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Exploring Communicatory Gestures for Simple Multi-Robot Systems

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Abstract. The presented online study (N=405) explores the impact of translational (towards, away, sideways) and rotational (spin and circle) motion patterns on the perceived communications of a three-robot group. All gestures were performed relative to a small humanoid figure at two speeds (slow and fast). Three of the gestures strongly predicted communicatory interpretation: *sideways* and *away* were seen as scared or fearful, and *spin* was seen as excited and joyful. *Circle* had low convergence and was seen as confused or frustrated. *Towards*, on the other hand, had a bimodal distribution: **slowly** towards was seen as greeting, whereas **fast** towards was seen as confrontational. The context prompts (party vs. meeting) did not affect participant interpretations.

Keywords: expressive motion · robotics · multi-robot

1 Introduction and Related Works

Clear and efficient communication between humans and robots is crucial for successful human-robot interaction [4, 3]. This work explores how emotions can be expressed with simple multi-robot motion using five different synchronous gestures on three simple robots and exploring how speed and context change the interpretation of expression of these gestures. In multi-robot systems, group motion patterns can be seen as exaggerated gestures, a powerful way for robots to communicate to humans without words [8].

While there have been many studies that looked at single robot motion and gestures [11, 7, 9, 6], this work explores whether such gestures can also be read via a robot group. Such investigations extend prior findings showing simple mobile robot gestures have strong communicatory power [7, 1]. Prior work in multiple robots has illustrated communicatory potentials for multi-robot systems, using parameterized motion generation [5, 12] and human-controlled gesture [13, 2].

The gesture and speed research conditions used in this paper were inspired by our prior work in single-root expression [10]. This study (first author participated) examined how a simple robot could incite storytelling in an improv scene using gesture (it did). This paper evaluates these same five gestures, finding similar communicatory interpretations when gestures are performed by congruent multi-robot systems.

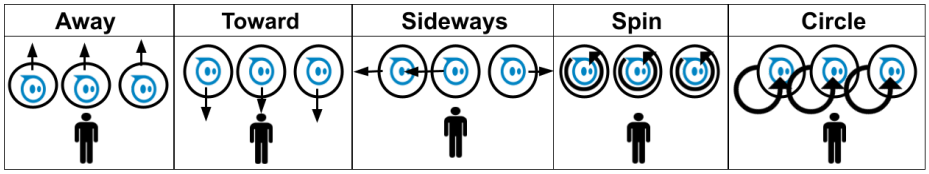


Fig. 1: Each isolated gesture was performed synchronously with all three robots.

2 Study Design

Three independent variables were explored to see how they affected perceptions of a multi-robot group: (1) gesture, meaning the way the multi-robot group moved as seen in Figure 1; (2) speed, being how fast the robots performed the gesture; and (3) the context given to participants about the robots. The gestures replicated our prior work on a single robot system [10], representative of Cartesian linear and rotational motions. Each gesture was performed at two speeds (fast and slow). These two speeds were chosen based on the max and min speed range of the Sphero robots. Finally, all participants were presented with one of three contexts ("A robot walks into a party," "A robot walks into a meeting," or no context).

Online Study Setup. An online video study was run using Amazon's MTurk Service, which allowed for the exploration of more variables with more participants than an in-person study. Each video opened with three robots in a line in front of a humanoid figure with a plain white background, as seen in Figure 1. The robots were placed in a straight line formation to reduce what role the formation played in perceived communication. Each participant was shown a video with one of five gestures at one of two speeds with one of three video contexts and was asked one question out of five possible questions.

Two questions used a seven-point Likert scale. Participants were given a sentence with a drop down menu of Likert scale responses. For example, the question "The actions taken were [blank]" had answer options "very positive," "positive," "somewhat positive," "neither positive or negative," "somewhat negative," "negative," and "very negative." Three questions were open-ended. Participants wrote a response after watching the video. The questions are as follows:

1. The actions taken were [very positive to very negative] (Likert).
2. The human felt [very welcome to very unwelcome] (Likert).
3. What emotion(s) are the robots portraying? (Extended Response)
4. Describe the story of what happened. (Extended Response)
5. What were the robots trying to achieve? (Extended Response)

Analysis Methods. The study was between-participants with non-normal data for the Likert scale questions, so Kruskal-Wallis tests and Mann-Whitney U tests were run to determine significance of the data. Each extended response was coded using grounded coding to find important positive, negative, and neutral

language used. There were three categories for important language used: (1) robot actions/reactions; (2) robot descriptions; and (3) robot emotions. Positive language was given a value of 1 and included words like "joy". Negative language was given a value of -1 and included words like "fear". Neutral language was given a value of 0 and included words like "following". In each response, the total positive, negative, and neutral language was totaled and averaged for a single value for each response.

3 Results

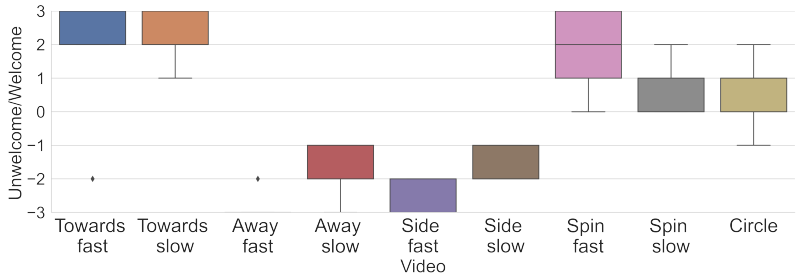
Participant Attributions of Robot Motion Results. The data showed a consistent trend in the influence gestures had in the interpretation of the robots' actions and emotions. Towards and spin were positive/welcoming, away and sideways were negative/unwelcoming, and circle was slightly positive/welcoming, but had a higher variance and neutrality. Context had no significant results.

For the question "the human felt [welcome/unwelcome]," it was seen that the sideways and away gestures were viewed as very unwelcoming. Towards was viewed as very welcoming and spin was somewhat welcoming. Circle was viewed as slightly welcoming, but was more neutral than any of the other gestures. The slow speed added more variance or neutrality for each gesture. Away, sideways, and spin had significant difference between fast and slow. However, this did not change the meaning of the movement; it simply skewed the slow speed towards neutrality. Results can be seen in Figure 2a.

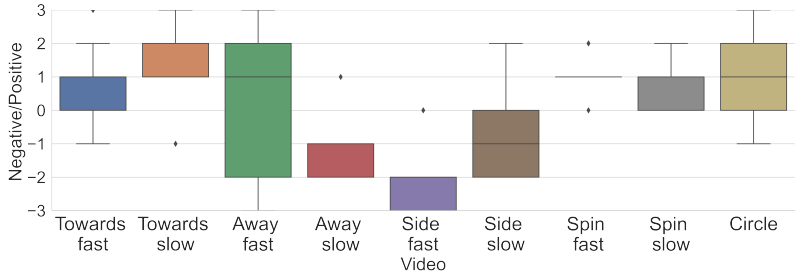
The results for the question "the actions taken were [positive/negative]," varied more than [welcome/unwelcome], but showed similar trends with all five gestures but with higher variance in responses. Spin had the lowest variance in answers and was viewed as somewhat positive. Towards and circle were also viewed as somewhat positive, but with a higher range in answers. Sideways and away had high variance. Away was somewhat negative and sideways was viewed as negative. Speed did not switch the views any of the gestures, but the slower speed pushed results to be more neutral. This additional neutrality at the slow speed was significant in the sideways gesture. Results can be seen in Figure 2b.

Extended Response Results. Overall, the results were similar to the Likert scale results where gesture was the leading variable and speed had some affect on the perceived expression of the robots. The special case was the towards gesture, which switched interpreted expressions based on speed.

Gestures affected participants' views on whether interaction between the robot and the human was described positively or negatively. Away and sideways led participants to think the robots were afraid and uncertain. The robots were often described as "scared" and "fearful." Most descriptions did not include language of aggression, but rather avoidance and wariness of the human. Spin was viewed positively with the robots' emotions often being described as "joyful" and "excited." The spin was sometimes described as a dance or an expression excitement. Circle was also sometimes described as a dance but the robots were



(a) The results from answers to the question "The human felt [welcome/unwelcome]" for each gesture at two different different speeds.



(b) The results from answers to the question "The actions taken were [negative/positive]" for each gesture at two different different speeds.

Fig. 2: Participant survey responses to Likert scale questions.

also described as "confused" or "frustrated." The towards gesture was highly variant because in these responses the gesture was dependent on speed.

For away, sideways, and spin, the fast and slow speeds did not change the perceived expression of the robots. The slow speed created more neutral responses for each gesture. The only motion where speed did affect the response was the towards motion. At a fast speed, the towards motion was interpreted as negative with participants saying the robots were "trying to block the human" and "confront the human angrily." At a slow speed the towards motion was interpreted as positive with participants saying the robots were "trying to greet the human."

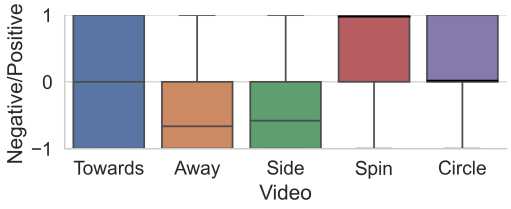


Fig. 3: A comparison of the descriptors used by participants for the five gestures in the extended response questions.

4 Discussion and Conclusions

Gesture significantly predicted communicatory interpretations across the board: (1) **Move away** was rated negatively, indicating fear/uncertainty or disengagement from the interaction. (2) **Sideways** was rated negatively, indicating fear or uncertainty relative to the figurine. (3) **Towards** had two interpretations: **slow towards** was seen as welcome, engaging, excited, whereas **fast towards** was seen as aggressive/confronting. (4) **Spin** was interpreted very positively, indicating "super happy," "joy," or similar. (5) **Moving in a circle** had more variation, ranging from neutral/happy to confused/frustrated, seeming to require additional cues. While speed did not flip the view of most gestures, the slower speed significantly neutralized the perception of the gestures.

This early work demonstrates the relevance of prior HRI motion communication research to domains in which multiple robots might operate in and around people. We conclude that the simple gestures can be used for communication by multi-robot groups and that such gestures have social and functional communicatory significance. The results show that four of the five gestures had convergent communicatory interpretations, though one of the four, *towards*, had a further division of communication at varied speeds ranging from more welcoming/friendly (when slow) to more threatening/hostile (when fast). Future work will continue to explore ways in which varied motions within the group affect multi-robot communications or indicate roles or intent within a robot group.

References

1. Agnihotri, A., Knight, H.: Persuasive chairbots. In: Ro-MAN. pp. 1–7. IEEE (2019)
2. Alonso-Mora, Javier, e.a.: Gesture based human-multi-robot swarm interaction and its application to an interactive display. In: ICRA. pp. 5948–5953. IEEE (2015)
3. Breazeal, Cynthia, e.a.: Effects of nonverbal communication on efficiency and robustness in human-robot teamwork. In: IROS. pp. 708–713. IEEE (2005)
4. Dragan, Anca D, e.a.: Legibility and predictability of robot motion. In: HRI. pp. 301–308. ACM/IEEE (2013)
5. Guzzi, Jérôme, e.a.: A model of artificial emotions for behavior-modulation and implicit coordination in multi-robot systems. In: GECCO. pp. 21–28 (2018)
6. Hoffman, G., Weinberg, G.: Gesture-based human-robot jazz improvisation. In: ICRA. pp. 582–587. IEEE (2010)
7. Knight, Heather, e.a.: I get it already! the influence of chairbot motion gestures on bystander response. In: Ro-MAN. pp. 443–448. IEEE (2017)
8. McNeill, D.: Hand and Mind. University Of Chicago Press, Chicago, IL (1992)
9. Perzanowski, D, e.a.: Integrating natural language and gesture in a robotics domain. ISIC (1998)
10. Rond, Jesse, e.a.: Improv with robots. Ro-MAN (2019)
11. Salem, Maha, e.a.: Generation and evaluation of communicative robot gesture. International Journal of Social Robotics **4**(2), 201–217 (2012)
12. Santos, M., Egerstedt, M.: From motions to emotions. International Journal of Social Robotics pp. 1–14 (2020)
13. St-Onge, David, e.a.: Engaging with robotic swarms: Commands from expressive motion. ACM Transactions on Human-Robot Interaction **8**(2), 1–26 (2019)