Designing Nonverbal Responses to Healthcare Robot Navigation Errors Through Performer-Based Enactments

Hideki Garcia Goo[1]**,Vanessa Evers**[1,2]

[1]Department of Human Media Interaction - University of Twente
Netherlands

[2]The Centrum Wiskunde & Informatica
Netherlands

Abstract. *Robots in public spaces will inevitably make mistakes, which can reduce user trust and acceptance. While verbal error mitigation strategies (e.g., apologies) are common, they may raise expectations of the robot's social capabilities. This paper explores robot errors and nonverbal responses using movement, sound, and shape-change as expressive modalities in a hospital environment. We conducted a qualitative study with 26 performers who enacted social navigation error scenarios as either a healthcare robot or stakeholders. Through video analysis, results provide insights into how robots might recover from errors without relying on speech and demonstrate the value of performer-informed methods for designing expressive robot behaviors.*

1. Introduction

Robots in public spaces such as hospitals inevitably make mistakes. For healthcare delivery robots to be accepted, they must respond appropriately to errors, as poorly handled mistakes can reduce trust and lead users to abandon the technology [de Graaf et al. 2017]. Common mitigation strategies include apologies, denials, promises, and forewarnings [Tolmeijer et al. 2020, Esterwood and Robert 2025]. While often effective [Cahya and Giuliani 2021], these approaches typically rely on speech, which can raise user expectations beyond current robot capabilities [Kwon et al. 2016]. Nonverbal behaviours have therefore been explored as an alternative for mitigating social errors [Pompe et al. 2022]. Performance-based methods in HRI, such as improvisation and embodied enactments with actors or dancers, have also been used to explore expressive robot behaviours and user expectations before implementation on robotic platforms [Sandry 2018, Troughton et al. 2022, Greer 2017]. In this study, we explore how *Harmony*, a nonverbal healthcare delivery robot with movement, an arm, expressive eyes, and sound, can respond to social navigation errors. Through performer enactments, we investigate nonverbal mitigation strategies, including shape-changing behaviours such as inflation and bending [Schadenberg et al. 2025], in scenarios involving personal space violations, calmness interruptions, and ignored social cues.

2. Background

Robot errors in human–robot interaction (HRI) can negatively affect user experience, particularly in settings where expectations for reliability and social appropriateness are high, such as healthcare. Errors including violations of personal space or social norms [Bremers et al. 2023] can reduce perceived competence, trustworthiness, and likability [Esterwood and Robert 2025] and they generally lead to more negative attitudes and reduced willingness to interact with robots [Tolmeijer et al. 2020]. To address these issues, researchers have explored mitigation strategies inspired by human social repair behaviours, such as apologies, denials, explanations, and promises [Esterwood and Robert 2025]. However, these approaches often rely on spoken language, which can raise expectations about a robot's communicative abilities beyond its actual capabilities [Kwon et al. 2016]. As a result, researchers have increasingly explored nonverbal expressive behaviours such as gaze, gesture, posture, movement, and sound can communicate intent or acknowledgment without speech [Pompe et al. 2022].

Performance-based approaches in HRI have also used actors and dancers to explore expressive robot behaviours through improvisation and embodied enactments [Sandry 2018, Troughton et al. 2022, Greer 2017].

3. Method

We conducted a three-hour qualitative study with performer-based enactments. In Block A, participants enacted three social error scenarios (navigation error, calmness interruption, and social expectation failure) as either the Harmony robot or hospital stakeholders. They were assigned modalities (arm use, sound, shape-change) and given physical constraints to simulate robotic expression. Block B involved improvisation with the Pepper robot and is not discussed in this paper.

3.1. Participants

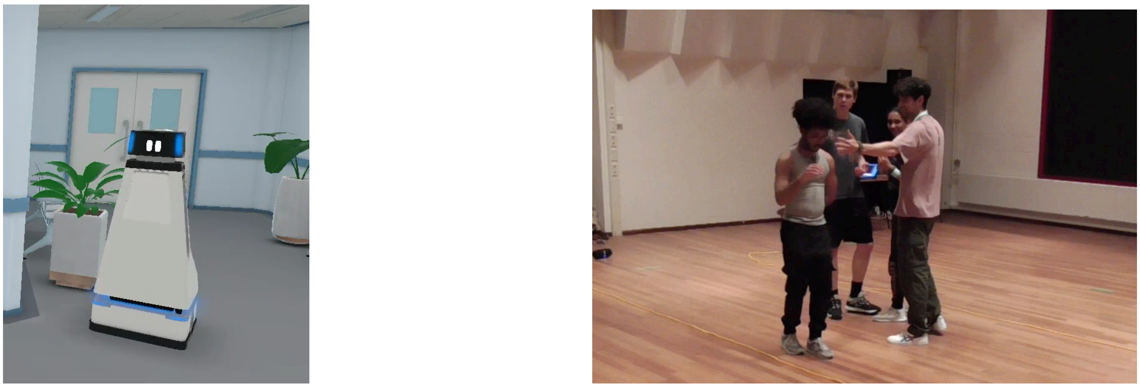
Twenty-six participants (aged 18–39, M = 23.73, SD = 4.68) were recruited from three distinct performative arts backgrounds: improv theatre (7), hip-hop dance (11), and modern dance (8). Fourteen identified as female, eleven as male, and one preferred not to disclose their gender. Nationalities included Dutch (13), German (3), Czech (2), Latvian (2), and one participant each from Estonia, Greece, Italy, Japan, Mexico, and one with dual Russian/Latvian nationality. Most had no prior interaction with robots (15), while ten reported some experience. All participants were over 18, proficient in English, and affiliated with collaborating student associations. They received a €25 bol.com gift card and refreshments. The study was approved by the University of Twente Ethics Committee (Ref. 230360).

3.2. Measures

We conducted qualitative observation of embodied interactions. Sessions were video recorded and analysed to identify patterns in (1) robot error behaviours, (2) user responses, and (3) mitigation strategies. Behaviours were thematically coded, focusing on spatial movement, sound, and full-body gestures.

3.3. Procedure

Sessions began with an introduction, consent, and a short VR interaction introducing the robot (Figure 1a). Participants then enacted scenarios in a mock hospital corridor, alternating roles between robot and stakeholder. Robot performers were assigned two of four modalities (**robot arm**, **whole-body movement**, **nonverbal sound**, **shape-change**) and performed one of three scenarios (**localization error**, **calmness interruption**, **social**



(a) Harmony robot in VR

(b) Robot performer blocked by hospital staff performer

Figura 1. Harmony robot and performers enacting an error scenario.

expectation failure) multiple times. Although structured descriptions were provided, performers were encouraged to interpret scenarios creatively to explore different robot behaviors, errors, and responses.

3.4. Analysis

Sessions were video recorded and thematically coded. Two researchers independently identified patterns in (1) robot error behaviours, (2) user reactions, and (3) mitigation strategies, and refined themes through discussion until agreement was reached.

4. Results

Analysis revealed behaviours enacted by both robot and user performers, grouped into error behaviours, user reactions, and mitigation strategies (occurrence counts in parenthesis).

Error behaviours. Invading personal space (22), often combined with robotic arm use (20). Performers also bumped into users (4) or walls (5), or followed users (5). In calmness interruptions, performers produced loud sounds (9), paused (2), or used shape-related gestures (3). In social expectation failures, performers pointed toward destinations (18) or used sound to signal urgency (36).

User reactions. Users redirected (24), halted (3), or repositioned (3) the robot. Some attempted to stop it via its imagined interface (4), while others approached or blocked it (36), took selfies (2), or inspected it (3).

Mitigation strategies. Distancing (8), bowing (7), spinning (3), head tilts (1), and signing “sorry” (1).

5. Discussion

Drawing on performer expertise [Sandry 2018, Troughton et al. 2022], this study examined how movement, sound, and shape-change can support robots in enacting and mitigating social navigation errors in healthcare. Our findings highlight proxemic behaviour as central to how users interpret robot actions: violations of personal space and calm environments were consistently perceived as social breaches, not just functional failures. Although performers frequently enacted errors, mitigation behaviours were less common and relied on a small set of legible cues. Gestures such as bowing, distancing, or reorientation signaled acknowledgment or apology [Esterwood and Robert 2025], functioning as embodied repair strategies. Shape-changing enactments further suggest that adaptable morphology could expand robots' expressive repertoire beyond conventional movement [Schadenberg et al. 2025]. Together, these findings point to a limited but effective design space grounded in visibility, legibility, and spatial modulation. These behaviours can be translated into robot control strategies, including adjusting approach distance, modulating speed, reorienting the body, or retreating to signal acknowledgment. This could be particularly relevant in healthcare contexts in Latin America, where resource constraints may limit speech-based systems and make simple nonverbal strategies more practical. Prior work in HCI, including studies in Latin American contexts, has explored how social interactions emerge from coordinated actions in shared environments and how embodied interaction shapes how users interpret system behaviour [Jiménez et al. 2015, Reyes-Flores et al. 2020]. This is consistent with cross-cultural HRI research showing that proxemic preferences vary across cultures [Joosse et al. 2014]. This study has limitations. Performer enactments do not fully capture robotic constraints, and we did not evaluate mitigation effectiveness. Future work should validate these behaviours on robotic platforms and examine how nonverbal repair strategies vary across cultural contexts, including with Latin American participants.

6. Conclusion

This work contributes a performer-based method for identifying nonverbal robot error and repair behaviours, extending prior HRI work by focusing on embodied, nonverbal mitigation strategies in healthcare navigation contexts. Findings show that users react strongly to proxemic violations and respond well to simple, legible cues such as distancing or bowing. These results suggest that nonverbal strategies can support more acceptable robot interactions in sensitive and multicultural environments such as hospitals.

ACKNOWLEDGMENT

This work was made possible through funding from the European Union's Horizon 2020 research and innovation program under grant agreement no: 101017008 (HARMONY).

Referências

Bremers, A., Pabst, A., Parreira, M. T., and Ju, W. (2023). Using Social Cues to Recognize Task Failures for HRI: A Review of Current Research and Future Directions. arXiv:2301.11972 [cs].

Cahya, D. E. and Giuliani, M. (2021). Appropriate Robot Reactions to Erroneous Situations in Human-Robot Collaboration. In Li, H., Ge, S. S., Wu, Y., Wykowska, A., He, H., Liu, X., Li, D., and Perez-Osorio, J., editors, *Social Robotics*, volume 13086, pages 166–177. Springer International Publishing, Cham. Series Title: Lecture Notes in Computer Science.

de Graaf, M., Ben Allouch, S., and van Dijk, J. (2017). Why Do They Refuse to Use My Robot?: Reasons for Non-Use Derived from a Long-Term Home Study. In *Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction*, pages 224–233, Vienna Austria. ACM.

Esterwood, C. and Robert, L. P. (2025). Repairing Trust in Robots?: A Meta-analysis of HRI Trust Repair Studies with A No-Repair Condition :: Data ::.

Greer, J. A. (2017). Method and improvisation: Theatre arts performance techniques to further HRI in social and affective robots. In *2017 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, pages 1255–1260, Lisbon. IEEE.

Jiménez, L., Benitez-Guerrero, E., Mezura-Godoy, C., and Martínez-López, E. (2015). Studying social interactions in groupware systems. *IEEE Latin America Transactions*, 13:3488–3497.

Joosse, M. P., Poppe, R. W., Lohse, M., and Evers, V. (2014). Cultural differences in how an engagement-seeking robot should approach a group of people. In *Proceedings of the 5th ACM International Conference on Collaboration across Boundaries: Culture, Distance & Technology*, CABS '14, page 121–130, New York, NY, USA. Association for Computing Machinery.

Kwon, M., Jung, M. F., and Knepper, R. A. (2016). Human expectations of social robots. In *2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, pages 463–464, Christchurch, New Zealand. IEEE.

Pompe, B. L., Velner, E., and Truong, K. P. (2022). The Robot That Showed Remorse: Repairing Trust with a Genuine Apology. In *2022 31st IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*, pages 260–265, Napoli, Italy. IEEE.

Reyes-Flores, A., Mezura-Godoy, C., and Benítez-Guerrero, E. (2020). Understanding social interactions for the design of tangible user interfaces. In *Proceedings of the IX Latin American Conference on Human Computer Interaction*, CLIHC '19, New York, NY, USA. Association for Computing Machinery.

Sandry, E. (2018). Encounter, story and dance: human-machine communication and the design of human-technology interactions. In *Proceedings of the 30th Australian Conference on Computer-Human Interaction*, pages 364–367, Melbourne Australia. ACM.

Schadenberg, B. R., Davo Sainz, J., Kolkmeier, J., Garcia Goo, H., and Evers, V. (2025). Goo-y: A robot's shape-changing capability for fast, non-anthropomorphic communication with people (and animals). In *Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems*, CHI EA '25, New York, NY, USA. Association for Computing Machinery.

Tolmeijer, S., Weiss, A., Hanheide, M., Lindner, F., Powers, T. M., Dixon, C., and Tielman, M. L. (2020). Taxonomy of Trust-Relevant Failures and Mitigation Strategies. In *Proceedings of the 2020 ACM/IEEE International Conference on Human-Robot Interaction*, pages 3–12, Cambridge United Kingdom. ACM.

Troughton, I. A., Baraka, K., Hindriks, K., and Bleeker, M. (2022). Robotic Improvisers: Rule-Based Improvisation and Emergent Behaviour in HRI. In *2022 17th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, pages 561–569, Sapporo, Japan. IEEE.