"Sit on me please": Investigating Perception of Furniture Robotic Movements Using Video Prototyping

RAY LC
City University of Hong Kong
Hong Kong SAR
LC@raylc.org

Natalie Friedman
Cornell Tech
New York, NY
nvf4@cornell.edu

J.D. Zamfirescu-Pereira
University of California, Berkeley
Berkeley, CA
zamfi@berkeley.edu

Kexue Fu
City University of Hong Kong
Hong Kong SAR
kexuefu2-c@my.cityu.edu.hk

Yanheng Li
City University of Hong Kong
Hong Kong SAR
yanhengli3-c@my.cityu.edu.hk

Wendy Ju
Cornell Tech
New York, NY
wendyju@cornell.edu

Figure 1: Evaluating participant perception of videos of how chairbot movement can affect human behavior. Video of one chair interacting with one human shown to participant (left). Video of one chair interacting with multiple humans (middle). Proposed 3D environment of multiple people interacting with chairbots in immersive spatial context (right).

ABSTRACT

As robots become embedded to greater extents in human environments, mobile furniture robots could be used to create narrate expressive movement to influence user behavior in a room. To investigate how different robot movement may affect the way humans perceive the robot's expressiveness, responsiveness, and spatial presence, we created video prototypes of chair-robots (chairbots) interacting with individuals or dyads. We used crowdsourcing to evaluate how people perceive these different movements, providing a quantitative overview of which particular movements are particularly effective in engaging perception for expressiveness and responsiveness. This work provides a still-in-progress understanding of perceptions of mobile robotic furniture actions in spatial contexts, suggesting future design strategies for real-life smart furniture interventions.

CCS CONCEPTS

• **Human-centered computing → Interaction paradigms**; **Empirical studies in HCI**.

CHI EA '24, May 11–16, 2024, Honolulu, HI, USA

ACM ISBN 979-8-4007-0331-7/24/05.
https://doi.org/10.1145/3613905.3650778

KEYWORDS

machine influence, smart furniture, persuasive technology

1 INTRODUCTION

Machines in everyday life can influence human perception of their behaviors through robotic movements. For example, in the context of robotic furniture, a moving ottoman may be interpreted as offering foot support or signaling a request to remove one's foot [17]. This extends to broader everyday environments, where individuals exhibit social responses to robotic devices. Humans might perceive an automatic door as a spatial limitation or react to the intentions and desires of a robotic trash bin [20]. The functions of robots provide clues to their anticipated behavior, and this is especially evident in the increasing use of smart furniture in environments like event venues, restaurants, cafes, or exhibition centers. Here, the need to move a large number of chairs or partitions automatically not only reduces manual labor but also introduces new challenges in coordinating these movements in spaces occupied by people, where spatial applications involving more complex and dynamic automated systems [2]. We decided to focus on the chair robot [7], which can move autonomously in space while serving the purpose of furniture, providing an example of a robot whose functional movements can affect human perception.

Studying how humans perceive and understand the nonverbal cues of robots [8] is crucial for future development of autonomous furniture systems. Understanding whether specific movements are interpreted positively or negatively is essential for enhancing the design of human-robotic furniture communication. To investigate how robot movements communicate their intentions to affect human behavior, we selected an instrument whose interaction with humans has previously been studied in spatial contexts: the chair. Chair-robot movements can explicitly signal purpose and agency [7], leading human subjects to interpret them as actionable requests. Using autonomous mobile chairs (chairbots), designers may influence human behavior through interaction with humans using programmed sequences of movements.

Although previous work has shown that bystanders have different perceptions of chairbot movements [2, 7], the perception of the interaction of a diverse range of chairbot movements with both individuals and multiple humans has not been explored. To investigate how particular chairbot movements with humans communicate their intentions to affect human behavior, we designed a series of chairbot movements involving single and pairs of humans, and utilized crowd-sourced video evaluations to probe human perception of robot movements in spatial contexts.

This work provides an assessment of how humans perceive and are impacted by the movements of mobile robotic elements, examining aspects such as responsiveness, relational dynamics, and expressiveness. We explored what are effective chairbot movements for communicating intent to humans in particular situations, and provided a framework for future integration these insights into practical applications.

2 RELATED WORK

2.1 Design of machine movements

A critical way we communicate with others is with nonverbal cues like posture, facial expression, and movements. Communicating with machines like user interfaces and robots rely on some of the same metaphors we apply to humans, such as "whether the system understand me," "where is it telling me to go," "what is going to happen now," etc. Effective communication with machines require an understanding of how humans interpret movements and nonverbal cues of machines.

Studies of movement in human-machine communication have focused on understanding situations when humans use movements in different contexts to communicate to real or artificial agents [16], and in designing systems that detect and respond to human gestures. When people were allowed to evaluate the gestures of robotic agents, a study found that they prefer gestures most like their own [15], analogous to unconscious mimicking of gestures during human conversations. In a study with mechanical ottomans, a furniture robot was able to get people to rest their feet on it, as well as understand a cue for getting their feet off: an up and down gesture [17]. Other work has explored movement from a performance art perspective [13, 14] using robotic lamps, micro-machines, and robot arms, for example, that elicit human compassion and understanding by creating a story of a troupe of robots that perform when the audience is not looking [9–12].

The chair robot was used in a study to get people to move out of the way after using overt movement behaviors like moving forward-backward or side-by-side while it moved across the room [7]. In that experiment, different physical chair movements communicated the idea that the human subject should move out of the way so it can get to the cabinet. Of the three movements used, the one most able to get humans to move away was the back and forth movement, suggesting that bystanders best respond to clear communication strategies and don't want to be interrupted. Another study of chairbots movements in-the-wild evaluated the effectiveness of four movement tactics in convincing passersby to join a ChairBot Chess Tournament. The finding of this study suggests that Forward-Back motion was the most effective strategy in getting people to come to the table and play chess, while Spinning was the worst. The findings also suggest that future robots could be effective in attracting participants to activities they may already find enjoyable. Together these robotic furniture studies show that robots can communicate with humans with movement behaviors, and that humans will perceive them with different efficacy depending on interpretation.

2.2 Design for social influence

By understanding the way human perceptions and actions are shaped by spatial arrangements and movement behaviors, we can design for purpose using patterns that situate machines and their actions in specific contexts. A related concept is "Mindless Computing," which uses persuasive technology on a subconscious level to do good [1], showing how System 1 (automatic, subconscious processing system) output can be sent to System 2 (decision-making, conscious processing) in a way to affect behavioral change. System 1 strategies don't rely on human motivation and self-control but rather on reflexive interventions that trigger behaviors without burdening the user.

Machines can exert their influence in collaboration with humans. One study described a paradigm based on human-like competencies like intentional action, collaboration, navigation, and learning [18]. In the context of robot planning of navigation, they introduced a model describing robot and human navigation as a two-way process require sensor data and active avoidance. The intention of humans is investigated in a work that uses a theory of mind kept track of by the robot to infer the human plans and needs help [5]. The robot and human make collaborative decisions, with the robot calculating a model of the human's intention, making its actions less intrusive. Similarly, data-driven approaches have been applied: in a "Mars Escape" game involving a robot with another player, a study showed that in-the-moment interpersonal dynamics affects interaction quality in a search-and-retrieval task with a human astronaut and a robot on Mars [3].

The research detailed so far takes place almost exclusively in the lab, but people interact with machines in complicated social settings. One group calls for research labs to go to workplaces, homes, and public arenas to study the complex dynamics involved when robots are asked to work with multiple people following rules of social interaction inherent in the public domain [6, 19].

These studies indicate that movement made by autonomous agents also shape human emotional response. To investigate how particular chairbot movements communicate their intentions to affect human behavior, we created videos of human-chair interactions and used crowd-sourced surveys to see how people perceive different chair movements.

The relationship of the chairs to the actors should depend on the chair both initiating change and being receptive of change. The chair has a relationship with the actors such that it can show understanding, disagreement, and responsiveness, while also being able to perform actions that communicate meaning. Therefore, we hypothesized that the perceived most-expressive chair movements will also show a high rating of the chair's responsiveness.

3 METHODS

Building on previous research that assessed the impact of three specific chairbot movements on bystanders [7], we brainstormed additional interactions involving one or more chairs and one and more participants to identify possible strategies for potential interactions. As a team, we listed out possible interactions involving humans and chairs into a table, and eliminated unfounded designs to our application. We then designed and created a set of movements that involved one or more people interacting with one chair that has agency, or with multiple chairs that work with or against each other. These movements are meant to capture stereotypical interactions with robotic chairs, and included the following (Fig. 2). "Follow me": the chair moves forward in space in the direction it wants the person to go. "I understand": the chair moves back and forth to signal acknowledgment. "I am not going": the chair shakes left and right to indicate it can't move. "I am occupied": the chair shakes so that the human can take a different seat. "I am available": the chair slides behind the human to show that it can be sat on. Other one-to-one movements deal with human-chair co-locomotion, and include the following. "I am tracking You": the chair rotates in the direction of the human walking. "After you": the chair lets the human go first when they encounter each other by stopping. "I avoid collisions": the chair walks around the preoccupied human who is on a cell phone, while she is not cognizant of the interaction. "I am on a mission": the chair does not stopping for anyone as it moves.

Table 1: Stereotypical Interactions Types We Designed

Interact with one chair		Interact with multiple chairs	
Follow me	I am not going	Work together	Let's help out
I understand	I am occupied	Sit on me please	Let's focus
I am available	I am tracking You	Let's walk together	Stop moving
After you	I avoid collisions	Let's go	
I am on a mission			

We further designed a set of interactions based on scenarios of multiple chairs helping to promote certain types of activities with multiple people, including the following (Figs. 3). "Work together": two chairs arrange themselves opposite each other to promote people talking to one another. "Sit on me please": two chairs compete to see where one human will choose to sit. "Let's help out": one chair comes into a situation with two humans and only one seat and offers itself to one of the persons. "Let's focus": the chairs arrange themselves aligned looking forward so that two humans can sit on them and focus on material on the wall. "Let's walk together": two chairs align themselves in speed so that the two humans following them can chat together. "Stop moving": two chairs bind the moving human so that she cannot go forward or backward in space. "Let's go": a chair pushes for a human to get up from a different chair and start moving. These movements are all directed at influencing human behavior and how they cooperate by using chair-based interactions like locomotion and demonstrating particular arrangements.

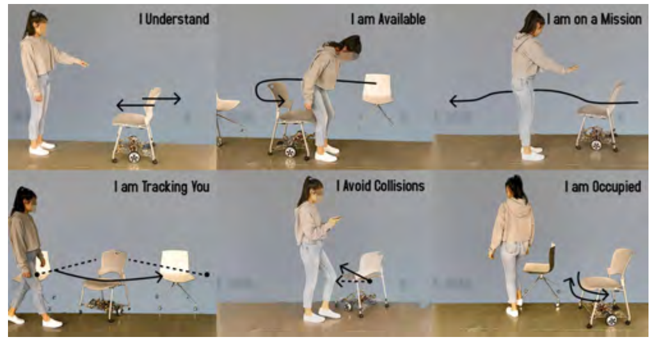

Figure 2: Examples of one-chair to one-person movements on video. "I understand": chair moves back and forth to acknowledge recognition. "I am available": chair slides behind human to indicate presence. "I am on a mission": chair doesn't stop for human. "I am tracking you": chair directs front towards the location of the human wherever she goes. "I avoid collisions": chair goes around human who doesn't notice because she's on a phone. "I am occupied": chair shrugs to indicate the seat is taken so she should go elsewhere.

We used green screen recording to simulate the movements of chairs and their interactions with humans. Next we made green-screen recordings of the interactions with student actors. One actor wore a green screen suit controlling the chairbot's movements to play the role of the chairs, while two actors served as human participants. A chroma key is used to convert green-screen content to a background image of the wall in Adobe Premiere, and the results are cropped to the same size. We used third-person points-of-view because they are the easiest to understand when compared to first-person viewpoints, and allows us to see the other human in the context better. Note that applied Wizard of Oz prototyping for this study and did not need actuators for the 360 degree of movement for the chairs.

A total of 16 videos are shown to human workers on Amazon Mechanical Turk without any labeling (n=50, 27 female, 23 male). We adapted a previous survey on human judgement of social attributes of robots [ROSAS] [4] to ask participants about the perceived responsiveness, relationship dynamic, expressiveness, and spatial presence of the chairbot in the video. Participants are asked to rate for each video under the following criteria: "Chair was responsive to the person" (Responsive measure), "Relationship between chair and the person in the scene is satisfactory" (Relationship measure), "This chair is very expressive" (Expressive measure), and "The person in the scene is affected by the chair's presence" (Affected measure). The Responsive measure examines perception of the chair's reaction to the person's actions, while the Affected measure studies perception of the person's reaction to the chair's actions. In addition to the ratings, qualitative questions like "Describe what you saw," "What's the chair's intent?", and "What is the chair communicating to the person?" are also given to the workers and the answers are coded by two independent raters whose correspondence is tested using Cohen's kappa.

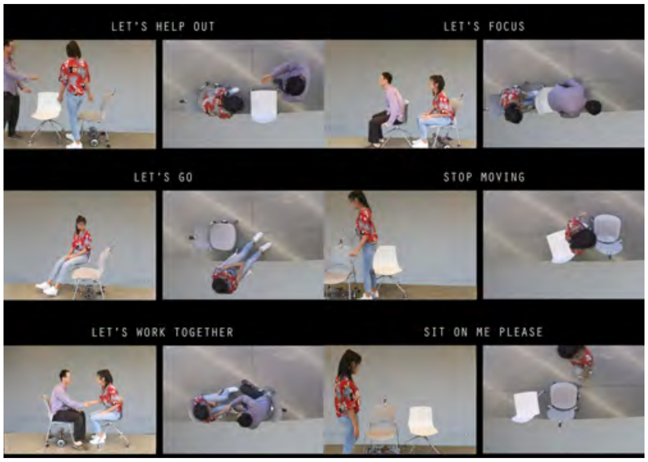

Figure 3: Examples of video-recorded multi-chair multi-person interactions that influence human behavior, viewed from side and from above. Amazon Mechanical Turk studies used on the videos on the left side without labels. "Let's help out": a moving chair helps out a group of humans who are short on chairs by showing up and making itself available. "Let's go": a moving chair urges a human to get out of her seat and walk. "Let's focus": two chairs arrange themselves to make two humans look at the content in front of them. "Stop moving": two chairs stop a human on its track so she has to stop. "Work together" two chairs face each other to encourage humans to meet each other and chat. "Sit on me please" two chairs compete for the sedentary attention of a single human.

4 RESULTS

To see how ratings vary with the question asked and the interaction video showed, we ran a two-way ANOVA using Interaction*Question as explanatory variables, and found Interaction, Question, and Interaction:Question to be significant ($p < 0.05$). Posthoc test (Tukey) reveals Expressive-Affected, Responsive-Expressive, and Responsive-Relationship to be significantly different, but that Responsive and Affected ratings are not significantly different ($p=0.6014$), indicating that whether chair serves as agent of change or subject of change by the person does not affect ratings about its expressiveness and relationship with the person.

Summary data (Fig. **??**) shows that "I am on a Mission" scored the lowest in all questions except Affected, because the chair acts independent of the person in going its own way. Interactions with high ratings on Affected tends to have high Responsive scores also, as suggested by the posthoc comparison (e.g. "I am Not Going," "Stop Moving," and "Let's Go.") "I Avoid Collisions," "I am Tracking You," and "After You" all scored low on Affected because the person goes her own way without being interrupted by the chair in both cases. The proportion of variance attributable to Interaction is 0.15, to Question, is 0.027, and to Interaction: Question is 0.23, showing the different responses to each question based on the video.

To see how each of the questions correlate with each other on each video of interaction, we ran a multiple regression model using Interaction*Question as explanatory variables (Multiple $R2=0.4004$). Only the coefficients for the Relationship and Responsive questions are significant, suggesting that the other variables may be correlated with these two, so that regression only need these two to explain the ratings. If we ran separate linear models for the ratings to each separate question, we get a similar result, where for the Responsive and Relationship data, the $R2=0.4617$, and 0.4243, respectively, but for the Expressive data, $R2=0.2002$.

To verify this finding, we computed the correlation coefficients between data from Responsive and Expressive (0.5657), Relationship and Expressive (0.1502), and Affected and Expressive (0.2239). This shows that Expressive is not a great explainer for the ratings because it correlates with Responsive, which explains a great deal of variance in the data. This lends support to one part of the hypothesis that chairs that appear to be responsive to the person in the video is perceived as expressive, even though its behavior is in reaction to the person.

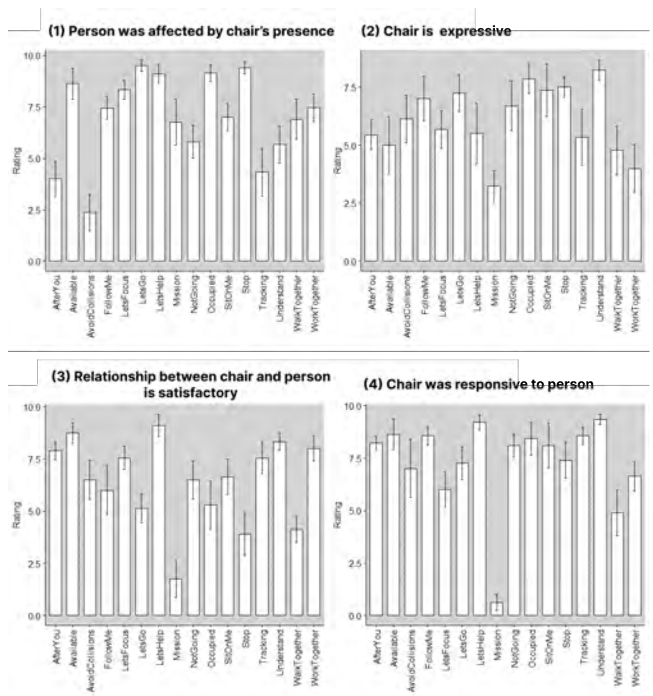

Figure 4: Human ratings on questions: (1) Affected "the person in the scene is affected by the chair's presence"; (2) Expressive "this chair is very expressive"; (3) Relationship "relationship between chair and the person in the scene is satisfactory"; (4) Responsive "chair was responsive to the person" for each of the videos of chair-human interactions. Different gestures showing different ability for each gesture to influence participant perception.

5 DISCUSSION

This study shows that people's perception of whether chair expressions are affecting humans is linked to whether chairs are responsive to humans. This supports the idea that chairs and humans as perceived in the video affect each other mutually, so that agency from one side is reflected in agency in the other. Both sides of the influence are reflected in the question of expressivity, which summarizes the interactions between chairs and people.

The methods utilized here allow us to evaluate which robotic movements are effective in communicating intent and response to humans using crowd-sourced data evaluation. For example, "Let's focus," "I am Occupied," and "Stop Moving" are most effective at evoking perception that the chair affects people by performing the

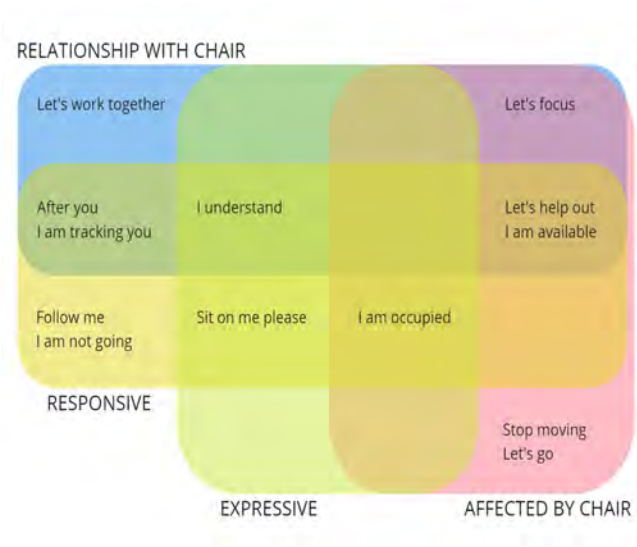

Figure 5: A visual representation of the highest rated chair movements for each combination of questions representing perceptual categories. The colored areas are associated with each of the 4 questions shown in Fig.4. Overlapping areas in the Venn Diagram indicate high ratings to multiple categories for that particular gesture.

gesture. On the other hand, chairs in "Follow Me," "I Understand," and "Let's Help Out" are best perceived as being responsive to the human. In particular, "I am Available" and "Let's Help Out" score high on both responsiveness and ability to affect, giving them a perceived high level of relationship with humans in the scene. We also noticed that the "I am Tracking You" movements is perceived to be highly responsive to the actor while not affecting her behavior at all (Fig. **??**). This means that the "Tracking You" gesture itself would not change the way participants behave. This led us to further employ the "Tracking You" movement in future studies in virtual environments. This video prototyping strategy allowed us to plan and posit certain chair movements as maximally effective at evoking particular responses from humans.

6 LIMITATIONS AND FUTURE WORK

We employed crowdsourcing to analyze how autonomous furniture movements influence human perception. Our research focuses on four dimensions: perceived relationship with chairs, responsiveness, expressiveness, and affectedness in space. Particular movements like 'Tracking You,' is perceived to be especially responsive to the user. However, our studies utilizes videos of interactions that occur in lab. The question remains: how do these movement-based influences function in real-world scenarios and impact human capacity, perception, and intended behavior? Conducting in-the-wild studies is difficult but yields data likely to be replicable in future systems [2]. While images and videos cannot replicate the realistic impact of spatial robots, we propose that experiencing chairbot movement in immersive spaces provides a framework for understanding interactions in more natural settings without constructing a physical, mechanically controlled agent. We also did not use first-person points of view for the study, which may limit the usefulness of the data for modeling how people actually behave in space when interacting with the furniture robots. Instead, we uncovered information about their perception of the entire setup as a prototype of the interaction as from third-person viewpoint.

Figure 6: Proposed future work to involve participants in VR to mimick chairbots movements in environments more akin to real-life situations. (left) Proposed participant in VR. (middle) VR environment for mimicking a group discussion enabled by circular chair arrangement. (right) Paths taken by mobile chairbot in VR context.

In the next phase, we aim to model real-life situations in VR. We will create scenes where chairbots use movements like 'Tracking You' to prototype physically unfeasible movements in the environment. This approach captures the explicit, movement-based influence of our work, placing it in an interactive space that cannot be fully experienced through video prototypes. Additionally, in VR, we can assess movements across different dimensions in various spatial scenarios, and can immersively simulate scenerios like chairbot were used to recruiting chess players in the wild which is studied by previous work [2]. VR can prototype real-life examples such as the 'Let's Focus' gesture, that can be applied in an educational setting to promote students to pay attention, while 'Let's Work Together' can be used in the group ideation phase. Meanwhile, communicative movements like 'I Understand' and 'I am Occupied' can be utilized in crowded conference applications to indicate who has access to a seat.

Conducting experiments in VR also enables more participants to be online at the same time than in real life, and supports the exploration of how robot movements affect multiplayer interactions. To simulate realistic scenarios of spatial influence with robotic chairs, we plan to create situations of physical chair use in a room, where chairbots dynamically arrange themselves for group discussions, debates, and presentations. In the VR environment, the chairbots can move between scenarios, mimicking how smart furniture can alter participants' capabilities and actions in natural settings. This begins to explore how robots using different nonverbal cues and movements can organize people's activities in a shared space throughout the day.

7 CONCLUSION

Our research explores the realm of mobile furniture robotics, focusing on robotic chairs and their potential to alter human perception through expressive movements in communal spaces. We designed a range of chair bot behaviors, examining their interactions with both individuals and groups. Utilizing crowdsourcing, we quantitatively evaluated public reaction to these varied movements, gaining insights into how these robots' actions are perceived across different dimensions. This study paves the way for future investigations, such as simulating chair bot movements in VR immersive environments, with the aim of applying these discoveries in real-world scenarios and enhancing human-robot interaction strategies for everyday use.

REFERENCES

[1] Alexander T. Adams, Jean Costa, Malte F. Jung, and Tanzeem Choudhury. 2015. Mindless Computing: Designing Technologies to Subtly Influence Behavior. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing* (Osaka, Japan) *(UbiComp '15)*. Association for Computing Machinery, New York, NY, USA, 719–730. https://doi.org/10.1145/2750858.2805843

[2] Abhijeet Agnihotri and Heather Knight. 2019. Persuasive chairbots: A (mostly) robot-recruited experiment. In *2019 28th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. IEEE, 1–7.

[3] Cynthia Breazeal, Nick DePalma, Jeff Orkin, Sonia Chernova, and Malte Jung. 2013. Crowdsourcing Human-Robot Interaction: New Methods and System Evaluation in a Public Environment. *J. Hum.-Robot Interact.* 2, 1 (Feb. 2013), 82–111. https://doi.org/10.5898/JHRI.2.1.Breazeal

[4] Colleen M Carpinella, Alisa B Wyman, Michael A Perez, and Steven J Stroessner. 2017. The robotic social attributes scale (RoSAS) development and validation. In *Proceedings of the 2017 ACM/IEEE International Conference on human-robot interaction*. 254–262.

[5] Orhan Görür, Benjamin Rosman, Guy Hoffman, and Sahin Albayrak. 2017. Toward Integrating Theory of Mind into Adaptive Decision- Making of Social Robots to Understand Human Intention.

[6] Malte Jung and Pamela Hinds. 2018. Robots in the Wild: A Time for More Robust Theories of Human-Robot Interaction. *J. Hum.-Robot Interact.* 7, 1, Article 2 (May 2018), 5 pages. https://doi.org/10.1145/3208975

[7] Heather Knight, Timothy Lee, Brittany Hallawell, and Wendy Ju. 2017. I get it already! the influence of ChairBot motion gestures on bystander response. In *2017 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*. 443–448.

[8] Heather Knight and Reid Simmons. 2016. Laban head-motions convey robot state: A call for robot body language. In *2016 IEEE international conference on robotics and automation (ICRA)*. IEEE, 2881–2888.

[9] RAY LC. 2019. Secret Lives of Machines. In *Proceedings of the IEEE ICRA-X Robotic Art Program*, Vol. 1. 21–23.

[10] RAY LC. 2021. NOW YOU SEE ME, NOW YOU DON'T: revealing personality and narratives from playful interactions with machines being watched. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Salzburg, Austria) *(TEI '21)*. Association for Computing Machinery, New York, NY, USA, Article 43, 7 pages. https://doi.org/10.1145/3430524.3442448

[11] RAY LC, Aaliyah Alcibar, Alejandro Baez, and Stefanie Torossian. 2020. Machine Gaze: Self-Identification Through Play With a computer Vision-Based Projection and Robotics System. *Frontiers in Robotics and AI* 7 (2020), 202. https://doi.org/10.3389/frobt.2020.580835

[12] RAY LC, Maurice Benayoun, Permagnus Lindborg, Hongshen Xu, Hin Chung Chan, Ka Man Yip, and Tianyi Zhang. 2022. Power Chess: Robot-to-Robot Nonverbal Emotional Expression Applied to Competitive Play. In *10th International Conference on Digital and Interactive Arts* (Aveiro, Portugal, series = ARTECH 2021). Association for Computing Machinery, New York, NY, USA, Article 2, 11 pages. https://doi.org/10.1145/3483529.3483844

[13] RAY LC, Sijia Liu, and Qiaosheng Lyu. 2023. IN/ACTive: A Distance-Technology-Mediated Stage for Performer-Audience Telepresence and Environmental Control. In *Proceedings of the 31st ACM International Conference on Multimedia* (Ottawa ON, Canada) *(MM '23)*. Association for Computing Machinery, New York, NY, USA, 6989–6997. https://doi.org/10.1145/3581783.3613791

[14] Ray LC, Sihuang Man, Xiying Bao, Jinhan Wan, Bo Wen, and Zijing Song. 2023. "Contradiction pushes me to improvise": Performer Expressivity and Engagement in Distanced Movement Performance Paradigms. *Proc. ACM Hum.-Comput. Interact.* 7, CSCW2, Article 333 (oct 2023), 26 pages. https://doi.org/10.1145/3610182

[15] Pengcheng Luo, Victor Ng-Thow-Hing, and Michael Neff. 2013. An Examination of Whether People Prefer Agents Whose Gestures Mimic Their Own. In *Intelligent Virtual Agents*, Ruth Aylett, Brigitte Krenn, Catherine Pelachaud, and Hiroshi Shimodaira (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 229–238.

[16] Lisette Mol, Emiel Krahmer, Alfons Maes, and Marc Swerts. 2009. The communicative import of gestures: Evidence from a comparative analysis of human-human and human-machine interactions. *Gesture* 9 (06 2009), 97–126. https://doi.org/10.1075/gest.9.1.04mol

[17] David Sirkin, Brian Mok, Stephen Yang, and Wendy Ju. 2015. Mechanical Ottoman: How Robotic Furniture Offers and Withdraws Support. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction* (Portland, Oregon, USA) *(HRI '15)*. Association for Computing Machinery, New York, NY, USA, 11–18. https://doi.org/10.1145/2696454.2696461

[18] Andrea Thomaz, Guy Hoffman, and Maya Cakmak. 2016. Computational Human-Robot Interaction. *Foundations and Trends in Robotics* 4, 2-3 (2016), 105–223. https://doi.org/10.1561/2300000049

[19] A. Weiss, R. Bernhaupt, M. Tscheligi, D. Wollherr, K. Kuhnlenz, and M. Buss. 2008. A methodological variation for acceptance evaluation of Human-Robot Interaction in public places. In *RO-MAN 2008 - The 17th IEEE International Symposium on Robot and Human Interactive Communication*. 713–718. https://doi.org/10.1109/ROMAN.2008.4600751

[20] Stephen Yang, Brian Ka-Jun Mok, David Sirkin, Hillary Page Ive, Rohan Maheshwari, Kerstin Fischer, and Wendy Ju. 2015. Experiences developing socially acceptable interactions for a robotic trash barrel. In *2015 24th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*. IEEE, 277–284.