# Prior Behavior Impacts Human Mimicry of Robots

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***Abstract*— Mimicry, the automatic imitation of gestures, postures, mannerisms, and other motor movements, has been shown to be a critical component of human interaction but needs further exploration in human-robot interaction. Understanding mimicry is important for building better robots, learning about human categorization of robots in social ingroups/outgroups, and understanding social contagion in human-robot interaction. We investigate the extent to which humans will mimic a robot during the task of describing paintings by comparing the time participants put their hands on their hips before and after observing a robot cue that behavior. We observed no significant difference in participants' hands on hips time before and after the robot's cue. However, we did find that some participants performed the behavior more after the robot's cue while others performed it less. Furthermore, the direction of this change was a function of whether or not a participant performed the specified behavior prior to the robot's cue. This was similarly observed both for frequency of behavior performance and for a second behavior (hands behind back). As such, this study informs future research on human-robot mimicry, particularly on the importance of prior behavior during a human-robot interaction. In doing so, this study provides a baseline for further understanding and exploring mimicry in human-robot interaction as well as evidence for a social component in human-robot mimicry.**

## I. Introduction

Behavioral mimicry—the imitation of gestures, postures, mannerisms, and other motor movements—is pervasive in human interactions [7]. Behavioral mimicry is often unconscious and unintentional [5], [33]. In Chartrand & Bargh's 1999 study, participants mimicked confederates by tapping their feet or touching their faces during interactions, even without realizing they were doing so [6]. Participants also found confederates more likable when the confederates mimicked the postures of the participants [6].

Mimicry is an important element of human-robot interaction for three main reasons. First, we can make better decisions not only about how to design robots generally but also about how to effectively use or avoid mimicry in human-robot interactions. Mimicry influences human-human interactions in a variety of ways, resulting in smoother interactions, smoother negotiations, more interpersonal trust, and more likability with their partners [18], [26], [27]. Leveraging this knowledge could be valuable when designing robots. Second, studying human-robot mimicry informs us about ingroup versus outgroup divides between humans and robots, and thus highlights how humans view robots as social partners. When mimicry is performed by a member of someone's ingroup, it can foster smoother and more positive interactions [6], and it has even been called the "social glue" that brings people together and bonds them [7]. However, this is not the case with mimicry and social outgroups. When mimicry is performed by a member of someone's outgroup, not only does it not increase rapport or liking but it also can have negative effects on the interaction between those partners [4], [7], [12], [34]. Mimicking can even backfire when it comes to public judgements of social competence when done inappropriately [7]. Given the difficulties seen with directly asking how people perceive robots [30], mimicry could serve as a proxy in determining how an individual perceives a robot partner. It would be difficult to rely on a human subject's own account or depiction of the relationship or social standing of a robot partner, but unconscious mimicry could be used to determine that instead. Lastly, understanding how mimicry works in human-robot interactions can act as a stepping stone to understanding the larger phenomenon of social contagion within human-robot interaction [7]. Social contagion is defined as mimicry with all aspects of social experience and not just motor behavior [7] (such as an emotional reaction or a judgement/opinion). This means that mimicry could be a first step towards understanding questions such as empathy between human and robot partners.

Similar to human-human interactions, people who are mimicked by robots have found the robots more likable and their interactions with them smoother, more persuasive, and more positive [1], [7], [23], [9], [24]. However, less work has explored the question of whether humans will mimic robots during interactions. The current study tests if humans mimic a humanoid robot's body postures while interacting during a task. In the study described below, the robot puts its hands on its hips while describing a painting to a human participant. We measure for what period of time and how often the participant displays this behavior before and after the robot performs it. We repeated this with the robot performing a second behavior.

## II. Related Work

This study aims to test the possibility of humans mimicking robots at the most fundamental level, while minimizing the use of catalysts (such as goal to affiliate, emotions, communicative behaviors, or pre-existing rapport) that have been shown to increase mimicry in human-human interaction [7], [8], [13], [17], [19]. This distinguishes this study from previous work [11], [20], [17], [31], [32] in that it does not uses facial expressions, emotion-conveying gestures, or communicative postures. This study instead employs a humanoid robot that uses behaviors (hands on hips and hands behind back) that do not convey any emotion and that are not overtly communicative. The experimental design also does not exploit goal to affiliate, pre-existing rapport, or any other facilitators seen to increase human-human mimicry. Lastly, this study also introduces a new line of questioning previously unexplored and unexpected in seeing how humans respond when already performing the behavior the robot performs, providing evidence for social mechanisms in human-robot mimicry [3].

In designing this study we drew heavily from one of the seminal papers in human-human mimicry, Chartrand & Bargh [6], which showed that people do mimic one another during social interactions, and that mimickees find mimickers more likeable and have smoother and more positive interactions with them [6]. In particular, this study demonstrated mimicry in both directions, participants mimicking and participants being mimicked, while they described paintings alongside a confederate. During this interaction, the confederate performed a behavior, and researchers measured the frequency with which the participant then performed that behavior as a means for quantifying mimicry. Analogously, this study uses a robot in the role of the confederate.

There has been some work examining the question of whether a human will mimic a robot. Activation of the mirror neuron system in humans can occur through the perception of robot behavior [21], robotic movement can support visuomotor priming enough to elicit automatic imitation [22], humans match emotional expressions of a hyper-realistic android in a mimicry-like manner [11], and gestural alignment occurs for humans when interacting when virtual agents [3].

Researchers have also looked at the question of human-human mimicry's impact in light of social ingroup/outgroup status. Lakin & Chartrand found that humans who are excluded in some way by a member of their ingroup will selectively and nonconsciously mimic that person, but that they will not do so if the excluder was a member of their outgroup [14]. These different kinds of treatment towards members of an ingroup or an outgroup are important concerns when designing human-robot interactions. If humans treat robots similarly to the way they treat other members of their ingroup, we can expect them to mimic robots.

Beyond evidence of whether a human will mimic a robot, there exists research suggesting mimicry impacts human-robot interactions and how humans view them as partners. Work by Li, Ju, and Nass showed that mimicry in a human-robot interaction can affect perceptions of the interaction, particularly that observers found a robot less attractive when a confederate mimicked a robot than when a robot mimicked a confederate (but not during human-human interactions) [16]. This suggests that mimicry and the role it plays with human-robot interaction is both important and distinct from human-human interaction, further necessitating a study to determine the most basic parameters of humans mimicking robots. Also, humans found a computer avatar more likable when it mimicked their head postures than when it did not [1], [7], demonstrating that non-human actors can elicit the positive effects of mimicry seen in human-human mimicry.

## III. METHOD

Following the method of Chartrand & Bargh [6], participants were given the task of describing paintings together with a robot. As it described the paintings, the robot switched from its initial standing pose to one of two test behaviors. We called this switch the *cue*. We measured how long and how many times the participants took on the cued posture both before and after the robot's cue. To assess mimicry, we looked for the difference between the two durations and frequencies.

We tested mimcry with two distinct behaviors: hands on hips and hands behind back. These behaviors were chosen because they were easily identifiable and could be clearly articulated by the robot. Our main question was whether robots could induce mimicry in people. Our hypothesis was:

**H:** People will display the behavior performed by the robot more after the robot's cue. In other words, people will mimic the robot.

### A. Procedure

For this experiment our robot platform was a Nao, a 58cm tall humanoid robot. Participants were first asked to fill out consent and video release forms. The experiment consisted of two 12-minute sessions and six paintings (Figure 1). The sessions differed only in which behavior was performed by the robot. The order of the sessions was randomly counterbalanced.

Participants were brought in to a closed 420cm x 300cm room and faced the robot at a distance of 180cm. The robot stood on a platform raised 75cm off the ground. Next to the robot stood a 68cm monitor which displayed a timed slideshow of paintings, and simultaneously controlled the robot's behaviors through a local area network. The monitor was placed adjacent to the robot to ensure that participants could see both the paintings and the robot's posture simultaneously. One camera was located at the back of the room and aimed at the participant's back, and a second camera was placed in the corner of the room facing the participant.

The participant was asked to read the first slide of directions while the experimenter turned on the cameras. The directions told the participant that the robot would describe the painting for one minute and that the participant would then describe the same painting for one minute.

The experimenter started the session by tapping the robot's head sensor. The slides and the robot's behaviors were synchronized. The robot would turn its head to "see" the painting, turn back to the participant, and describe the painting using pre-defined scripts for one minute, after which the participant was notified on-screen that it was his or her turn (Figure 1). The robot displayed no other idle behaviors while describing paintings or while the participant described paintings. This continued for three paintings total. At this point, the robot performed the cue by moving to the test posture and maintaining that posture for three more paintings. Therefore, half of the session (six minutes) was before the robot's cue, and half of the time was after the

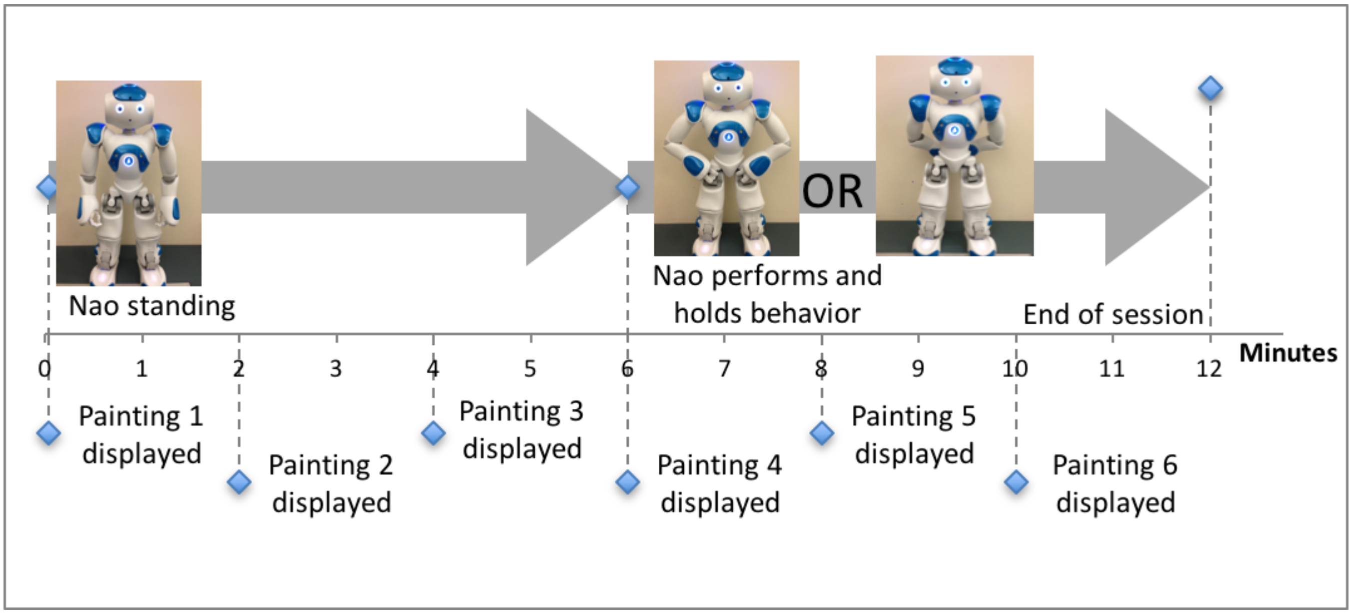



Fig. 1: Each painting was displayed for two minutes; the robot spoke for the first minute, and the participant spoke during the second. The robot changed its posture from standing to the cued posture at minute six.

robot's cue. During the second part of the session, the robot continued to turn its head to "see" the painting at the start of its turn. After six total paintings (12 minutes), the robot returned to a crouch position. To begin a new session, the experimenter replaced the robot with a new one to make it clear to participants that they were interacting with a different robot. The second session was the same as the first, but with the other cued posture.

We used two robots to replicate the setup of the Chartrand & Bargh study, which had two different humans perform separate behaviors (touching the face and tapping the feet). The use of continuous postures (like hands on hips) rather than a discrete behavior (like tapping feet) was largely due to limitations of the robot. We had little reason to believe continuous postures would not be effective behaviors given their use in human-human mimicry research [7], [28], [29].

The robot's descriptions of the paintings were kept as simple as possible, with little to no emotion or interpretation. The robot also made no acknowledgement of the participants or their descriptions and the behaviors of hands on hips and hands behind back were chosen to minimize postural communication. This fell in line with our goal for understanding human mimicry of robots at its most basic level without any facilitators or inhibitors.

After both sessions were completed, participants filled out a survey comprising of Likert scale questions on intelligence and likability, short answer questions on what they liked/noticed about the trial, and demographic questions.

### B. *Participant Information & Coding*

Participants were 47 university undergraduates, 27 males and 20 females, ages 18 to 23. Four participants were excluded from analyis due to technical problems, such as a loss of internet connection during the trial. In total,

(a) (b) (c) (d)

Fig. 2: Examples of behavioral postures: hands on hips (a) strict and (b) loose, hands behind back (c) strict and (d) loose.

data from 43 participants were used in the final analysis. Participants were recruited through direct appeal and fliers. They were compensated $5 for their participation. Videos of the participants were collected through two cameras in the room.

For analysis, we defined strict and loose variants of each behavior (Figure 2). For hands on hips, the strict definition matches the robot's behavior of putting two hands on hips. The loose definition is a superset of this, with the participant exhibiting *at least* one hand on hip. For hands behind back, the strict definition matches the robot's behavior of putting two hands behind back. The loose definition is a superset of this, with the participant exhibiting *at least* one hand behind the back. Having a strict and loose interpretation allowed us to take into account participants who partially performed the behavior in our analysis.

The videos were coded using ELAN 4.7.3. The coders were two of the authors, who were blind to the conditions while coding by not being able to see the robot's actions in the video recordings. Interrater reliability was high, with

97.8% agreement on a validation sample of 10% of the videos.

## IV. Results

We tested our hypothesis using both duration and frequency of displayed behaviors. Duration measures how long participants held a particular posture, while frequency measures how many times they did so. For a given participant and posture, the "before" measure is the total time/number of times for which that participant displays that posture before the robot's cue, and the "after" measure is the total time/number of times the participant displays that posture after the cue.

We analyzed the data with a 2-tail paired t-test. We found no statistically significant difference between the "before" duration ($M$ = 18.9s, $SD$ = 53.7s) and the "after" duration ($M$ = 16.1s, $SD$ = 34.8s), $t(42)$ = -0.43, $p$ = 0.66. We found no statistically significant difference between the "before" frequency ($M$ = 0.51, $SD$ = 1.33) and the "after" frequency ($M$ = 0.74, $SD$ = 1.25), $t(42)$ = 1.21, $p$ = 0.23.

However, further analyses yielded an unexpected effect of participants' prior behavior on mimicry. Some participants displayed the robot's posture before the robot ever did while others did not. We defined these to be two categories: postures that are performed independently before the robot's cue (which we call *spontaneous* behavior) and the absence of such postures before the cue (which we call *non-spontaneous* behavior). So spontaneous participants performed the specific behavior before the robot did at the halfway point while non-spontaneous participants did not.

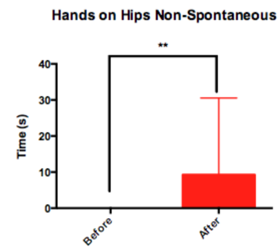
We observed that participants whose prior behavior was non-spontaneous started displaying the cued behavior after the robot's cue significantly more than before the cue. Additionally, spontaneous participants performed the behavior less after the robot's cue, albeit at non-significant levels. Analyses of these two groups are separated by duration and frequency below, and reported in Figures 3 and 4.

Non-spontaneous behavior, by definition, has a "before" duration and "before" frequency of zero. Since duration and frequency can only go in the positive direction, we applied one-tailed t-tests in this analysis. For the spontaneous group, we applied two-tailed t-tests because duration and frequency can go in either the negative or positive directions.

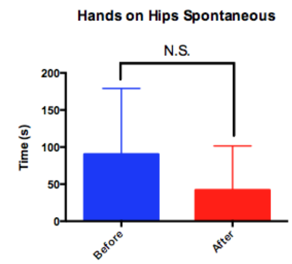
### A. Hands on Hips, Duration

We examined the difference in duration times for participants placing their hands on their hips before and after the robot's cue. We analyzed the results for spontaneous and non-spontaneous participants separately. These results are displayed in Figure 3. These results are for the strict definition of hands on hips, and the same levels of significance were found for the loose definition of hands on hips for both non-spontaneous and spontaneous participants.

We found that **non-spontaneous** participants ($N = 34$) had significantly higher "after" duration ($M$ = 9.28s, $SD$ = 21.27s) than "before" duration ($M$ = 0.00s, $SD$ = 0.00s), $t(33)$ = 2.51, $p$ < 0.01. This means that participants who never put their hands on their hips before the robot's cue did so significantly more after seeing the robot do so.




(a) Duration of behavior, non-spontaneous group.




(b) Duration of behavior, spontaneous group.

Fig. 3: Duration with which participants performed the hands on hips behavior before and after the robot's cue, split by spontaneous and non-spontaneous groups. Significant differences between pre- and post-cue behaviors are indicated on the graphs ($** = p < 0.01$, N.S.=Not Significant).

**Spontaneous** participants ($N = 9$) had non-significantly lower "after" duration ($M$ = 42s, $SD$ = 59.6s) than "before" duration ($M$ = 90.38s, $SD$ = 88.71s), $t(8)$ = -2.16, $p$ = 0.05 (participants who previously did put their hands on their hips before the robot's cue did so less after seeing the robot do so).

### B. Hands on Hips, Frequency

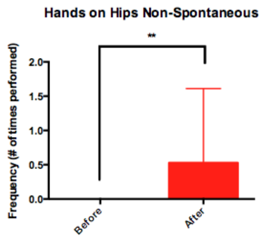
The results for the frequency of the displayed hands on hips behaviors mirror those that we found for duration. These results are displayed in Figure 4. The timepoints of the individual occurrences of hands on hips are displayed in Figure 5. Also, no statistical significance was found for "both hands behind back" occurrences following the robot cue of hands on hips ($M$ = 0.12, $SD$ = 0.50), $t(42)$ = 1.53, $p$ = 0.07.

### C. Hands Behind Back

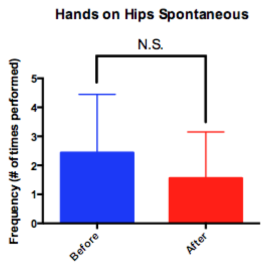
The results for hands behind back showed a similar pattern of results as the results for hands on hips.

## V. Discussion

Our results provide some support for our hypothesis, albeit with some caveats. We found no significant difference between the before and after durations or frequencies for either hands on hips or hands behind back. In observing the recordings and reading through the survey responses,




(a) Frequency of behavior, non-spontaneous group.




(b) Frequency of behavior, spontaneous group.

Fig. 4: Frequency with which participants performed the hands on hips behavior before and after the robot's cue, split by spontaneous and non-spontaneous groups. Significant differences between pre- and post-cue behaviors are indicated on the graphs ($** = p < 0.01$, N.S.=Not Significant).

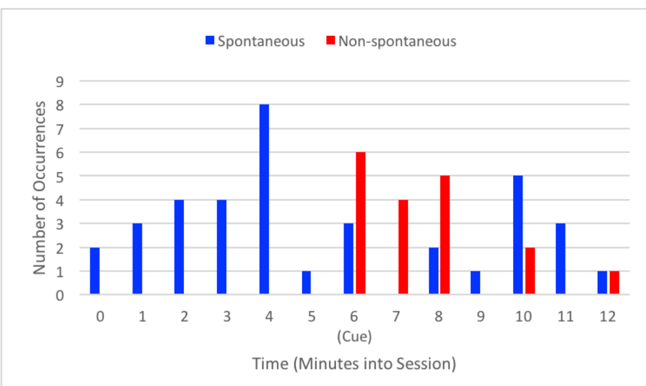



Fig. 5: Timeplot of hands on hips occurrences across all participants. The robot cued hands on hips at minute six.

we noticed that some participants did in fact perform the behaviors more after the robot's cue while others performed it less. This motivated us to consider our sample as two groups: *non-spontaneous* and *spontaneous* (i.e. those who perform a behavior before ever seeing the robot's cue for that behavior). Doing so highlighted a curious result: non-spontaneous and spontaneous participants behaved in opposite directions. The opposite direction of the spontaneous participants (on average 48.38s less hands on hips after the robot's cue, $N = 9$) effectively canceled out the effect of the non-spontaneous participants (on average 9.28s more hands on hips after the robot's cue, $N = 34$) in the initial analysis.

For both the strict and loose definitions of hands on hips, non-spontaneous participants significantly put their hands on their hips *more* after seeing the robot do so, in terms of both duration (Figure 3a) and frequency (Figure 4a). Most of the hands on hips occurrences for non-spontaneous participants were observed in the first three minutes after the robot's cue, with occurrences trailing off after (Figure 5). This supports the explanation that the robot was prompting the participants' behavior. It also weakens other possibilities such as participants getting tired (which would show more occurrences at the end of the trials), participants switching to a more comfortable position (which would show an even distribution), or participants generally putting their hands on their hips more over time. Furthermore, participants did not display hands behind back significantly after the robot's cue of hands on hips, suggesting some degree of specificity in their response to the robot cue.

Surprisingly, participants who spontaneously performed hands on hips prior to the robot doing so actually performed that behavior *less* after the robot performed it. This group was fairly small ($N = 9$), and the results were not significant for the strict or the loose definitions of hands on hips, in terms of both duration (Figure 3b) and frequency (Figure 4b). This effect's magnitude was larger than the one seen in non-spontaneous participants, but our statisictical tests were limited by the small sample size (which in turn was so small because we did not anticipate this result and did not prescreen participant's tendencies to perform the specific behaviors).

While we cannot conclude why this would happen, we can make inferences, especially with the help of our survey responses. Several responses by spontaneous participants noted that when they saw the robot first put its hands on its hips, they thought the robot was mimicking their behavior. This thought process makes sense when we recall that the spontaneous participants had performed that behavior before the robot's cue.

Mimicry research in psychology has shown that mimicry can lead to socially cold feelings or the feeling that something is "off" [10]. In particular, an inappropriate amount of mimicry arouses suspicion in the party being mimicked [2], [15], [25], [35]. This might help explain why there was a decrease in performance of our targeted behaviors for spontaneous participants. If participants were suspicious about being mimicked, they might have decreased their postural changes in order to prevent further mimicry. This is potentially useful for future studies examining whether mimicry can be used as a proxy for determining outgroup status. However, given that non-spontaneous participants do mimic the robot, it is still unclear what conclusions can be drawn about social ingroup/outgroup status of robots more generally.

Our results regarding non-spontaenous participants provide evidence that robots can induce mimicry in humans. In particular, this was observed while minimizing the use of catalysts, providing a baseline from which to move forward. This opens many new research possibilities and questions.

For example, is the salience of mimicry in human-robot interaction similarly affected by facilitators in the same patterns as it is in humans? Does having a goal or similarity between partners induce greater mimicry in human-robot interaction as it does in humans?

Our results regarding spontaneous participants raises concerns about building mimicry into human-robot interaction, especially in terms of having robots mimic humans. There may be conditions in which mimicry is unfavorable or damaging to the interaction. Furthermore, the opposite responses of spontaneous and non-spontaneous participants provides support for the existence of social mechanisms in human mimicry of robots [3] and contrasts against the view that it is primarily "motor-driven" [11].

Further research should more formally consider the spontaneous scenario with a larger sample size, possibly through pre-screening participants and their tendencies to perform a cued behavior. In addition, a control study could further cement the findings presented through the timeplot of hands on hips occurrences and the specificity of behaviorial response (i.e. non-spontaneous participants performed hands on hips but not hands behind back after the robot cued hands on hips). Prior behavior impacts mimcry during human-robot interaction, and future studies should incorporate these findings when considering experimental design and interpretations.

## VI. Acknowledgements

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