# Enhancing Action Transparency of Robot Contact through Self-Referential Preparatory Demonstration in Humanoid Robots

Chenyu Tai[1], Tamon Miyake[2], Yushi Wang[2], Misa Matsumura[3], and Shigeki Sugano[4]

***Abstract*— Physical contact is essential for many humanoid robot applications, yet users often struggle to anticipate where and how a robot intends to touch them before contact occurs. Existing predictive cues, including verbal explanations and predictive robot motions, improve action transparency but provide limited information about intended contact locations. This paper proposes a self-referential preparatory demonstration strategy that exploits humanoid embodiment by allowing a robot to demonstrate an upcoming contact action on its own body before approaching a user. The proposed strategy was evaluated through an online questionnaire study ($N = 30$) and an in-person physical human–robot interaction experiment ($N = 33$). The results demonstrate that self-referential demonstrations significantly improve users' understanding of robot behavior and contact predictability compared with conventional verbal cues. However, perceived fear showed comparatively smaller improvements, suggesting that cognitive transparency and emotional acceptance are distinct aspects of physical human–robot interaction.**

## I. Introduction

Humanoid robots are expected to perform an increasing variety of physical assistance tasks, including rehabilitation, dressing assistance, and mobility support. [1], [2]. These applications require direct physical contact between humans and robots, making users' understanding of robot intentions as important as physical safety for successful physical human–robot interaction (pHRI) [3]–[5]. Even when robot motions are physically safe, uncertainty regarding where and how contact will occur may reduce user confidence and acceptance.

Previous studies have demonstrated that predictive cues, including verbal instructions, gaze behaviors, and legible robot motions, improve users' ability to anticipate robot actions. [6]–[9]. However, these approaches primarily communicate that a robot is about to act rather than explicitly indicating where physical contact will occur. This limitation becomes particularly important in body-contact tasks, where communicating the intended contact location is critical for reducing uncertainty before interaction.

*This work was supported by JST Moonshot R&D Grant No. JPMJMS2031.

[1]Chenyu Tai is with the Graduate School of Creative Science and Engineering, Waseda University, Tokyo, Japan.

[2]Tamon Miyake and Yushi Wang are with the Future Robotics Organization, Waseda University, Tokyo, Japan.

[3]Misa Matsumura is with the Biomedical Precision Engineering Laboratory, The University of Tokyo, Tokyo, Japan.

[4]Shigeki Sugano is with the Faculty of Science and Engineering, Waseda University, Tokyo, Japan.

Corresponding author: Tamon Miyake (e-mail: tamon-miyake@aoni.waseda.jp)

Humans naturally communicate intended physical actions through self-referential gestures. For example, caregivers often touch their own shoulder before touching another person's shoulder to indicate the intended contact location. Inspired by this observation, we investigate whether humanoid robots can exploit their own embodiment as an intuitive communication interface. Before approaching the user, the robot first demonstrates the intended contact action on its own body while verbally explaining the task, enabling users to anticipate the upcoming interaction before physical contact begins.

The central hypothesis of this work is that self-referential preparatory demonstrations improve the transparency of robot contact actions by leveraging the robot's embodied structure. To evaluate this hypothesis, we conducted an online questionnaire study and an in-person physical interaction experiment involving a range-of-motion assistance task. The results demonstrate significant improvements in users' understanding of robot behavior and contact predictability, whereas perceived fear showed comparatively smaller improvements. These findings indicate that improving cognitive transparency alone is insufficient to fully enhance emotional acceptance during pHRI.

## II. Self-Referential Preparatory Demonstration

The proposed interaction strategy enables a humanoid robot to communicate its intended physical contact before approaching a user. As shown in Fig. 1, the interaction consists of three stages: (1) self-referential demonstration, (2) robot approach, and (3) physical contact. First, the robot reproduces the intended contact action on the corresponding part of its own body while verbally explaining the task. After completing the demonstration, the robot approaches the user and performs the same motion during physical interaction. By exploiting the robot's own body as an explanatory interface, the proposed strategy improves the transparency of forthcoming contact actions before physical interaction begins.

## III. Preliminary Evaluation

To evaluate the proposed strategy, we conducted two complementary user studies. An online questionnaire study assessed users' interpretation of robot intentions using recorded interaction videos, while an in-person experiment examined participants' responses during actual physical human–robot interaction. Both studies compared three predictive cue conditions: (1) no predictive cue, (2) verbal explanation with

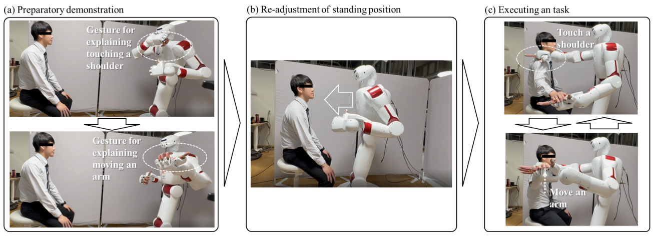


Fig. 1. Overview of the proposed self-referential preparatory demonstration. The robot first demonstrates the intended contact action on its own body before approaching the user and performing the physical interaction.

a non-informative arm motion, and (3) the proposed self-referential preparatory demonstration.

### A. *Participants*

Thirty participants completed the online questionnaire study, and thirty-three participants participated in the in-person physical interaction experiment.

### B. *Experimental Task*

Participants observed or experienced a range-of-motion assistance task performed by a humanoid robot. Before physical contact, the robot presented one of three predictive cue conditions: (1) no predictive cue, (2) verbal explanation with a non-informative arm motion, or (3) the proposed self-referential preparatory demonstration.

### C. *Evaluation Metrics*

Participants evaluated the interaction using five-point Likert-scale questionnaires measuring (1) understanding of the robot's intention, (2) contact predictability, and (3) perceived fear. Statistical differences among the three conditions were analyzed using one-way ANOVA followed by post-hoc multiple comparisons.

## IV. Results

Fig. 2 summarizes the experimental results. Compared with both the baseline and verbal-cue conditions, the proposed self-referential preparatory demonstration significantly improved participants' understanding of the robot's intended contact actions. Participants also reported significantly higher contact predictability, indicating that they were better able to anticipate where physical contact would occur before the robot approached.

Although perceived fear tended to decrease under the proposed condition, the differences were comparatively small and were not consistently significant across all experimental conditions. These results suggest that improved understanding of robot intentions does not necessarily lead to a corresponding improvement in emotional acceptance.

## V. Discussion

The results indicate that self-referential preparatory demonstrations provide an intuitive means of communicating intended physical contact by exploiting the robot's own embodied structure. Unlike conventional predictive cues, which primarily indicate that an action is about to occur, the proposed strategy explicitly conveys where physical contact will occur before the robot approaches the user. Consequently, participants demonstrated improved understanding of the robot's intentions and greater confidence in predicting the forthcoming interaction.

Interestingly, the improvements in cognitive transparency were not accompanied by comparable reductions in perceived fear. This finding suggests that cognitive understanding and emotional acceptance represent different dimensions of physical human–robot interaction. [4], [5]. Although the proposed strategy effectively reduces uncertainty regarding robot intentions, emotional responses are likely influenced by additional factors such as interpersonal distance, robot appearance, motion characteristics, and users' prior experience with robots. Future work will investigate how embodied communication can be combined with adaptive robot behaviors to further improve user acceptance during physical interaction.

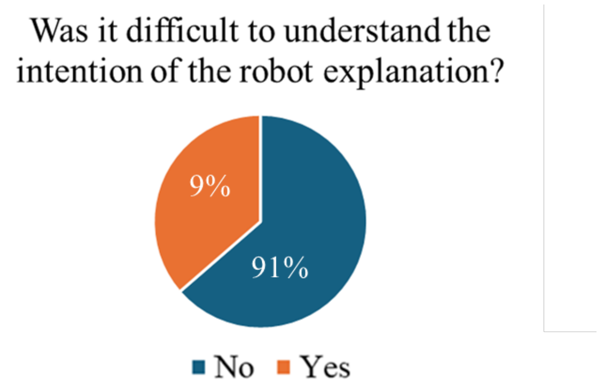


Fig. 2. Experimental results under the three predictive cue conditions. The proposed self-referential preparatory demonstration significantly improved users' understanding of robot behavior and contact predictability, whereas perceived fear showed comparatively smaller improvements.

## VI. Conclusion

This paper presented a self-referential preparatory demonstration strategy for enhancing the action transparency of robot contact. By allowing a humanoid robot to demonstrate an intended contact action on its own body before approaching a user, the proposed method exploits embodied communication to improve users' understanding of forthcoming physical interactions. Results from both an online questionnaire study and an in-person physical interaction experiment demonstrated significant improvements in users' understanding and contact predictability compared with conventional predictive cues, whereas perceived fear showed comparatively smaller improvements. These findings suggest that self-referential demonstrations represent a promising approach for improving transparency in future physical human–robot interaction.

## Acknowledgment

This work was supported by JST Moonshot R&D Grant JPMJMS2031.

## References


[1] W. Chen, S. Huang, H. Zhang, Y. Tu, Y. Lu, Q. Li, and J. Zhang, "Feeding, grooming, dressing, and body repositioning: Categorizing four pillars of learning-based manipulation for robotic caregiving," *Artificial Intelligence Review*, vol. 59, p. 113, 2026.

[2] T. Tsukakoshi, T. Miyake, T. Ogata, Y. Wang, T. Akaishi, and S. Sugano, "Close-fitting dressing assistance based on state estimation of feet and garments with semantic-based visual attention," *IEEE Robotics and Automation Letters*, 2026.

[3] P. A. Lasota, T. Fong, and J. A. Shah, "A survey of methods for safe human-robot interaction," *Foundations and Trends in Robotics*, vol. 5, no. 4, pp. 261–349, 2017.

[4] M. Rubagotti, I. Tusseyeva, S. Baltabayeva, D. Summers, and A. Sandygulova, "Perceived safety in physical human–robot interaction—a survey," *Robotics and Autonomous Systems*, vol. 151, p. 104047, 2022.

[5] N. Akalin, A. Kiselev, A. Kristoffersson, and A. Loutfi, "A taxonomy of factors influencing perceived safety in human–robot interaction," *International Journal of Social Robotics*, vol. 15, no. 12, pp. 1993–2004, 2023.

[6] K. Yamada, S. Nishigaki, and H. Iwata, "Evaluation of a mobile robot with predictive display of future motion in human-interactive environments," *Journal of Human Interface Society*, vol. 10, no. 1, pp. 11–18, 2018.

[7] L. Naendrup-Poell and L. Onnasch, "Predictive robot eyes enhance attentional guidance in cooperative human–robot interaction," *Scientific Reports*, vol. 15, p. 32661, 2025.

[8] L. Peternel and T. Petric, "Human-robot interaction with robust prediction of movement intention surpasses manual control," *Frontiers in Neurorobotics*, vol. 15, p. 695022, 2021.

[9] Y. Zhang and T. Doyle, "Integrating intention-based systems in human-robot interaction," *Frontiers in Robotics and AI*, vol. 10, p. 1233328, 2023.