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Persuasive ChairBots: A (Mostly) Robot-Recruited Experiment

Abhijeet Agnihotri & Dr. Heather Knight
Collaborative Robotics and Intelligent Systems Institute
Oregon State University
Corvallis, OR, USA
{agnihota, knighth}@oregonstate.edu

***Abstract*—Robot furniture is a growing area of robotics research, as people easily anthropomorphize these simple robots and they fit in easily to many human environments. Could they also be of service in recruiting people to play chess? Prior work has found motion gestures to aid in persuasion, but this work has mostly occurred in in-lab studies and has not yet been applied to robot furniture. This paper assessed the efficacy of four motion strategies in persuading passerbyers to participate in a ChairBot Chess Tournament, which consisted of a table with a chessboard and two ChairBots – one for the white team, and another for the black team. The study occurred over a six-week period, seeking passersby to play chess in the atrium of our Computer Science building for an hour each Friday. *Forward-Back* motion was the most effective strategy in getting people to come to the table and play chess, while *Spinning* was the worst. Overall, people found the ChairBots to be friendly and somewhat dog-like. In-the-wild studies are challenging, but produce data that is highly likely to be replicable in future versions of the system. The results also support the potential of future robots to recruit participants to activities that they might already enjoy.**

***Keywords*—human-robot interaction; robot furniture; robot persuasion; chairbot; expressive motion.**

Fig. 1. *ChairBot chess tournament setup*. Two ChairBots near the table having a chessboard on it in the computer science school atrium. As seen here, *'White's turn'* ChairBot is parked at the table and the other chair is outside attempting to recruit bystanders and passerbyers because its Black's turn at the chessboard.

I. INTRODUCTION

Intelligence is entering objects all around us and furniture will likely become part of this. Robot furniture can offer an inexpensive research platform for robotics because it meshes well with our everyday lives as a pervasive object, and its simple form is a good proxy for common consumer robots such as Roombas or telepresence platforms. Functional robot furniture can also benefit in situations when many chairs need to be rearranged at a high frequency, such as weddings, conferences and events. Doing so would reduce the workload on the people in the space, but introduces new communication challenges because this arrangement would need to happen around people.

While there have been two papers considering the expressive capabilities of robot furniture [1] [2], there is still significant work to be done before such systems could be deployed in the real world. These prior works have found that robots can influence human reactions such as moving out of the way when a chair is passing, or raising one's feet as a robot ottoman wiggles in front of a seated user. To further develop this work, [3] has shown significant benefits to conducting wizard-of-oz studies in real world. Such studies illustrate ways in which simple robots should be programmed in the future. Moreover, as social robotics researchers, we were curious about the potential of robots to recruit their own study participants in real-world settings.

The approach in this paper is unique in several ways: it explores the concept of persuasion, it utilizes more than one robot, and it takes place in a real-world environment. Rather than just asking someone to move out of the way, the robot seeks to interrupt what they were previously doing, and come and play a move of chess. This study involves a six-week "*ChairBot chess tournament*," with the aim of exploring persuasive communication for simple robots. During the six-week experiment, two ChairBots sought out participants for a game of chess in a public atrium on campus (Fig. 1). One of the robots corresponded to the white pieces, and another to the black; there was also a sign on the table asking people to play just one move only to enable cycling of participants. The ChairBots would appear each Friday for an hour, and they were controlled by a remote robot teleoperator out of view from an office on the second floor. There was also a confederate in the area who could observe participants and interview a small subset of the people interacting with the robot.

During the deployment, we explored four recruitment strategies, all of which used ChairBot's motion capabilities. The control condition was *None*, i.e., no motion at all, the chair would stay by or outside the table. The moving conditions were *Forward-Back* (occurring in front of the table), *Approach* (the robot seeks out someone away from the table), and *Spin* (the robot spins in space, at a location close or far from the table). The human behavior annotations were *played a chess move*, *went to table*, and *sat on chair*. Our expected results are encapsulated by the following hypotheses:

1) H1: Forward-back and Spin would be most effective at getting people to play a move of chess and to sit.
2) H2: Approach people outside the table area would be most successful in getting people come to the table.
3) H3: None would be least effective for all behavioral measures.

The *None* strategy was surprisingly effective, likely due to people's inclination to play chess and *Spin* was not effective at all. H1 was partially validated; forward-back motion had the highest conversion rate for getting people to come sit at the table and play chess, but H2 was not, with *Approach* performing worse than both *Forward-Back* and *None* at getting people to come to the table. The reason we include the word mostly in the title is because, as shown by the *None* strategy, chessboard at the table was fairly effective at recruiting participants all by itself.

Overall, 81 chess moves were played, with 188 independent visits to the table, and 59 instances of people sitting on the chairs during the six hours and nineteen minutes of collected video data. This bodes well for future in-the-wild studies of robots, as the robot was successful in recruiting 13.5% of people entering the scene to play chess, and almost one third of all people to come and check out the table. The robot (and chessboard) were successful at recruiting many participants on their own, so perhaps robots *can* recruit their own study participants. The simple motion behavior results also provide useful opportunities for future work, indicating useful strategies that can now be programmed into an autonomous version of this system.

II. BACKGROUND

Minimal social robots are robots that have limited degrees of freedom but exude certain characteristics that enables them to engage with users socially. As these robots are starting to be integrated into our everyday lives, their success heavily depends on their ability to effectively communicate and interact with us. Simple scenarios in which a robot conveys information to a human, robot's ability could be enhanced given a deeper understanding of persuasion in the context of human robot interaction. These robots can further increase their utility with moving around and being responsive to people. Movement and gestures are important to the coordination and performance of joint activities, where they serve to communicate intentions and refer to objects of common ground [4] [1]. Therefore, modeling non-verbal behaviors like motion is key for designing socially interactive robots, especially when they do not have a human-like form.

Robotic furniture are instances of minimal social robots, and thus much rely on non-verbal communication [5] [1]. In the past, a robotic ottoman explored expressive motion and encouraged participants to put up their feet up by approaching in different manners [1]. Similarly, consider a familiar object like a chair and embellishing it with actuation while keeping it simple [6]. Several reasons for this approach have been discussed in the past including the exceeding expectations one has of a robot bearing a human form and the need for emphasis on behavior over appearance [5], and studies demonstrate that non-anthropomorphic robots have a calming effect on humans [7]. These simple, recognizable robots can be more easily accepted by us when compared to anthropomorphic robots. Prior work in designing these robots tell us that complex set of movements alone from minimal number of DoFs are able to produce desired interactions [5]. Movement and gestures are important to the coordination and performance of joint activities, where they serve to communicate intentions and refer to objects of common ground [8] [1]. Previous work with ChairBots presented a methodology to design personalities in a café setup, where people themselves could design motion behaviors of a *friendly* or a *grumpy* chair [6]. Other work with ChairBots has demonstrated robot intent via gestures such as forward-back and side-to-side [2]. Although, there has been work with expressive motion in robotic furniture, work that specifically evaluated the effect of motion behaviors on the persuasive power of the robot is very limited.

Persuasive robotics is the scientific study of robots - artificial, embodied agents - that are intentionally designed to change a persons behavior, attitudes, and/or cognitive processes [9]. Prior work in persuasive robotics has looked at the effect of gender [9], speech [10] [11], gaze [12] [13], gestures or motion [11] [13] on robot's persuasive power. Prior study [14] has also examined the effect of reactive movements when performed by a non-humanoid robots shaped like a chair and cube to analyze intention attribution. In [15], a persuasive robot with the highest number of interactive social cues like head mimicry lowered psychological reactance and induced liking.

Prior work [11] showed that motion behaviors alone improved compliance and increased effectiveness, while verbal behaviors alone did not. Prior study with ChairBots [2] suggested the use of forward-back gesture for communicating robot's intent to pass by a bystander. Other work with robot motion communication has studied the effect of velocity on perception of cobot's state [16] and how the same motion characteristic mean a different state for robot heads doing a particular task [17]. While in [13], the authors showed with a NAO robot the dominance of gaze over gestures in persuasion power. However, prior work in human-human communication suggested the use of gestures to improve communication [18] and earlier research in robotics has suggested that robot's gesture can influence variables that are related to persuasion [19] [2], although direct evidence for persuasiveness due to

Fig. 2. Before the start of the session, the two ChairBots are parked at the table. A note saying "*please play a single move only*" is placed on the table for enabling the cycling of participants.

robotic gestures is still lacking. Hence, we focus on the effects of robot motion behaviors on robot persuasiveness using ChairBots.

III. CHAIRBOT CHESS TOURNAMENT

This section discusses the motivation for running an in-the-wild ChairBot chess tournament, details the study setup and experimental manipulations, describes the data collection process, and finishes with a discussion of the labor-intensive video coding process. The user study took place after getting IRB approval from Oregon State University.

A. Why Robot Chess?

One of the aims of this study was to explore robot motion strategies in naturalistic in-the-wild scenarios. We wanted a familiar object of interest to explore recruitment by the robot and the object respectively. We were able to secure many passersby to be part of our experiment and generate enough data to do a quantitative analyses. The idea remained to explore persuasion as it applies to minimal robots – ChairBots; and specifically persuading people to play a move of chess. Finally, we wanted to accommodate use of multiple robots, so it's interesting to place two robots on different teams. Even though, that was not the main focus of this experiment but this experiment let us differentiate the role of the two robots – white's and black's turn.

B. Study Setup

"ChairBot chess tournament" analyzed robot motion behaviors for persuading a passerbyer to play chess. A description of the ChairBot platform used for this study is explained in prior work [2] [6] [20]. A stefan IKEA chair is used as the chair and fits with the neato robot base using a laser cut chassis, which have springs, so when a person sits on the chair all the weight goes through the pegs and not through the robot. As shown in Fig. 1, there were two ChairBots parked at a table with a chessboard placed on it. Neato robot bases were connected to micro-processors which were connected to a central WiFi network, and ran the Robot Operating System. The two ChairBots had '*white's turn*' and '*black's turn*' written on them. There were two cameras in the environment: (1) Overhead camera (*for video recording and human teleoperator*), and (2) Static camera in the environment (*for video recording*). The ChairBots were teleoperated by a human present in a different room in the building. The control interface constituted of a laptop with video feed from the overhead camera along with a joystick controller that let the human switch between different ChairBots and manually trigger motion behaviors.

This study ran over a six-week period in which the ChairBot chess tournament appeared each Friday afternoon in our computer science building by a café for an hour. The study evaluated four recruitment strategies, as illustrated in Fig. 3. Forward-back gesture was used as it was successful in attracting bystander's attention and expressing intent in ChairBots [2]. Approach strategy was inspired from improv sessions and our past deployments of the ChairBot system, we wanted to explore the effectiveness of approaching outside. Spinning and None strategies were used as rather control strategies, where spinning is continuous motion at a fixed robot location and None is not doing any motion at all.

In all the six sessions, ChairBots randomly chose an action and tried its luck in recruiting the participant. Once the ChairBot was successful in leading a person to the table, it would scoot in and offer itself as a seat. At the beginning of each session, ChairBot with '*white's turn*' would become active and try to recruit participants to play a chess move at the table. Once a chess move was played, the '*white's turn*' ChairBot would park itself at the table and the other ChairBot would become active and try to do the same. Also, in order to maintain cycling of participants we placed a note on the table which said "*please play a single move only*". For every 10 minutes or for an interesting interaction, an assistant would perform a semi-structured interview with the participant to ask open ended question about robot intent and persuasion.

C. Data collection: Video and Informal Surveys

The two data channels for this analysis were video that allowed us to code for people's behavioral responses to the robot and study setup, as well as interviews to a subset of people experiencing the ChairBot Chess Tournament. We explicitly decided to approach 10% or less of all participants to respect the in-the-wild nature of the study, and minimize impact on people's natural behaviors. The fact that the teleoperator was also in a far-away location also helped in this goal.

Two video cameras (*GoPro*) were used to collect videos during each session. One was an overhead camera and another was down in the interaction square of ChairBot chess setup. Videos from both the cameras were recorded at all times, and the video feed from the overhead camera was piped to the teleoperating interface and used by the teleoperator to control ChairBots.

During each session, a human confederate would invite a subset of the participants to discuss their experiences

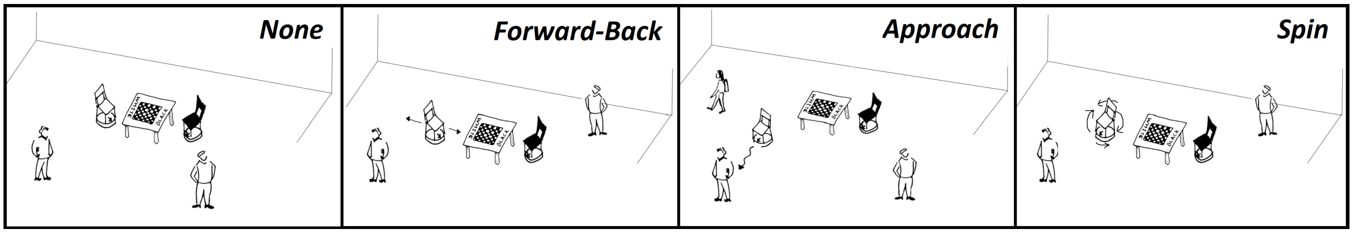

Fig. 3. *Illustrations of robot recruitment strategies:* **None**, control condition where ChairBot did nothing, **Forward-back at the table**, where ChairBot went back and forth at the table, **Approach person outside table**, where ChairBot would approach, go close and maybe bump at the person followed by returning back to table, **Spinning**, where ChairBot would spin at one place.

(see list below). Our goal was to interview about 10% of the participants, so as not to interrupt the in-situ nature of the experiment, but also allow for partial explanations and the ability to find out more about particularly interesting reactions. In total, we collected 40 interviews from the six sessions, each lasting 1 to 4 minutes. The interviews were not our main source of data in this experiment, however, they do clarify our statistical findings, and offer deeper insights to into participant experience, as you will see in the next section. Semi-structure interview questions included:

- Can you tell me about the experience you just had?
- Tell me about the sequence of events?
- Which chair(s) did you interact with?
- What convinced you to come/not-come over?
- Did you find ChairBot to be friendly/unfriendly? If so, please describe?
- What use cases can you imagine for robot furniture?

TABLE I
MEASURES: HUMAN BEHAVIORS OBSERVED

Person played a chess move
Person went to the table
Person sat on the chair

Videos from the overhead camera were coded post-study completion to generate quantitative data. One challenge in generating and analyzing data from such a study was to define what constituted as a participant and an interaction data point. We considered a participant as a person or group of people entering into the study area - experimental frame (see Fig. 4, area inside the red perimeter). We define an interaction data point to consider all cases when a motion behavior (listed in Fig. 3) or human response occurred (listed in Table. I).

D. Data analysis: Video Coding Takes Forever

The benefit of in-the-wild nature of this study is that we collect naturalistic real-world responses of people to robots; the downside is that it takes a long time to code video data. This subsection describes our definition of a participant during the video coding process, the behavioral measures we sought to annotate and their definition, and our partial testing of inter-coder reliability.

The video coding process took place in two phases. In the first phase, the first author coded interaction points when any of the three human behaviors were observed (successful interactions). In the second phase, other interaction points were coded - by the same person - when the robot employed a recruitment strategy that did not have any effect on the participant's behavior. During this process, we only coded instances in the video when a human participant was present in the study area. Robot recruitment strategies (see Fig. 3) were characterized as:

- **None**: ChairBot is idle and not moving, it can either be parked at the table or outside in the study area.
- **Forward-Back**: In this case, ChairBot moves forward and back at the table using a to-and-fro motion. This behavior was always done near/at the table, close to a standard seating position.
- **Approach**: In this case, the ChairBot would approach a person not near the table, which we define as at least 2 ChairBot lengths away from the table, where one ChairBot length is the length of the seat. This measure was selected for tractable video coding.
- **Spinning**: In this case, ChairBot is spinning constantly for at least 10 seconds, irrespective of whether ChairBot is near the table or outside of it.

We obtained data for each robot recruitment strategy and its corresponding effect on the human behavior. We introduce a factor '*conversion rate*', which is defined for a *particular robot strategy* and is the ratio of successful interactions to total attempted interactions.

IV. RESULTS

Overall, the video data consisted of six ChairBot Chess Tournament sessions, in which 6 hours and 19 minutes of video was collected from the overhead camera (Fig. 4). After completing the video coding process described in the previous section, there were a total of 597 instances in which a human came into the interaction square of the robot.

We present a summary of robot recruitment type totals, as well as human behavioral measure totals in Table IV: **None** was used 84 times, **Forward-Back** was used 77 times, **Approach** was used 327 times, and **Spin** was used 109 times. We also observed 81 instances when a person *played a chess move*, 188 times in which a person went to the table, and 59 times in which a person *sat on one a chair*. We also observed the number of times a robot recruitment strategy

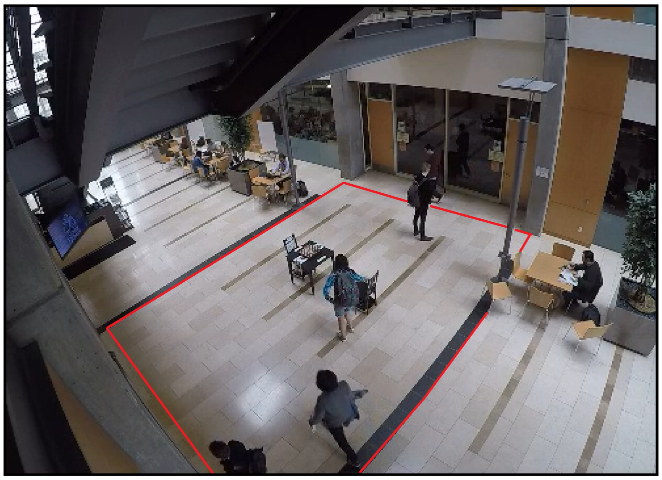

Fig. 4. View as seen from the overhead camera feed in which the human teleoperator used during the study. The red perimeter shows the area of study in which the ChairBots roughly moved around in and people entering this area were the participants considered in the study.

TABLE II
Conversion Rates for Robot Recruitment Strategies

HUMAN \ROBOT	None	FwdBack	Approach	Spin
Played a chess move	26.2%	**33.8%**	26.2%	3.6%
Went to the table	47.6%	**64.9%**	25.6%	12.8%
Sat on a chair	15.5%	**35.0%**	5.5%	0.9%

TABLE III
Percentage of successful interactions observed

Total number of interactions	**597**
Played a chess move	81 (*13.5%*)
Went to the table	188 (*31.4%*)
Sat on the chair	59 (*9.8%*)

was triggered and correspondingly the effect it had on the human behavior.

The most effective recruitment strategy, as depicted in Table II, was *Forward-Back* motion, resulting in almost 34% conversion rate of people to playing a chess move, and 65% conversion from person passing through to person coming to the table. For example, one interviewee said that *"It did a non-ambiguous inviting gesture to sit me at the table"*, referring to the forward-back robot action at the table. Against our hypotheses, spinning performed the worst across all human behavioral measures. We explore these human response results in the sections that follow, focusing on the human responses *played a chess move*, *went to the table*, and/or *sat on a chair* overviewed in Table IV, alongside one-way ANOVA analyses. The subsections conclude with quotes from the interviewees.

A. Played-a-chess-move Results

In total, there were 81 instances in which someone played at least one chess move. We do see a significant effect for robot recruitment strategies on this human behavioral

TABLE IV
Summary of total types of human behaviour observed for robot recruitment strategy employed.

HUMAN \ROBOT	None	FwdBack	Approach	Spin
Played a chess move	22	24	31	4
Went to the table	40	50	84	14
Sat on a chair	13	27	18	1
Total instances	84	77	327	109

measure; robot recruitment strategy very significantly predicting a participant playing a chess move **($F(1, 597)=16.31$, $p \leq 0.010$**)**. For example, forward-back motion succeeded 24 times out of 77, approach succeeded 31 times out of 327, spinning succeeded 4 times out of 109 & none strategy succeeded 22 times out of 84.

While the robot was always exhibiting a recruitment strategy, it did seem like some of the people were mainly attracted to the chess board itself. This is illustrated by the 26.2% success of the None motion gesture. In other words, the robot was not moving, but a quarter of the people passing by still came over to play a move. This is the reason we include the word mostly in the title of this paper.

Almost all people who were interviewed reported having positive experiences interacting with the chessboard. One person said "*I only came to play chess*", another said "*I like to play chess*", and "*I was wondering whose turn it is, so I thought the chair inviting was it*", "*I was able to make out it was white's move*". This interaction could also be summed up through this quote "*I saw a chair move, I saw a chess board. This is great!*".

B. Went-to-table Results

In total, there were 188 instances when someone went to the table. In a one-way ANOVA analyses, robot recruitment strategy (**Forward-Back**) significantly predicted when a person went to the table **($F(1, 597)=27.4$, $p<0.01$**)**. We observed that forward-back motion succeeded 50 times out of 77, approach succeeded 84 times out of 327, spinning succeeded 14 times out of 109 & none strategy succeeded 40 times out of 84.

Robot was successful in getting people to come to the table however chessboard alone was also able to recruit people as shown by the None gesture's success rate 47.6%. We think that forward-back motion at the table acted as a pointing gesture which increased it's legibility in emphasizing the table. Whereas, spinning turned out to be a bit ambiguous and approaching people outside the table could have been a bit disconnecting by going away from the table.

Many people attributed it being friendly: *"I just fell in love with it", "It seemed friendly", "it was like a puppy", "like a playful trained dog"* while some also found a moving chair to be creepy: *"It was creepy that it kept bumping into me", "Creepy at first, but I kinda liked it"*. However, people had varied responses to ChairBot's actions like "*I came to the table because I saw a moving chair associated with the table*", "*We were intrigued by the moving chair, it was a* *new experience*" and "*but when it approached me, it was dominating in a funny way*".

C. Sat-on-chair Results

In total, there were 59 instances when a person sat on the chair. In a one-way ANOVA analyses, we see a significant effect of robot recruitment strategy (**Forward-Back**) in getting someone to sit on the chair **(F(1, 597)=28.2, p<0.01**)**. We observed that forward-back motion succeeded 27 times out of 77, approach succeeded 18 times out of 327, spinning succeeded 1 times out of 109 & none strategy succeeded 13 times out of 84.

Robot was successful in getting people to sit on the chair as shown by the result, it is followed by the None gesture again, and spinning was least successful as one could imagine sitting on a spinning chair to be hard task. Since, ecologically chairs are parked at the table, we think the positioning of the forward-back gesture (at the table) played a role in getting more people to sit on the chair.

People generally enjoyed interacting with the chair. Many had questions like "*will the chair move if I sit on it?*", "*I was attracted by the moving chair*". "*I figured out I should sit on it*". "*It was a submissive chair, as when I sat on it, as it didn't move*". One participant said that "*It did a non-ambiguous inviting gesture to sit me at the table*", referring to the forward-back robot action at the table.

V. DISCUSSION

For robot designers, a main takeaway is that robot motion can persuade people to do things in the context of "ChairBot chess tournament" and robot does not need to display familiar anthropomorphic cues, such as a face or voice. The results have suggested a significant effect of robot recruitment strategies on measured human behaviors. Simple robots such as a robot chair was successful in persuading people in a naturalistic setting to play a move of chess.

Outstanding research questions include some of the following:

- **Proxemics:** Future work could explore the impact of location and proxemic distances on the effectiveness of the individual gestures. For example, what would happen if the *Forward-Back* strategy was used away from the table? During teleoperation, the usage of some of these strategies was influenced by the teleoperator's own social knowledge, so running this again with more even distributions of locations could result in specifications that could be used by future robots.
- **Sequence:** Sequences of gestures could also have an significant impact. During the experiment, for example, the teleoperator noted that approaching people followed by forward-back motion seemed like a logical sequence. The results presented here might also alter in sequence (as per [21]), for example if a robot stops spinning upon the arrival of a person, it might become more effective.
- **Timing:** Triggering a gesture with the right timing, for example, when the person is about to cross in front of the robot, would also be an area where the robot could increase or decrease its persuasiveness. There are also potential impacts of the timing of the motion iteself, such as velocity and acceleration.
- **User History:** Results might also change for regular visitors to the tournament. Perhaps the robot remembering someone would enable simpler gestures (or no gestures) to be effective, or perhaps it would require a greeting gesture, otherwise the apparently forgotten person would be less likely to play. In this experiment, the teleoperator did not notice repeat visitors, but for longer deployments or other applications, this may become a big issue.

One of the limitations of this study was the uneven numbers of robot gestures, e.g., *Approach* was used 327 times, but *None* was used 84 times. Another limitation, is the use of chessboard, what would happen if we had used a less attractive activity? This also highlights a limitation of robot-recruited experiments, in general, they will be much more applicable to activities that people around them want to do.

VI. CONCLUSIONS

In contrast to traditional user studies, in which humans recruit participants, this experiment involved participants who a robot attempted to recruit. It also took place in a naturalistic setting where people just happened to be passing by, and involved persuading them to interrupt their day to come to a table and play a chess move or even sit down. We manipulated four robot recruitment strategies. The most effective strategy was *Forward-Back* motion at the table, followed by *None* (no motion), which we also dub the chessboard-recruited condition. *Approach* was also a moderately effective strategy, although it makes sense that attempting to recruit people far from the table is more difficult. *Spin* was ineffective everywhere for all measures. We believe appropriate persuasiveness requires an understanding of both robot motion communications and of the robot task. For example, moving forward-back in front of the table conveyed a clear directional cue at the location that it mattered, while spinning made it difficult for someone to consider sitting down. To clarify the role of the chessboard alone in recruitment, future work could also benchmark of effectiveness of robot behaviors versus a sign on the table alone.

Another exciting aspect of the work was that robot recruitment worked in the wild. A robot chair was successful in persuading people in a naturalistic setting to visit a chess table and play a move of chess. This is exciting, because it suggests that user studies could sometimes be conducted by actual robots. If robots can persuade someone to come interact, rather than play a chess move, perhaps they could ask a person to rate their latest robot dance moves or some other research question that would be attractive for bystanders to interrupt their day to participate in.

Finally, the study results establish effective motion strategies for robots in this context. This paper offers early insights about which strategies an autonomous ChairBot system might use to attract future chess tournament participants. Future editions of this study could program autonomous versions of these motion demonstrations, but would require development of human perception systems. It would be interesting to see if we could replicate the results here with an autonomous system, and, with perception, we might even be able to explore what kinds of people are easiest to convert.

In a future where robots could collect more in-the-wild data, it makes sense for robots to use their deployment time strategically. Future systems could iterate over recruitment strategies for learning purposes, analyzing behavioral responses on the fly and seeking models of what works best in what context.

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