of the subscales significantly impacted emotion recognition: *perspective taking (PT)* — β = -0.10, *95% CI* [-0.47, 0.27], p = .604; *personal distress (PD)* — β = -0.14, *95% CI* [-0.42, 0.14], p = .315; *fantasy (FT)* — β = -0.04, *95% CI* [-0.38, 0.29], p = .795; *empathic concern (EC)* — β = -0.17, *95% CI* [-0.58, 0.23], p = .402.

*2) **The Influence of Dispositional Empathy on Emotion Contagion.***

To investigate the influence of empathic traits on emotion contagion of Cozmo's expressions, we conducted a generalized linear mixed effects model, with IRI scores as the fixed factor, emotion contagion as the binary dependent variable (if what they felt was the same as what they recognized from the videos, it was coded as 1; otherwise it was 0). We controlled subject-level and trial-level random intercepts. We did not find a significant effect from subjects' IRI overall scores, β = -0.10, *95% CI* [-0.65, 0.44], p = .711. Again, we explored whether the four IRI subscales had differential influences on emotion contagion, and ran another model with the four subscales as the fixed factors while keeping the rest of the model design the same. We found a significant effect of *empathic concern (EC)* subscale (β = -0.40, *95% CI* [-0.78, -0.01], p = .042), but the other three subscales were non-significant (*PT*: β = 0.009, *95% CI* [-0.34, 0.36], p = .957; *PD*: β = 0.02, *95% CI* [-0.25, 0.28], p = .909; *FT*: β = 0.26, *95% CI* [-0.06, 0.58], p = .113). The effects of the four IRI subscales were visualised with the R package "effects" (v4.1.4) [23] in Fig. 4.

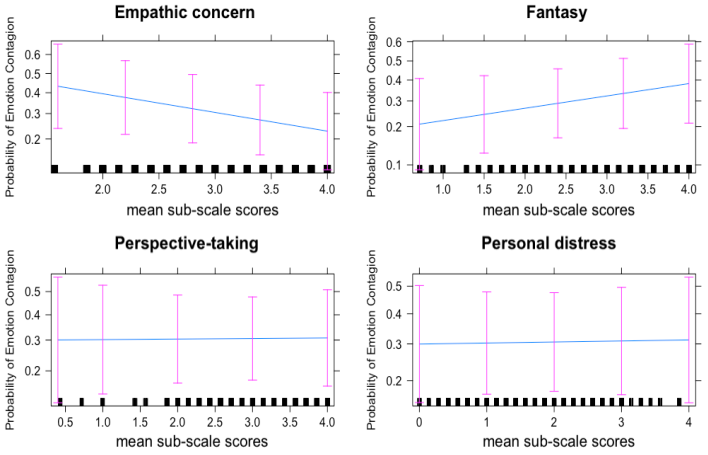

Fig. 4. The effects of the four empathy subtypes (IRI subscales) on emotion contagion participants experienced after watching the Cozmo's emotional expressions in videos. Only the "empathic concern" subscale was found to significantly predict emotion contagion. The items of these subscales were all rated on a five-point Likert scale from 0 (does not describe me well) to 4 (describes me very well). The effect plot was generated with the R package "effects" (v4.1.4) [23].

IV. Discussion

We designed an online experiment to investigate people's emotion recognition of a Cozmo robot's emotional expressions and whether such emotion recognition is shaped by individuals' dispositional empathic traits (measured by the IRI [19]). We also explored the extent to which participants' affective states might synchronize with the robot after watching the robot's emotional displays, which is known as emotion contagion — an important aspect of empathy. We expected more empathic participants to more accurately recognize the robot's emotional displays and also to report the displays more emotionally contagious. Below we consider our findings in detail.

First, the emotions participants recognized from Cozmo's videos were generally in line with the experimenters' predictions, except for the neutral videos. Contrary to human emotion recognition evidence suggesting that happiness is the most easily recognized emotion [24] and usually shows high agreement rates among testing samples [1], our results show that participants most consistently recognized Cozmo's anger. Moreover, as we compared the current emotion recognition rates with the mean recognition rates of 43 previous HRI studies reviewed in Stock-Homburg's paper [6], we found that Cozmo's anger (recognition rate = 78.40%), sadness (recognition rate = 69.18%), and happiness (recognition rate = 62.38%) performed better than the literature's average recognition rates of robotic emotions displayed by both facial and bodily expressions (anger: 56.77%; sadness: 55.95%; happiness: 62.09%; [25]). However, Cozmo's surprise (recognition rate = 63.35%) performed worse than the average of the literature (76.08%). The findings validate that, even in the context of online experiment, Cozmo is capable of displaying perceivable and recognizable emotion animations. It is also worth noting that participants recognized various different emotions – such as happiness, surprise, curiosity, fear – from the videos we regarded as neutral. The diverse responses we received for the neutral stimuli point to Kuleshov effect, which proposes that people evaluate the emotion of a neutral face by contextual cues (such as the emotional stimuli preceding the face) [25], [26]. Consequently, researchers who wish to manipulate a robot to be neutral in expression (e.g., in a control condition) should be aware of the potential Kuleshov effect, especially in online experiments where we have less control over participants' environments.

Second, we explored the influence of empathic traits on emotion recognition and emotion contagion effects by mixed effects models. None of the empathy variables – neither the overall IRI scores nor the scores of IRI subscales – significantly impacted recognition of Cozmo's emotional displays. However, when we looked into the relationship between empathic traits and emotion contagion, we found a significant effect from the *empathic concern (EC)* subscale of IRI. Surprisingly, people who scored higher on this subscale were *less* likely to report the same feeling as what they had just recognized from Cozmo's display. Although the result confirms that empathy subtypes could have unique links with emotional processes like emotion recognition [7] and facial mimicry [27], we urge replication of this finding before attempting to explain why the relationship was counter to our prediction. It is worth reiterating that IRI is a scale to measure individuals' empathy toward other people (not robots), and it might thus not be a suitable or precise measure for this research question. Further research is needed to clarify this and to gain insights into the mechanism(s) underpinning emotion contagion effects of robots and influence of personal empathy traits.

Some limitations to our approach require addressing. First, our current investigation of Cozmo's emotional displays was done via online experiments. It would be valuable for future work to deploy an embodied Cozmo robot to determine the extent to which emotion recognition in embodied emotion displays matches what we report here for video displays, since physical embodiment crucially shapes real-life HRI [28]–[30]. Second, the current stimulus selection was based on three experimenters' subjective choices, which could be biased by individual idiosyncrasies related to emotion perception. Therefore, the animation set selected here might not necessarily be the best or most representative emotional stimuli available for Cozmo to display the five emotion types researched in the study. The present study aimed to provide preliminary evidence and an example of how people perceive a small set of Cozmo's emotional displays and whether such emotion perception is related to their empathic traits. Future research could extend the exploration to a bigger set of the robot's repertoire (such as in [16]). Finally, researchers could explore additional emotion categories for Cozmo, to test the extent to which this particular social robotic platform can reliably display an even more diverse range of emotional cues.

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