Emotional Inference through Ambiguous Robot Gestures

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***Abstract*—Understanding how users interpret emotional cues from social robots, especially when ambiguous, is crucial. This study investigated if positive emotional priming influences the perception of a robot's ambiguous behaviors, applying mood-congruent perception theories. Eight participants were primed with a happy video then interacted with a Nao robot using ambiguous gestures and vocal tones during a story. Post-interaction, participants completed questionnaires on the robot's perceived emotions and their own emotional states. While participants reported moderately positive moods (M = 4.88), their interpretation of the robot's emotions leaned toward neutrality (M = 2.38 on a 1–7 happy-neutral scale). The robot was perceived as more neutral (M = 5.00) than happy (M = 3.25). Qualitative feedback showed mixed clarity in the robot's gestures. Findings suggest happy priming did not strongly bias participants towards interpreting the robot's ambiguous behaviors as positive, with the robot's neutral expressivity dominating perceptions. This indicates potential limits to mood-congruent effects in human-robot interaction and emphasizes the need for clearer emotional signaling in robot design**

***Index Terms*—Social Robots, Emotional Priming, Ambiguous Behaviors, Human-robot Interaction**

I. Introduction

Robots are increasingly integrated into everyday human environments, ranging from domestic households to healthcare settings [8]. As their roles become more social, users are expected not only to interact with them functionally but also to interpret their emotional cues [8]. However, current social robots often lack consistent and clear emotional expressivity, leading to challenges in human interpretation of robot behavior [6].

Emotional priming is known to influence how people interpret ambiguous stimuli [10]. Prior research in psychology has shown that a person's mood can bias their perception of facial expressions—for example, the same ambiguous face tends to be seen more positively when the viewer is in a happy state [9]—and can similarly color the interpretation of tone of voice or narrative scenarios.

Applying this to human–robot interaction, it is important to understand how a user's emotional state might alter their perception of a robot's displays, especially when those displays are intentionally ambiguous. This study explores how happy emotional priming affects the interpretation of emotionally ambiguous robot behavior [7]. Specifically, we ask: *To what extent does positive emotional priming influence how participants interpret a robot's ambiguous emotional expressions?*

By focusing on a single priming condition (happiness) and using a robot with intentionally ambiguous tone and gestures, this study aims to isolate the effect of user mood on perception. The findings will provide insights relevant for designing emotionally aware robot interactions.

II. Related Work

A. Communication in HRI

The motivation for equipping robots with natural language and other forms of fluid communication stems from the desire to allow humans to interact with robots in a natural manner, similar to how they interact with other humans. Humans are accustomed to interacting through a mixture of natural language and nonverbal signs, and capitalizing on this existing ability by building robots that don't require humans to adapt significantly makes the interaction more fluid. To address the shortcomings of early systems and guide future research towards more natural and fluid human-robot communication, ten specific desiderata have been proposed by [1]. These desiderata serve as an organizational axis for discussing research in the field.

These desiderata are neither exhaustive nor truly orthogonal, yet they prove to be an excellent way to partition the current SOTA research. For our study we tried to implement the desiderata D3-Mixed initiative dialogue-where the NAO initiated the story and the desiderata D6-Motor correlates and Non-Verbal Communication-for adding the required emotional elements within the story spoken by NAO.

B. Emotion Recognition in HRI

Emotion recognition (ER) is considered a critical capability for enabling fluid and natural human-robot interaction. Emotions are fundamental aspects of human beings, influencing decisions and actions, and emotional intelligence, the ability to understand, use, and manage emotions, is crucial for successful interactions.

The field of emotion in HRI can be viewed from three main perspectives: formalizing the robot's own emotional state, enabling the emotional expression of the robot, and allowing robots to infer the human emotional state. The paper [2] focuses specifically on the third aspect: the ability of robots

to infer and interpret human emotions, reporting on recent advances and future perspectives in this area, particularly within the context of actual HRI with physical robots. Our study incorporated affective displays into a NAO robot. Rather than focusing on methods for the robot to infer the human user's emotional state, this work centered on the robot's ability to convey emotion. The robot's emotional states were predetermined and hardcoded to coincide with specific moments during a storytelling narrative. These pre-programmed emotional displays were implemented through the robot's use of specific body poses and kinematics and variations in its voice.

C. Ambiguous Emotional Expressions

The paper [3] distinguishes between prototypical emotion expressions, defined as consistently recognized by a set of human evaluators, and non-prototypical emotion expressions, which are not consistently recognized but occur naturally in human communication. Integrating techniques like emotional interpolation, profiling, and various hard-labeling methods is expected to lead to more robust and human-like automated emotional classification. Dialogue-level emotion classification can be improved by considering the dynamics of the underlying classification process, not just acoustic features, allowing the system to classify emotion based on emotionally clear data rather than attempting to integrate ambiguous content directly. The paper helped us clearly differentiate between ambiguous gestures portrayed by NAO and the prototypical emotional gestures.

D. Emotional Priming

Emotional priming is defined as the technique of using emotion-related stimuli to affect the user's affective processing. Subliminal emotional stimuli are used to alter moods and trigger particular responses. The paper [4] proposes a novel approach to the role of emotions in storytelling, inspired by emotional priming theory. Instead of emotions acting as a real-time modifier of story output (where storytelling elicits emotions which then adjust the story output), emotional priming can bring about a more active state of mind in preparation for storytelling.

The idea of using videos with a universal happy tone was inspired by this paper as it had proven, with enough evidence that storytelling quality can be improved through subliminal emotional priming.

E. Postures for NAO

The paper [5] focuses on implementing emotional body postures, specifically for anger, sadness, and happiness, on the NAO humanoid robot. The Nao robot is a 58 cm high robot with 25 degrees of freedom, commonly used in social robotics. The approach presented involves adapting postures developed for a virtual human body model to the physical Nao robot. This is based on the idea that emotional behaviours and postures observed in humans can be applied to robots with robot-specific modifications. This study demonstrated that the Nao robot can convey intended emotions through specially adapted postures with a considerable recognition rate among university students.

The gestures implemented in our study was inspired from the NAO gestures used during the above study beacause of similar constrained variables of both of these studies.

III. Methods

This section outlines the design, hypotheses, procedure, and measures employed in the user study investigating emotional inference from ambiguous robot gestures, specifically under the influence of happy emotional priming.

A. Hypothesis

Our study was designed to test the following hypothesis:

H1: Participants exposed to happy emotional priming will infer a significantly more positive (happy) emotion from the Nao robot's ambiguous gestures and consistently ambiguous vocal tone compared to a baseline theoretical neutral interpretation.

B. User Study Design

This study employed a single-group experimental design focusing on the effect of happy emotional priming on the interpretation of ambiguous robot emotional displays.

The experimental setup consisted of two distinct areas:

- **Priming Area**: A viewing station equipped with a monitor and headphones, used for presenting the emotional priming video.
- **Interaction Area**: A dedicated space for the Nao robot interaction, featuring the Nao robot positioned on a stable surface at eye level with a seated participant. This area was designed to minimize distractions.

All participants experienced the same single study condition.

Happy Priming & Ambiguous Robot Tone: All participants watched a video designed to induce a happy mood. Following this, they interacted with the Nao robot, which told a story using a standardized set of ambiguous gestures and a consistently ambiguous vocal tone. There was no varying robot tone or other priming conditions in this study.

C. User Study Procedure

Participants were guided through the study systematically to ensure consistency and adherence to ethical guidelines, particularly concerning the use of deception.

- **Participant Arrival and Initial Consent**: Upon arrival, participants were greeted and led to an initial study space. They were given a deceptive cover story, stating that the study's purpose was to assess how well people can identify emotions displayed by robots. Participants then reviewed and signed a consent form that outlined the general procedures, guaranteed confidentiality, and stated that a full debriefing would occur at the study's conclusion, without revealing the true hypothesis or the emotional priming component.

- **Emotional Priming**: Following initial consent, participants were escorted to the priming area. They were instructed to watch a short video, which was specifically chosen to induce a happy mood and served as the emotional primer.
- **Nao Robot Interaction**: After the video, participants were led to the interaction space where the Nao robot was positioned. The Nao robot then proceeded to tell a pre-programmed story. Throughout the story, Nao performed a standardized set of ambiguous gestures and used a consistently ambiguous vocal tone.
- **Questionnaire Completion**: Immediately after the Nao robot finished its story, participants were moved to a separate, quiet area to complete a questionnaire. This questionnaire included "trick questions" designed to measure their inference of the robot's emotions (e.g., how happy or neutral they perceived the robot to be), as well as "real questions" assessing their own current emotional state (e.g., how happy or neutral they felt).
- **Full Debriefing**: Upon completion of the questionnaire, a comprehensive debriefing session was conducted. The true purpose of the study was fully revealed, explaining the use of deception, the emotional priming technique, and the intentional ambiguity of the robot's gestures and vocal tone.

D. Dependent Measures

The primary dependent measures were collected via a post-interaction questionnaire. This questionnaire was designed to capture both participants' perception of the robot's emotions and their own current emotional state.

Inferred Robot Emotion: Participants' perception of the Nao robot's emotional display during storytelling was assessed through several questions:

- Overall perceived emotional conveyance: "How well do you think the Nao robot conveyed emotion during the story?" on a 7-point scale from "Not at all well" to "Very well".
- Perceived happiness of the robot: "Based on the robot's gestures and voice, how happy do you think the robot was trying to seem while telling the story?" on a 7-point scale from "Not at all happy" to "Very happy"
- Perceived neutrality of the robot: "Based on the robot's gestures and voice, how neutral do you think the robot was trying to seem while telling the story?" on a 7-point scale from "Not at all neutral" to "Very neutral".
- Overall perceived emotion on a happy-neutral continuum: "Overall, on a scale from 1 (Very Neutral) to 7 (Very Happy), where would you place the emotion the robot conveyed during the story?".
- Clarity of emotional expressions: "How clear were the robot's emotional expressions to you?" on a 7-point scale from "Not at all clear" to "Very clear".
- Belief in intentional emotional display: "Do you believe the robot was intentionally trying to show a specific emotion during the story?" on a 7-point scale from "Not at all" to "Very much".
- Qualitative feedback on specific cues: An optional open-ended question asked about "any specific moments or gestures where you felt the robot's emotion was particularly clear or unclear".

Participant's Current Emotional State: Participants' self-reported current feelings were measured:

- Current happiness: "How happy do you feel right now?" on a 7-point scale from "Not at all happy" to "Very happy".
- Current neutrality: "How neutral do you feel right now?" on a 7-point scale from "Not at all neutral" to "Very neutral".
- Descriptive mood: An open-ended question "Please describe your current mood in a few words"
- Overall mood: "On a scale from 1 (Very Negative) to 7 (Very Positive), how would you describe your overall mood right now?".

General Impressions and Confidence

- Prior robot interaction: "Have you interacted with a Nao robot or any other social robot before?" (Yes/No). An optional follow-up asked how this interaction compared to previous experiences.
- Overall feeling towards Nao: "Overall, how did you feel about the Nao robot you interacted with?" on a 7-point scale from "Very Negative" to "Very Positive".
- Confidence in robot emotion rating: "How confident are you in your rating of the robot's overall emotion during the story?" on a 7-point scale from "Not at all confident" to "Very confident".

IV. Results

This section shows what we found from the answers of eight participants who joined our study. In the study, they watched a happy video first and then interpreted the emotions of a robot making ambiguous gestures.

A. Quantitative Results

Participants evaluated various aspects of the robot's emotional expression and reported their own emotional state using 7-point Likert scales. The table below summarizes the average ratings and standard deviations for all relevant questions:

TABLE I
SUMMARY STATISTICS FOR ALL LIKERT-SCALE QUESTIONS

Question	Mean	Standard Deviation
Q1 (Perceived Emotion Conveyance)	4.63	1.41
Q2 (Perceived Happiness of Robot)	3.25	0.89
Q3 (Perceived Neutrality of Robot)	5.00	1.31
Q4 (Overall Emotion Rating)	2.38	0.52
Q5 (Clarity of Emotional Expression)	4.00	1.60
Q7 (Belief in Robot's Intentionality)	3.63	1.51
Q8 (Participant's Current Happiness)	4.38	0.92
Q9 (Participant's Current Neutrality)	5.25	1.16
Q11 (Participant's Overall Mood)	4.88	0.99
Q14 (Overall Impression of Robot)	5.13	1.13
Q15 (Confidence in Emotion Rating)	4.50	1.51
Q16 (Participant Age)	24.00	2.00

To explore whether participant ratings differ significantly from the neutral midpoint which equals to 4, we conduct one-sample t-tests for Q1–Q5. Results are presented in the following table:

TABLE II
ONE-SAMPLE T-TESTS FOR Q1–Q5 AGAINST NEUTRAL MIDPOINT (4)

Question	t Value	p Value	Significant ($p < 0.05$)
Q1 (Emotion Conveyance)	1.26	0.25	No
Q2 (Robot Happiness)	-2.38	0.048	Yes
Q3 (Robot Neutrality)	2.16	0.068	No
Q4 (Overall Emotion)	-8.84	< 0.001	Yes
Q5 (Clarity of Expression)	0.00	1.00	No

B. Qualitative Results

Participant Mood Descriptions (Q10): Participants used terms such as "mostly neutral", "calm", "neutral & slightly positive tone", "happy, peace", "thoughtful", "awkward / in peace", and "happy" to describe their emotional state after the interaction.

V. DISCUSSION

This study investigated how a happy emotional priming influences participants' interpretation of ambiguous emotional cues displayed by a Nao robot.

A. Interpretation of Findings

Our primary hypothesis (H1) posited that happy emotional priming would lead participants to infer a more positive (happy) emotion from the Nao robot's ambiguous gestures and consistently ambiguous vocal tone. The quantitative results offer partial support for this. The mean rating for "Perceived Happiness of Robot" (Q2) was 3.25 (SD = 0.89), which was significantly lower than the neutral midpoint of 4 (p = 0.048). More strikingly, the "Overall Emotion Rating" (Q4), on a scale from 1 (Very Neutral) to 7 (Very Happy), yielded a mean of 2.38 (SD = 0.52), which was also significantly below the neutral midpoint (p ¡ 0.001). This suggests that despite happy priming, participants generally perceived the robot's ambiguous emotional display as tending towards the neutral or even slightly less happy than neutral, rather than being biased towards happiness. This contradicts our initial expectation that happy priming would pull the perception towards a more positive interpretation. Conversely, the mean for "Perceived Neutrality of Robot" (Q3) was 5.00 (SD = 1.31), which was not significantly different from the neutral midpoint (p = 0.068). This indicates that participants largely perceived the ambiguous display as neutral, aligning with the design intent of the robot's ambiguous tone. The lack of significant difference for "Perceived Emotion Conveyance" (Q1, mean 4.63, p = 0.25) and "Clarity of Emotional Expression" (Q5, mean 4.00, p = 1.00) further emphasizes that the robot's emotional display was indeed perceived as somewhat ambiguous or not strongly conveying any specific emotion, which was the goal of the study. Regarding participants' own emotional state, the mean for "Participant's Current Happiness" (Q8) was 4.38 (SD = 0.92) and "Participant's Overall Mood" (Q11) was 4.88 (SD = 0.99). The qualitative mood descriptions, such as "happy, peace" and "happy", alongside "calm" and "neutral & slightly positive tone", suggest that the happy priming was at least somewhat effective in inducing a positive or at least non-negative mood, although "mostly neutral" and "awkward / in peace" were also present. The fact that participants reported relatively moderate levels of happiness and overall positive mood after the happy priming, yet still rated the robot's emotion towards the neutral/less happy end, suggests that the ambiguity of the robot's gestures and tone might have been a stronger influence than the induced positive mood. This challenges a simple mood-congruent perception hypothesis in the context of highly ambiguous HRI. The mean rating of 3.63 (SD = 1.51) for "Belief in Robot's Intentionality" (Q7) suggests a mixed perception, with participants generally leaning towards not believing the robot was strongly intentionally trying to show a specific emotion. This aligns with the designed ambiguity and the goal of observing unbiased interpretation.

B. Contributions to the Research Field

This study contributes to the field of Human-Robot Interaction by specifically investigating the under-explored area of emotional inference from ambiguous robot gestures under varying emotional states. While prior research has examined how robots convey emotions, less work has focused on how a human's internal affective state influences their interpretation when the robot's cues are deliberately unclear. Our preliminary findings suggest that for highly ambiguous robotic cues, the inherent ambiguity might be a stronger determinant of interpretation than a subtle mood induction, pushing the perceived emotion towards neutrality despite positive priming.

C. Limitations and Reflection

A significant limitation of this study was the small sample size of eight participants. This severely limits the generalizability of our findings and the statistical power to detect subtle effects, particularly for a single-group design where comparisons against a true baseline (e.g., a non-primed or negatively primed group) were not conducted.

Reflecting on the process of conducting the study:

- What went well? The overall procedure for guiding participants through the phases (priming, interaction, questionnaire, debriefing) was generally smooth. The Nao robot performed its script consistently, and the questionnaire effectively collected the intended quantitative and qualitative data. The debriefing process allowed for ethical closure and participant feedback.
- What went badly? A major issue was the extremely noisy environment during the study procedure. This undoubtedly reduced participants' ability to concentrate on Nao. Furthermore, the limited number of participants did not allow for investigation of subtle within group differences. The data only provided a trend on the macro level.
- How would we change the study design and execution to improve it?
  - Broader Priming Conditions: To more robustly test the hypothesis, future studies should include a neutral priming control group and potentially a negative priming group for comparison against the happy priming condition. This would allow for statistical comparisons of perceived robot emotion across different induced moods.
  - Increase Sample Size: A substantially larger participant pool is essential to increase statistical power and the reliability and generalizability of the findings.
  - Validate Priming Effectiveness: Implement a brief, pre-Nao-interaction mood check to empirically verify the success of the emotional priming technique before the robot interaction. This would confirm that participants were indeed in the intended emotional state.

VI. Conclusion

This study investigated the influence of happy emotional priming on the interpretation of ambiguous emotional gestures and vocal tones displayed by a Nao robot. Contrary to our initial hypothesis, participants, despite receiving happy emotional priming, generally perceived the robot's ambiguous emotional expressions as tending towards neutrality or even less happy than neutral. This suggests that the inherent ambiguity of the robot's cues might have been a stronger determinant of interpretation than the induced positive mood.

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