Are Emotions Important? A Study on Social Distances for Path Planning based on Emotions

Vasileios Mizaridis[1,3*], Francesco Vigni[2,3*], Stratos Arampatzis[1], and Silvia Rossi[2,3]

Abstract— **This study explores the complex dynamics between humans and robots, focusing on how emotional states influence proxemics. We conducted a user study using a standard mobile robot to investigate whether emotions elicited from a loudspeaker, affect human perception of robot proximity. Based on previous research on Human-Human Interaction (HHI), we analysed participants' responses to robots displaying different behaviours. Participants observed the robot's approach while experiencing positive or negative emotions. Our findings suggest that emotional states induced by external stimuli can affect participants' perception of robot proximity. In detail, the results indicate that while comfortable stopping distances were unaffected by participants' emotional state, individuals who experienced positive emotions judged the same proxemics distance used while performing an avoidance behaviour to be more acceptable compared to the case of negative emotions. This study describes the extent to which our emotions can alter the perception of robot behaviours, ultimately affecting our acceptance of these novel social agents.**

I. INTRODUCTION

The integration of robots into our social environment goes beyond functional utility; it involves complex interactions with humans but also the possibility of sharing the same space with them without interacting [1]. Indeed, as they become more ubiquitous, the need for them to be both efficient and socially acceptable is becoming increasingly important [2].

This consideration significantly influences trajectory planning in shared spaces whereas additional factors related to the human state could be taken into account. For instance, in tasks involving user monitoring, the robot must maintain appropriate distances from the user considering their discomfort while being involved in other activities [3]. Also, when planning trajectories to achieve a goal, factors such as people's comfort regarding distances, speed, direction, and adherence to social norms must be considered [4], [5]. In this direction, research is starting to address not only the technical aspects of algorithms or design but also how people perceive robots while moving in the same space. Previous studies have shown the importance of acceptance when it comes to social robots and the importance of transferring social norms to Human-Robot Interactions (HRI) [6].

Human interactions are frequently influenced by emotional states, ranging from subtle gestures of empathy to uncontrolled displays of joy or anger. Context, emotional states and other factors can influence how we perceive and use the space around us [7]. Therefore, our perception of the social context is significantly impacted by the emotional states of those around us [8]. Moreover, the appropriateness of different robot navigation behaviours (approaching, not moving or moving away) has been shown as linked to the observer's emotional states [9]. In this work, we aim to contribute in this direction and, in detail, to whether *robots should adapt their behaviour according to the emotional states of the people they encounter*. While some argue for a uniform approach where consistency promotes predictability and trust, others claim that the richness of human emotion requires a more nuanced response and robots are not yet capable of reproducing it or adapting to it effectively [10], [11].

Inspired by the approach of [12], [13], we set up a user study to provide initial insight into whether emotion might affect the perception of human-robot proxemics and trajectories. In our study, each participant observed a mobile robot approaching them. The first time, we asked the user to use a controller to stop the robot at a minimum preferred distance, while the second time, the robot computed a path to avoid them according to the preference set in the first encounter. Emotions are induced by using sounds from an external speaker. Based on the findings of Ruggiero *et al.* [14], where the peripersonal/interpersonal spaces of humans are immediately affected by their emotions, our user study investigates 1) whether preferred stopping distances might be affected by a negative or positive emotional state (exploratory hypothesis), and 2) whether humans might have a different perception of the appropriateness of the robot trajectory, while avoiding them, according to a different positive/negative emotional state (exploratory hypothesis). Our long-term goal is to evaluate whether the robot should take this information into account when planning future paths with a human experiencing such an emotion.

The rest of this work is developed as follows: In section II, we provide the current state of research, and section III describes how we designed and executed the user study. The results are shown in section IV, while in section V there is a discussion over them. Final remarks on this work are in

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[1] are with Noosware B.V., Eindhoven, Netherlands `{vm,sa}@noosware.com`

[2] is with the Interdepartmental Center for Advances in Robotic Surgery - ICAROS, University of Naples Federico II, Naples, Italy `francesco.vigni@unina.it`

[3] is with the Department of Electrical Engineering and Information Technologies - DIETI, University of Naples Federico II, Naples, Italy `silvia.rossi@unina.it`

section VI.

II. Related Work

Robots deployed in public spaces can establish interactions by displaying interest in their performed motions [15], emotions [16] and behaviours [17]. Inspired by how humans naturally generate social motions in space, Wen *et al.* [18] explored Inverted Optimal Control (IOC) methods to generate robot motions. Participants found these trajectories to be more appropriate than the control ones. Ko *et al.* [19] and Raggioli *et al.* [3] tried to understand human intentions (posture and position) and have the robot respond accordingly. In their work, the robot 1) detected the user's behaviour, 2) selected a predefined behaviour based on a HHI dataset, and 3) adapted its behaviour based on the user's posture and position. Moreover, in Raggioli *et al.* [3] the human's discomfort is also considered. Similarly, Narayanan *et al.* [20] predicted human emotions by tracking their walking gaits with an onboard robot camera. These predicted emotions were then utilised for emotion-guided navigation, considering both social and proxemic constraints. Samarakoon *et al.* [21] proposed a novel method for adapting the termination position of a mobile robot approaching a user based on their behaviour and feedback. The authors analysed the skeletal joint movements of the user to assess their physical behaviour. They then fed this information into a fuzzy neural network to determine the appropriate interpersonal distance. The study's findings indicate that users are more satisfied when the robot considers their preferences in its proxemics behaviour.

The work of Papadakis *et al.* [22] analysed HHI and introduced a social map where individuals' personal and social spaces are taken into consideration for human-aware navigation, while in [23], they improved the way to describe the social zones. Lam *et al.* [24] proposed a set of rules for socially acceptable navigation. The rules consider not only the final goal and obstacles on its path but also whether it should interfere with a human's personal space or another robot's working space. Zhang *et al.* [25] investigated to what extent a companion robot could track and follow humans at a comfortable distance, while Bera *et al.* [26] proposed a system that combines people's facial expressions and trajectories to enable socially-aware robot navigation.

Kim *et al.* [27] focused on the importance of social distance in HRI and its relation to the interaction role (supervisor vs. subordinate). In their work, participants identified the comfortable interpersonal distance between themselves and the robot during a task. Depending on the role of the robot, participants had different preferences on the comfortable distance between them and the robot (close or distant). Torta *et al.* [28], explored how a robot should approach a seated participant from different directions and angles. With a questionnaire, the participant could determine a comfortable distance. Petrak *et al.* [9] designed an online study to investigate which robot proxemic behaviour (approaching, not moving, moving away) was more appropriate based on participants' expressed emotional state. Their findings suggest that *moving away* is considered inappropriate in most cases. When participants expressed fear, sadness or joy the preferred behaviour was robot *approaching*. Neggers *et al.* [29] extracted spatial information about participants' comfort levels with a passerby robot. Their results show an asymmetry between participants' comfort when the robot is passing in front of them or behind them.

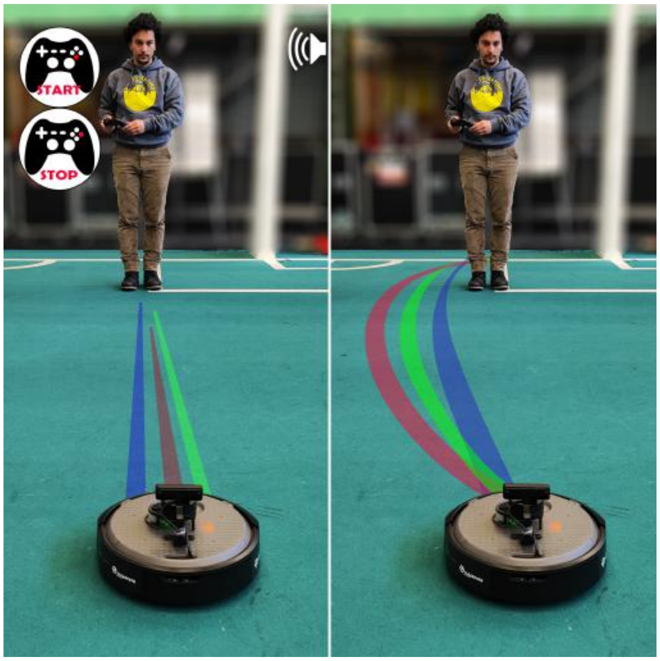

Fig. 1. Experimental setup: A snapshot from the two robot approaches with sketched trajectories. The measured distance between the robot and the participant by the end of the first interaction is considered as "personal space" for the second interaction. The robot plans a trajectory avoiding coming closer than that.

Previous research has mostly focused on detecting and computing proxemics and personal space from a purely spatial perspective. In contrast, this work explicitly considers how emotions influence our perception of robot proxemic behaviours. By addressing this gap, we hope to provide a better understanding of the complex dynamics between humans and robots, paving the way for more effective and meaningful interactions in the future.

III. Methods

Emotions play a significant role in our daily lives. However, when it comes to the foreseeable future of robots that move around us as effective social actors, it remains unclear how our emotional state affects our perception of these devices. This section describes the study's setup in which a mobile robot is approaching participants, exposed to different emotional states. The study tackles the relation between one of the simplest forms of interaction, i.e., proxemics behaviours in approaching and avoiding humans, considering humans' emotional state.

The scenario, we evaluated, started with a participant standing about $3m$ from the popular robot Turtlebot4 lite[1]

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[1] https://clearpathrobotics.com/turtlebot-4/

in a hall. The participant was handed a remote controller and instructed to observe the robot approaching them (see Figure 1). With the remote controller, they were able to initiate the robot approach and halt its motion according to the individual's preference. Upon loading the script, the external speaker played a sound utterance according to the experimental condition. Then, the participants had to initiate the robot's straight motion towards them by pressing the button *Y*. This approach is inspired by Cook *et al.* [30], who demonstrated that different music genres play different roles in emotion regulation, contributing to either positive or negative emotional experiences. Therefore, we elicited an intended emotion (positive or negative) in participants according to the sound utterance. This choice makes it possible to simplify the emotion recognition problem to its extreme valence values.

The two experimental conditions are:

- The participant is elicited with a **Positive emotion** via the sound utterance;
- The participant is elicited with a **Negative emotion** via the sound utterance.

The positive sound utterance was a recording of a baby babbling and laughing, while the negative emotion was a recording of a baby crying, publicly available[2]. This choice is made starting from the neuroscience literature on aversive and inviting stimuli and their link to emotional regulators [31].

The maximum speed of the robot was set to $0.20m/s$. By pressing X on the remote controller participants were free to stop the robot's motion implicitly setting their minimum comfortable distance to it. Its low speed ensured low error in the measured distance when commanded to stop. At this point, the approach terminated, the speaker silenced, and the robot initiated a path to its initial pose. If the participant decided never to press the stop button on the remote control, the robot was instructed to stop at a minimum fixed distance of $0.1m$.

At this point, the robot was informed of the participant's preference for the minimum comfortable distance and was instructed to navigate from the starting position at $3m$ to a point at $1m$ behind the participant avoiding the collision using live laser scan data while respecting the social distance that was set before. Again, the robot waited for the participant to press the start button *Y*, to start the process. Throughout this interaction, the external speaker was off. The robot proceeded in computing and performing a path which was modulated to take the distance preference into account for the parts of the path that were closer to the participant (see Figure 2). For example, if a participant decided that the minimum comfortable distance was $0.50m$, the robot would have taken a path with the same minimum distance to the participant. This functionality was achieved by modifying the inflation layer of the navigation stack used by the robot to compute the path to the given goal autonomously.

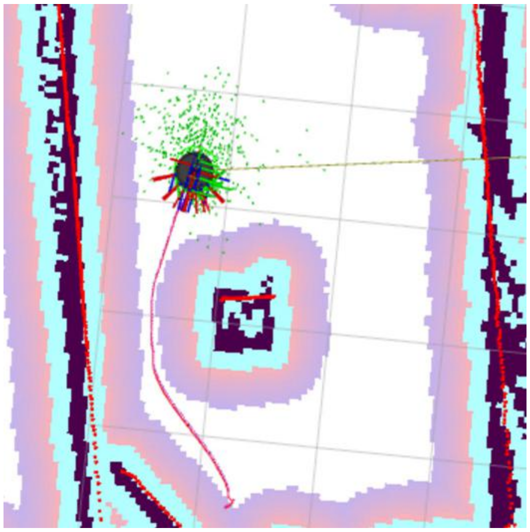

Fig. 2. Example of robot's path during the second approach. The robot maintained a distance coherent with the preference expressed by the participant during the first approach. Black pixels represent obstacles. White pixels free space. The red line is the robot's path. Green dots are from the particle filter used in localisation. Purple shade represents the inflated obstacles (safety margin around obstacles). Pink shade indicates local cost (difficulty of traversing each cell). Blue shade indicates global cost (overall path planning constraints). The red dots are laser data.

A. *User Study*

The Ethics Committee of the University of Naples Federico II approved the within-subjects user study reported here. The study was conducted at Noosware VB premises in Eindhoven, The Netherlands. All participants were exposed to both experimental conditions only one time. To reduce order effects, the order in which participants were exposed to the experimental conditions was counterbalanced.

An a priori power analysis was conducted, and to achieve an effect size of 0.50 with a statistical power of 0.88 and a significance level of 0.05 a sample size $N = 34$ was required. This analysis was performed by selecting as a statistical test the "difference between two dependent means", as the same participant is exposed to both experimental conditions.

Consistent with the research question introduced above, this user study will focus on the following hypotheses:

- **H1**: Emotions, whether positive or negative, might result in a different minimum comfortable distance to stop the approaching robot (exploratory hypothesis);
- **H2**: Participants might have a different perception of the robot's avoiding trajectory considering a positive or a negative emotional reaction (exploratory hypothesis).

We included all adults and healthy participants with no declared impaired hearing while participants with declared healthy-related issues were excluded from the study. This approach was adopted to ensure that the experiment would yield reliable and unbiased results.

Our convenience sample was drawn from university staff and students. A total of 34 participants were recruited, of whom 8 self-identified as female and 26 as male. Age ranged from 22 to 57 years ($M = 27.50$, $SD = 5.84$).

Participants were asked to assess their experience with

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[2] https://tinyurl.com/4jszu78a

robots on a scale from 1 (no experience at all) to 7 (very experienced).

B. *Post-Interaction Survey*

After 1) observing and deciding on the minimum comfortable distance, and 2) observing the robot navigating accordingly to a point behind them, participants were asked to fill in a survey for calculating the *Human-Robot Interaction Evaluation Scale* (HRIES) [32]. The survey was augmented with questions about prior experience with robots, demographics and the following entry: "Considering the last robot path, how closely are these sentences with you? 1 (not at all) - 7 (totally)":

- The robot maintained an appropriate distance
- The robot moved too close to me
- The robot moved too far from me

C. *Technical Details*

The robot used was shipped with ROS2 Humble version[3]. A laptop with Ubuntu Jammy Jellyfish (22.04) was orchestrating the communication using the same robot ROS version. Dedicated software was written to:

- Read the inputs from the remote controller *Speedlink rait*[4] (connected via USB-A)
- Control the navigation of the robot as per the interaction scenario
- Store in a `.csv` file the minimum comfortable distance as set by the participant during the first robot approach
- Control the sound played by the external speaker (connected via Bluetooth)

The distance stored in the `.csv` file was measured in meters and acquired via the onboard robot LiDAR sensor during the first robot approach. For computing the path needed for the second approach, this file was read and the information was fed to the navigation stack Nav2[5] to adjust the robot path coherently.

IV. RESULTS

To analyse our results, we first performed a paired t-test on the minimum interpersonal distances collected (means and standard deviations are reported in Table I).

	Mean	**SD**
Positive	0.87	0.31
Negative	0.90	0.30

TABLE I

MEAN AND STANDARD DEVIATION OF THE MINIMUM COMFORTABLE DISTANCE GROUPED PER CONDITION.

The average values are smaller for the "positive" condition. However, the statistical test shows that the controlled variable had no significant effect on the minimum interpersonal distance, as expressed by the participants' input during the robot's first approach.

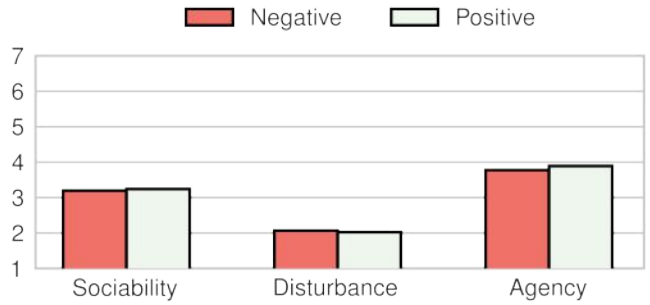

Fig. 3. Mean responses to the HRIES's factors grouped per condition.

To assess the reliability of the factors of HRIES [32] we performed their Cronbach's alpha and show the results in Table II. The factors "Sociability", "Disturbance" and "Agency" are considered reliable as Cronbach's alpha of their subitems is greater than 0.70, which is the commonly accepted value in the community [33]. Furthermore, attempting to increase Cronbach's alpha by only considering a subset of the "Animacy" items did not yield successful results. No further results are reported for the HRIES factor "Animacy" as it cannot be considered a reliable composite score.

	Sociability	**Disturbance**	**Agency**	**Animacy**
Negative	0.78	0.82	0.81	0.52
Positive	0.74	0.77	0.83	0.55

TABLE II

CRONBACH'S ALPHA OF THE FACTORS OF HRIES PER CONDITION.

To further the investigation, we examined whether the responses to the HRIES [32], whose factors were found to be reliable, differed between the two experimental conditions. We tested the assumptions for performing the paired samples t-test and concluded that it can be performed on the "Sociability" and "Agency" factors while the Wilcoxon signed-rank test is the appropriate one for the "Disturbance" factor. Figure 3 shows the means of the responses to HRIES grouped by condition, but no statistical differences are found between the conditions.

Regarding the three questions related to the appropriateness of the robot motion described in subsection III-B, the assumptions to perform the paired sample t-test are not met, so we resort to the Wilcoxon signed-rank test. The average of the responses is shown in Figure 4. Interestingly, participants rated with high scores the statement: "the robot maintained an appropriate distance", and a significant difference between its mean values per condition is obtained ($Z = 107$, $p = 0.007$) with a higher evaluation of the appropriateness of the robot's avoiding behaviour in the case of a positive emotional state. The data indicates that participants perceived the distance of the robot to be more "appropriate" when they experienced a positive emotion compared to when they experienced a negative one.

V. DISCUSSION

Our study reveals compelling insights into the influence of emotional states on HRI dynamics, particularly concerning

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[3] https://docs.ros.org/en/humble/index.html

[4] https://www.speedlink.com/

[5] https://navigation.ros.org/

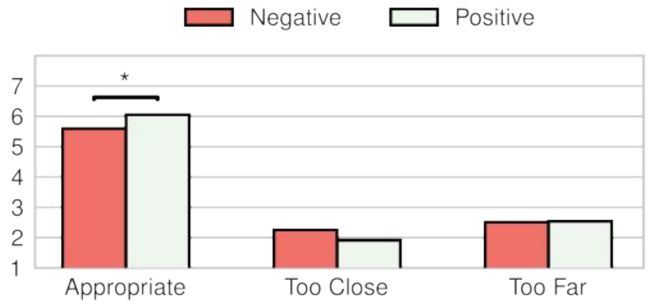

Fig. 4. Mean responses to the survey questions grouped per condition, significant differences have been indicated with * for $p < 0.05$.

proxemics. In a previous study by Spatola *et al.* [32], Cronbach's alpha values for the factors of the HRIES were found to be 0.93, 0.88, 0.81, and 0.74 for Sociability, Disturbance, Agency, and Animacy, respectively. In our analysis, as seen in Table II, we found that the results for Sociability, Disturbance, and Agency were consistent with those of the previous study. However, the results for Animacy did not yield a reliable composite score. Animacy encompasses traits such as *human-like*, *real*, *alive*, and *natural*. Further analysis of the participants' responses revealed that *human-like* and *alive* traits negatively affected the Animacy score. The study's findings suggest that the Turtlebot4-lite's lack of human-like features and unchanging behaviour may have affected how alive participants perceived it to be, highlighting the need to improve how we assess Animacy.

Participants with prior experience with robots (greater than 4 - from 1 to 7) kept on average a greater distance ($1.22m$) from the robot, compared to less experienced participants ($1.19m$), similar to the work of Takayama *et al.* [34]. Despite the heterogeneous self-assessed prior experience with robots ($M = 4.51$, $SD = 1.85$), the feedback gathered from the post-interaction survey revealed that positive emotions made the robot's path more acceptable, even though the trajectory was similar between the two conditions. This finding suggests that emotional stimuli can influence individuals' subjective assessment of robot behaviour (sustaining hypothesis $H2$) when linked to proximity but not to social distances *per se* (not sustaining hypothesis $H1$). Indeed, contrary to our initial hypothesis $H1$, the statistical analysis of minimum interpersonal distances set by participants during the first robot approach did not reveal significant differences between positive and negative emotions. This discrepancy between participants' objective behaviour and subjective perceptions is consistent with De Houwer's research on implicit measures [35]. Consequently, while participants may objectively maintain similar distances from robots across different emotional states, their subjective evaluation of these interactions can vary significantly. As seen in Figure 4, participants generally perceived the interpersonal distance to the robot as "appropriate." The figure also indicates that the statements were effectively formulated, as responses to both *Too Close* and *Too Far* concurrently yielded low scores, indicating their mutual exclusivity. These categories had no subjective values to distinguish from one to the other, meaning that participants were in control of the distance kept by the robot and then, they commented on their perception of the robot's path. As in the work of XU *et al.* [36], the fact that the robot had a steady predictable trajectory without gazing throughout the whole experiment, made participants feel less intimidated and more comfortable being closer to it.

Similarly, other works have investigated the complexity of emotions in HRI and found differences in implicit and explicit measures [37], [38]. Moreover, in the first case, the human was in control of the robot's behaviour, by deciding the comfortable stopping distance, compared to the second interaction where the robot's behaviour was autonomous. In future works, we aim to further investigate the possible connection between autonomy, the emotional state of the user, and proxemics.

$Limitations$ — Our study offers valuable insights into the impact of emotional states on human-robot interaction dynamics. However, it is important to acknowledge a few limitations. Firstly, the use of Turtlebot4-lite as our robot model may have affected participants' perceptions and responses, as factors such as robot size, speed, and shape can elicit different reactions. Additionally, some participants felt that the baby sounds we used were inconsistent with the type of robot we used. It may have been more relatable and engaging if the sounds were coming from a human-like robot instead of an external speaker.

One major limitation of our study is the difficulty of accurately eliciting human emotions in a real-world scenario. Even in a controlled environment, external disruptions can affect the accuracy of our results. Using a pair of headphones that isolate external noise could be a more effective solution.

Finally, our conclusions were drawn from a relatively homogeneous sample of university students, which may limit their generalisability. Including a more diverse range of participants, such as a balanced representation of genders and individuals with different levels of knowledge about robotics, would increase the reliability of our sample.

VI. CONCLUSION

This study focuses on the complex relationship between human emotions and robotic behaviour in human-robot interaction. The research highlights the importance of considering proxemics when designing socially intelligent robots.

We conducted an experiment with 34 university participants to explore how emotions influence their comfort level when approached by a mobile robot. Positive emotions enhanced the participants' subjective perception of the robot's appropriateness, despite objective measures showing no significant differences between the two conditions: positive and negative emotions.

Future studies should expand the sample size to capture a more diverse range of perspectives. Additionally, exploring different robot types such as humanoids or pet robots may yield further nuances in human-robot dynamics. Finally, precision in eliciting human emotions remains paramount.

Our quest is to pave the way for socially attuned robots that seamlessly integrate into our emotional landscape.

REFERENCES

[1] S. Rossi, A. Rossi, and K. Dautenhahn, "The secret life of robots: Perspectives and challenges for robot's behaviours during non-interactive tasks," *International Journal of Social Robotics*, vol. 12, no. 6, pp. 1265–1278, 2020.

[2] M. Luber, L. Spinello, J. Silva, and K. O. Arras, "Socially-aware robot navigation: A learning approach," in *2012 IEEE/RSJ International Conference on Intelligent Robots and Systems*, 2012, pp. 902–907. DOI: `10.1109/IROS.2012.6385716`.

[3] L. Raggioli, F. A. D'Asaro, and S. Rossi, "Deep reinforcement learning for robotic approaching behavior influenced by user activity and disengagement," *International Journal of Social Robotics*, 2023. DOI: `10.1007/s12369-023-01044-7`.

[4] S. M. B. P. Samarakoon, M. A. V. J. Muthugala, A. G. B. P. Jayasekara, and M. R. Elara, "Adapting approaching proxemics of a service robot based on physical user behavior and user feedback," *User Modeling and User-Adapted Interaction*, vol. 33, no. 2, pp. 195–220, 2023.

[5] J. Rios-Martinez, A. Spalanzani, and C. Laugier, "From proxemics theory to socially-aware navigation: A survey," *International Journal of Social Robotics*, vol. 7, no. 2, pp. 137–153, 2015.

[6] S. Brondi, M. Pivetti, S. Di Battista, and M. Sarrica, "What do we expect from robots? social representations, attitudes and evaluations of robots in daily life," *Technology in Society*, vol. 66, p. 101 663, 2021.

[7] M. Cristani, G. Paggetti, A. Vinciarelli, L. Bazzani, G. Menegaz, and V. Murino, "Towards computational proxemics: Inferring social relations from interpersonal distances," in *2011 IEEE Third International Conference on Privacy, Security, Risk and Trust and 2011 IEEE Third International Conference on Social Computing*, IEEE, 2011, pp. 290–297.

[8] C. Marinetti, P. Moore, P. Lucas, and B. Parkinson, "Emotions in social interactions: Unfolding emotional experience," *Emotion-oriented systems: The humaine handbook*, pp. 31–46, 2011.

[9] B. Petrak, J. G. Stapels, K. Weitz, F. Eyssel, and E. André, "To move or not to move? social acceptability of robot proxemics behavior depending on user emotion," in *2021 30th IEEE international conference on robot & human interactive communication (RO-MAN)*, IEEE, 2021, pp. 975–982.

[10] S. Daronnat, L. Azzopardi, M. Halvey, and M. Dubiel, "Inferring trust from users' behaviours; agents' predictability positively affects trust, task performance and cognitive load in human-agent real-time collaboration," *Frontiers in Robotics and AI*, vol. 8, p. 642 201, 2021.

[11] F. Cavallo, F. Semeraro, L. Fiorini, G. Magyar, P. Sinčák, and P. Dario, "Emotion modelling for social robotics applications: A review," *Journal of Bionic Engineering*, vol. 15, pp. 185–203, 2018.

[12] S. Rossi, M. Staffa, L. Bove, R. Capasso, and G. Ercolano, "User's personality and activity influence on hri comfortable distances," in *Social Robotics: 9th International Conference, ICSR 2017, Tsukuba, Japan, November 22-24, 2017, Proceedings 9*, Springer, 2017, pp. 167–177.

[13] B. Bilen, H. K. P. Uluer, and H. Kose, "Social robot navigation with adaptive proxemics based on emotions," *arXiv preprint arXiv:2401.17663*, 2024.

[14] G. Ruggiero, F. Frassinetti, Y. Coello, M. Rapuano, A. S. Di Cola, and T. Iachini, "The effect of facial expressions on peripersonal and interpersonal spaces," *Psychological research*, vol. 81, pp. 1232–1240, 2017.

[15] G. Angelopoulos, F. Vigni, A. Rossi, G. Russo, M. Turco, and S. Rossi, "Familiar acoustic cues for legible service robots," in *2022 31st IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*, IEEE, 2022, pp. 1187–1192.

[16] F. Vigni, A. Rossi, L. Miccio, and S. Rossi, "On the emotional transparency of a non-humanoid social robot," in *International Conference on Social Robotics*, Springer, 2022, pp. 290–299.

[17] F. Vigni and S. Rossi, "Exploring non-verbal strategies for initiating an hri," in *International Conference on Social Robotics*, Springer, 2022, pp. 280–289.

[18] Y. Wen, X. Wu, K. Yamane, and S. Iba, "Socially-aware mobile robot trajectories for face-to-face interactions," in *International Conference on Social Robotics*, Springer, 2022, pp. 3–13.

[19] W.-R. Ko, M. Jang, J. Lee, and J. Kim, "Adaptive behavior generation of social robots based on user behavior recognition," in *International Conference on Social Robotics*, Springer, 2022, pp. 188–197.

[20] V. Narayanan, B. M. Manoghar, V. S. Dorbala, D. Manocha, and A. Bera, "Proxemo: Gait-based emotion learning and multi-view proxemic fusion for socially-aware robot navigation," in *2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, IEEE, 2020, pp. 8200–8207.

[21] S. B. P. Samarakoon, M. V. J. Muthugala, A. B. P. Jayasekara, and M. R. Elara, "Adapting approaching proxemics of a service robot based on physical user behavior and user feedback," *User Modeling and User-Adapted Interaction*, vol. 33, no. 2, pp. 195–220, 2023.

[22] P. Papadakis, A. Spalanzani, and C. Laugier, "Social mapping of human-populated environments by implicit function learning," in *2013 IEEE/RSJ International Conference on Intelligent Robots and Systems*, IEEE, 2013, pp. 1701–1706.

[23] P. Papadakis, P. Rives, and A. Spalanzani, "Adaptive spacing in human-robot interactions," in *2014 IEEE/RSJ International Conference on Intelligent Robots and Systems*, IEEE, 2014, pp. 2627–2632.

[24] C.-P. Lam, C.-T. Chou, K.-H. Chiang, and L.-C. Fu, "Human-centered robot navigation—towards a harmoniously human–robot coexisting environment," *IEEE Transactions on Robotics*, vol. 27, no. 1, pp. 99–112, 2010.

[25] R. Zhang, W. Jiang, Z. Zhang, Y. Zheng, and S. S. Ge, "Indoor mobile robot socially concomitant navigation system," in *International Conference on Social Robotics*, Springer, 2022, pp. 485–495.

[26] A. Bera, T. Randhavane, and D. Manocha, "The emotionally intelligent robot: Improving socially-aware human prediction in crowded environments," in *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops*, 2019, pp. 0–0.

[27] Y. Kim and B. Mutlu, "How social distance shapes human–robot interaction," *International Journal of Human-Computer Studies*, vol. 72, no. 12, pp. 783–795, 2014.

[28] E. Torta, R. H. Cuijpers, J. F. Juola, and D. van der Pol, "Design of robust robotic proxemic behaviour," in *Social Robotics: Third International Conference, ICSR 2011, Amsterdam, The Netherlands, November 24-25, 2011. Proceedings 3*, Springer, 2011, pp. 21–30.

[29] M. M. Neggers, R. H. Cuijpers, and P. A. Ruijten, "Comfortable passing distances for robots," in *Social Robotics: 10th International Conference, ICSR 2018, Qingdao, China, November 28-30, 2018, Proceedings 10*, Springer, 2018, pp. 431–440.

[30] T. Cook, A. R. Roy, and K. M. Welker, "Music as an emotion regulation strategy: An examination of genres of music and their roles in emotion regulation," *Psychology of Music*, vol. 47, no. 1, pp. 144–154, 2019.

[31] C. E. Parsons, K. S. Young, E.-M. Jegindoe Elmholdt, A. Stein, and M. L. Kringelbach, "Interpreting infant emotional expressions: Parenthood has differential effects on men and women," *Quarterly journal of experimental psychology*, vol. 70, no. 3, pp. 554–564, 2017.

[32] N. Spatola, B. Kühnlenz, and G. Cheng, "Perception and evaluation in human–robot interaction: The human–robot interaction evaluation scale (hries)—a multicomponent approach of anthropomorphism," *International Journal of Social Robotics*, vol. 13, no. 7, pp. 1517–1539, 2021.

[33] G. Hoffman and X. Zhao, "A primer for conducting experiments in human–robot interaction," *ACM Transactions on Human-Robot Interaction (THRI)*, vol. 10, no. 1, pp. 1–31, 2020.

[34] L. Takayama and C. Pantofaru, "Influences on proxemic behaviors in human-robot interaction," in *2009 IEEE/RSJ International Conference on Intelligent Robots and Systems*, IEEE, 2009, pp. 5495–5502.

[35] J. De Houwer, "What are implicit measures and why are we using them," *The handbook of implicit cognition and addiction*, pp. 11–28, 2006.

[36] X. Xu, L. Liying, M. Khamis, G. Zhao, and R. Bretin, "Understanding dynamic human-robot proxemics in the case of four-legged canine-inspired robots," *arXiv preprint arXiv:2302.10729*, 2023.

[37] M. Tielman, M. Neerincx, J.-J. Meyer, and R. Looije, "Adaptive emotional expression in robot-child interaction," in *Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction*, 2014, pp. 407–414.

[38] R. Stower, N. Calvo-Barajas, G. Castellano, and A. Kappas, "A meta-analysis on children's trust in social robots," *International Journal of Social Robotics*, vol. 13, no. 8, pp. 1979–2001, 2021.