

Robot-Induced Mimicry in Humans

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ABSTRACT

As robots become more and more integrated with our lives, particularly beyond a functional role, there is an increasing need to understand human-robot interaction at a social level. One such area in need of further exploration is mimicry between humans and robots, particularly in the direction of humans mimicking robots. We know mimicry plays an important role in smoothing interactions between humans, so we believe its study could positively influence our design of social robots. This study explores human-robot interaction in terms of behavioral mimicry - the imitation of gestures, postures, mannerisms, and other motor movements. We conducted an experiment looking at how much humans mimicked a robot during the task of describing paintings. We find that humans do mimic a robot more after observing a robot perform an action. Interestingly, we also find that humans already performing a behavior actually perform that behavior less after seeing the robot perform it.

Keywords

human-robot interaction, mimicry, chameleon effect

1. INTRODUCTION

We now live in a world where robots are becoming more and more integrated into our daily lives. Fields like service robotics, socially assistive robotics, or physically assistive robotics aim to develop robots that interact both physically and socially with people in their natural environments. With this new movement, there is a pressing need to understand the social effects and impact of robots, particularly humanoid or anthropomorphized robots. Understanding the

social effects of a robot will provide us with new information on how to better design robots for human interaction, how to structure human environments for robot presences, and how to anticipate the impact robots will have on our society moving forward. In trying to understand the social effects of robots, robotics must look to the field of psychology. Psychology can provide us a framework and a baseline to assess human-robot interaction. This is done by taking social constructs and effects from human-human interaction and mapping them to robots. This space of human-human effects mapped to human-robot interaction is still largely unexplored. In this study, we hope to elucidate a part of this space: social mimicry.

Behavioral mimicry - the imitation of gestures, postures, mannerisms, and other motor movements, is pervasive in human interactions [7]. Automatic mimicry in particular is often unconscious and unintentional. For example, studies have shown participants mimicking confederates tapping their feet or touching their faces during interactions, even without realizing they were doing so [6]. Furthermore, research has also shown that participants found confederates more likeable when the confederates mimicked the postures of the participants. There are several reasons why such a behavior exists. From a neurological standpoint, there exist certain parts of the brain responsible for this mimicry, known as mirror neurons or the “mirror system” in humans, first highlighted in macaques in 1992 at the University of Parma [9]. In fact an actual perception-behavior link exists behind automatic mimicry. This means that actions seen can trigger the mirror system in humans [6]. Beyond the neurology, there is a social component and possible evolutionary explanation for mimicry. Mimicry has been shown to create liking, empathy, and affiliation between interactants and act as the “social glue” that brings people together and bonds them [7], [13]. Also, research suggests that mimicry serves a prosocial communicative purpose [4], [7].

We find several reasons as to why mimicry should be studied in human-robot interaction. In the broadest sense, mimicry is a thinly explored area of human-robot interaction that has

a parallel in human-human interaction. Given that psychological research on mimicry has highlighted questions about mimicking the “right” people (i.e. ingroups vs. outgroups) [5], [7], [11], [22], mimicry could highlight how humans view robots as social actors. Also, it has been observed that mimickers, and not just mimickees, have smoother interactions, smoother negotiations, more interpersonal trust, and more likability with their partners [15], [20], [21], so finding out if humans mimic robots could give us information on how to shape interactions between humans and robots. From a practical standpoint, if robots can induce mimicry in humans, it provides us insight into how a robot may induce behavior in humans within the real world. One can foresee possible concerns of a child or infant mimicking a robot in the home. One could also foresee issues regarding individuals mimicking a robot in public, perceiving the robot’s actions as a sign of permissibility. All these new questions, however, rest on the assumption that a robot could in fact elicit mimicry in humans, an assumption we show to be true in this study. Observing no mimicry or some kind of adverse social effect would also raise questions about why the perception-behavior link in human-human interaction does not extend to human-robot interaction.

Lastly, mimicry of physical behaviors is the first step in the larger phenomena of social contagion [7], so understanding how human-robot interaction works for automated mimicry can act as a stepping stone to social contagion with human-robot interaction.

2. RELATED WORK

There is evidence in research that suggests a robot could elicit mimicry in humans. Oberman demonstrated through EEG that activation of the mirror neuron system in humans can occur through the perception of robot behavior, even without objects. This is significant as it informs us that the mirror neuron system and the perception-behavior link in humans is not uniquely limited to perceiving and reacting to human actions [16].

Bailenson successfully demonstrated that liking, rapport, and affiliation can be increased with mimicry even with a digital agent, which they showed using a virtual agent on a computer screen mimicking the head posture of the participants [2]. This highlights one direction of the mimicry effect, in which a participant being mimicked has a more positive experience with a mimicker. The existence of this direction with a non-human agent suggests the possibility of the opposite direction, a human mimicking a non-human agent.

Riek conducted a study hoping to observe improved likability with an embodied robot (resembling an ape) mimicking head posture of a participant. Their study identified problems with assessing human-robot interactions using a survey and the difficulties of capturing and mimicking behaviors between humans and robots. Their work guided us in our planning of behaviors [17]. Riek did find some support for more satisfactory interactions when facial expressions were mimicked by the same ape-like robot, although the findings were preliminary and in a pilot [18].

Hofree most significantly found that humans can sponta-

neously match facial expressions of an embodied android present in the room. Their study suggested that the salience of mimicry depended on how human-like the android presented is [10].

Little work has been done with human-robot mimicry in general, particularly with humans mimicking robots. Hofree’s work broaches this area partially, but our study provides a more rigorous baseline for human mimicry of robots. Hofree’s finding pushed our study to focus on a robot that minimized human-like features and emotions, allowing us to test on a more basic set of behaviors, devoid of expressions or emotions such as anger or happiness. Our study also aimed to minimize features that would increase the likelihood of mimicry such as goal to affiliate, which has been shown to increase mimicry [7], [8], [12]. This makes our results stronger as they showed mimicry without a catalyst. Finally, our study employed a robot that is humanoid but did not have a human-like face like the one in the Hofree study [10].

3. METHODS

Participants were given a task to complete while interacting with the robot. Our study borrowed heavily from Chartrand & Bargh’s experimental design [6]. We initially ran a pilot study from which we observed there were two groups of people, those who spontaneously performed a behavior without the robot doing so and those who did not. Knowing this we designed our study as follows.

We define spontaneous exhibition of a behavior to be performing a specified behavior for any period of time prior to observing the robot perform said behavior.

Participants alternated describing paintings with a Nao robot. Halfway through the trial, the Nao would assume a posture (either putting its hands behind its back or putting its hands on its hips) while continuing with the description of paintings. We measured the times the participant assumed the posture before and after the Nao assumed the posture respectively. The “before” period acted as the control while the “after” period acted as the observed variable, making this a within-subjects study.

This whole process was repeated with a different Nao for the same participant. The different Nao was brought in by the experimenter immediately after the conclusion of the first session. During the second session, the Nao performed whichever behavior the first Nao did not (either putting its hands behind its back or putting its hands on its hips). This gave us a larger data set of behaviors to observe and also helped us to control for participants who had existing tendencies to do one behavior or another.

Employing two separate Naos came from the use of two different confederates in the Chartrand & Bargh study, which also had two different behaviors (touching the face and tapping the feet) [6]. The use of continuous postures (like hands on hips) rather than a discrete behavior (like tapping feet, which can be counted) was largely due to limitations of the robot, but we had little to reason to believe continuous postures would not be effective behaviors given their use in mimicry research [7].

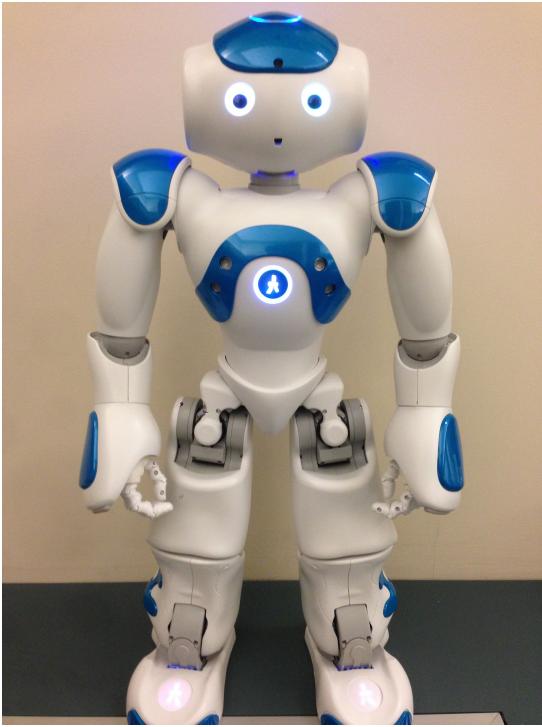


Figure 1: Standard Nao, No Behavior, “Before”

The Nao’s descriptions of the paintings were kept to be as simple as possible, with little to no emotion or interpretation [10]. The Nao also made no acknowledgement of the participants or their descriptions and the behaviors of hands behind back and hands on hips were chosen to minimize postural communication. This falls in line with our goals for understanding human mimicry of robots at its most basic level.

At the start of this study, we hypothesized the following:
H1 People who do not spontaneously exhibit a behavior will perform that behavior more after seeing a robot perform it.
H2 People who do spontaneously exhibit a behavior will perform that behavior less after seeing a robot perform it.

3.1 Robot Platform

Nao is a 58-cm tall humanoid robot, as shown in figure 1, designed by Aldebaran on the Naoqi operating system [1]. Nao has 25 degrees of freedom, 2 cameras, 4 microphones, speakers, touch sensors, and an inertial measurement unit. For the study, Nao’s legs were employed for standing up, Nao’s arms were used to assume 1 of the 2 aforementioned postures, Nao’s touch sensors were used to start a script of behaviors, and Nao’s speakers were used to voice the painting descriptions. Python was used to program the Nao for the study.

3.2 Procedure

Participants were first asked to fill out consent and video release forms. Participants were randomly assigned to a group that saw hands behind back, as shown in figure 3, or hands on hips, as shown in figure 2, during the first session (with the other behavior occurring in the second session). Par-

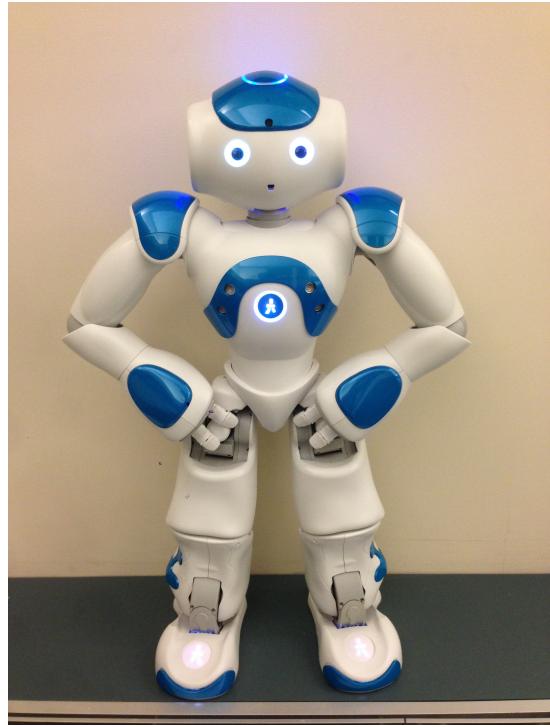


Figure 2: Nao Robot With Hands on Hips



Figure 3: Nao Robot With Hands Behind Back

ticipants were brought in to a closed 420cm x 300cm room. The setup of the room can be seen in figure 4. Participants faced the Nao at a distance of 180cm. The Nao stood on a platform raised 75cm off the ground. Next to the Nao stood

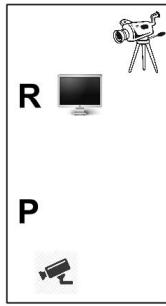


Figure 4: Setup of the Room

a 68cm Apple iMac monitor which ran Python scripts for the Nao’s behaviors through a local area network connected to the Nao’s head and displayed a PowerPoint presentation on Keynote. The monitor was placed immediately adjacent to the Nao to ensure that participants could describe the paintings without missing the Nao perform its gestures. A GoPro was located at the back of the room and aimed at the participant’s back. A camcorder 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. Next, the experimenter started the PowerPoint and tapped the Nao’s head sensor to start the Nao’s Python scripts. The PowerPoint slides and scripts were synchronized. The Nao would turn its head to “see” the painting, turn back to the participant, and describe a painting (descriptions were pre-scripted) for 1 minute after which the participant was notified on-screen to do so as well. This continued for 3 paintings total. At this point, the Nao performed the assigned behavior for session 1 and maintained that posture for 3 more paintings. Thereby, half of the time (3 paintings worth) was before the Nao performed the behavior and half of the time was after the Nao performed the behavior. After 6 total paintings, the Nao returned to a crouch position and the experimenter replaced the Nao with a new one. The same process was repeated with 6 more paintings, except the other behavior was performed in session 2.

After both sessions were completed, the participant completed a survey on Qualtrics, received \$5, and left.

3.3 Data Collection

Video of the participants were collected through a camcorder that captured the front of the participant and a GoPro that captured the back of the participant (this was necessary in order to validate any behaviors the participants portrayed behind their backs).

The videos were coded using ELAN 4.7.3. Both behaviors and variations of the behaviors were coded for. Participants

also 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. Participants comprised of 47 Yale Undergraduates of which 43 were used in the final data analysis (6 participants did not qualify for the study or experienced a technical problem, such as losing internet connection, during the trial).

4. RESULTS

The central question of this study is whether or not a robot can induce mimicry in humans. This experiment yielded quantitative results from video coding of the recordings of participants and from self-reporting through a survey of Likert scale and short-answer questions.

Video Coding We coded a participant putting hands on hips with 4 different designations and a participant putting hands behind back with 3 different designations. The different designations ensured we were able to cover all variations of the behaviors in the event they were displayed. For hands on hips the designations were two hands on hips, one hand on hip, hands in pockets, and hands in belt loops. We ultimately did not use hands in pockets or hands in belt loops because they did not accurately resemble the Nao’s behavior. For hands behind back the designations were two hands behind back, one hand behind back, and hands in back pockets. We ultimately did not use hands in back pockets because it did not accurately resemble the Nao’s behavior.

Strict vs. Loose For our analysis we broke both behaviors into a strict and loose definition. For hands on hips, the strict definition matches the Nao’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 Nao’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 back. Having a strict and loose interpretation allowed us to take into account participants who partially performed the behavior in our analysis.

Statistical Methods Our determinations for statistical significance used the following guidelines and justifications. Given that the experiment was run as a within-subjects study, a paired t-test was used. We used one-tailed t-tests because of our division of spontaneous and non-spontaneous participants based on their performance of a behavior being 0 or positive before the Nao performed the respective behavior. We did this because of the observations we were able to make as a result of our initial pilot, as mentioned in the Methods Section. Thereby, we knew the direction for the spontaneous group would be negative and the direction for the non-spontaneous group would be positive. This justifies our use of a one-tailed t-test.

For a given participant, the “before” period is defined as the time before the Nao performs the specified behavior and the “after” period is defined as the time after the Nao performs the specified behavior.

Hands on Hips For the **strict** definition of hands on hips, non-spontaneous participants performed the behavior more in the “after” period ($M = 9280.71$ ms, $SD = 21273.90$ ms)

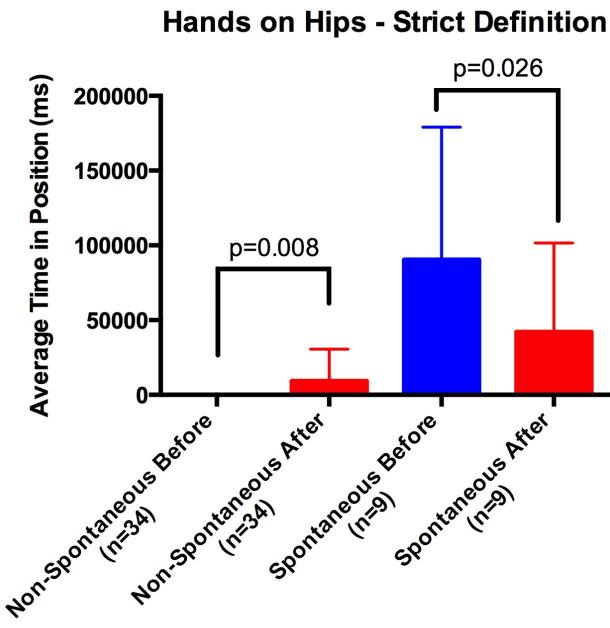


Figure 5: Hands on Hips- Strict Definition

than in the “before” period ($M = 0.00$ ms, $SD = 0.00$ ms), $t(33) = 2.54$, $p = 0.008$.

For the **strict** definition of hands on hips, spontaneous participants performed the behavior less in the “after” period ($M = 42047.00$ ms, $SD = 59608.97$ ms) than in the “before” period ($M = 90381.00$ ms, $SD = 88705.54$ ms), $t(8) = 2.29$, $p = 0.026$.

The results for the strict definition of hands on hips, both non-spontaneous and spontaneous, are shown in figure 5.

For the **loose** definition of hands on hips, non-spontaneous participants performed the behavior more in the “after” period ($M = 11592.13$ ms, $SD = 25920.62$ ms) than in the “before” period ($M = 0.00$ ms, $SD = 0.00$ ms), $t(32) = 2.53$, $p = 0.008$.

For the **loose** definition of hands on hips, spontaneous participants performed the behavior less in the “after” period ($M = 39655.36$ ms, $SD = 64828.17$ ms) than in the “before” period ($M = 80540.36$ ms, $SD = 92746.96$ ms), $t(10) = 2.11$, $p = 0.030$.

The results for the loose definition of hands on hips, both non-spontaneous and spontaneous, are shown in figure 6.

Hands Behind Back For the **strict** definition of hands behind back, non-spontaneous participants performed the behavior more in the “after” period ($M = 13420.10$ ms, $SD = 47423.54$ ms) than in the “before” period ($M = 0.00$ ms, $SD = 0.00$ ms), $t(29) = 1.55$, $p = 0.066$.

For the **strict** definition of hands behind back, spontaneous participants performed the behavior less in the “after” period ($M = 49043.77$ ms, $SD = 99975.38$ ms) than in the “before”

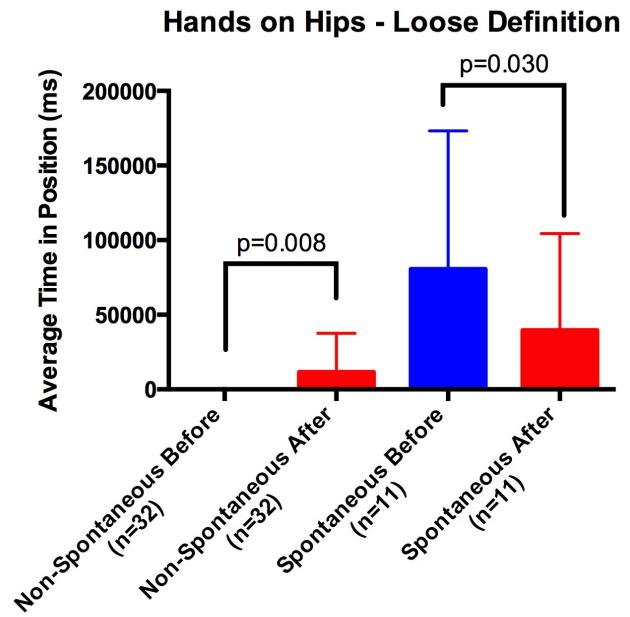


Figure 6: Hands on Hips - Loose Definition

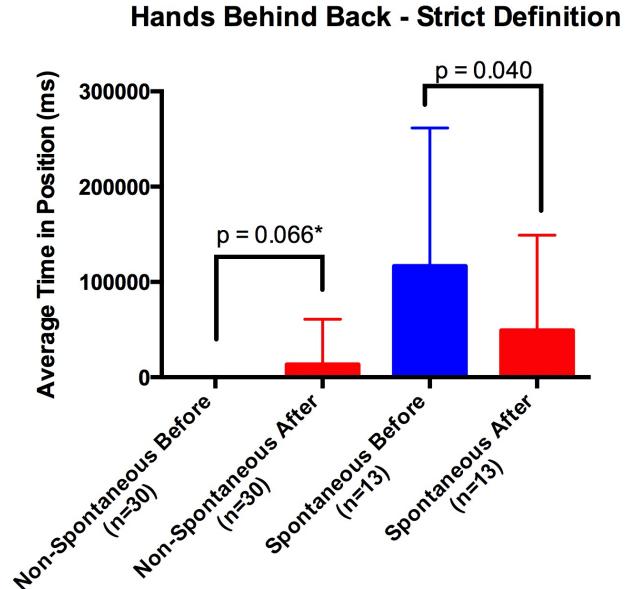


Figure 7: Hands Behind Back - Strict Definition

period ($M = 116665.08$ ms, $SD = 144992.65$ ms), $t(12) = 1.91$, $p = 0.040$.

The results for the strict definition of hands behind back, both non-spontaneous and spontaneous, are shown in figure 7.

For the **loose** definition of hands behind back, non-spontaneous participants performed the behavior more in the “after” period ($M = 22292.48$ ms, $SD = 63531.61$ ms) than in the

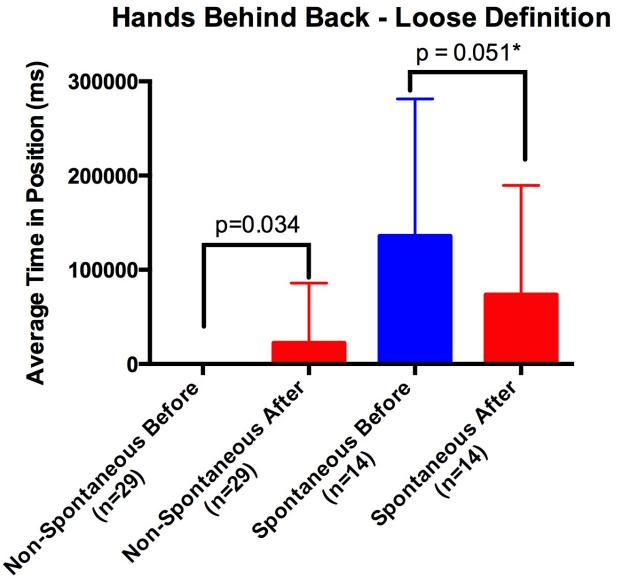


Figure 8: Hands Behind Back - Loose Definition

“before” period ($M = 0.00$ ms, $SD = 0.00$ ms), $t(28) = 1.89$, $p = 0.035$.

For the **loose** definition of hands behind back, spontaneous participants performed the behavior less in the “after” period ($M = 73551.36$ ms, $SD = 116104.35$ ms) than in the “before” period ($M = 135802.93$ ms, $SD = 145636.49$ ms), $t(13) = 1.76$, $p = 0.051$.

The results for the loose definition of hands behind back, both non-spontaneous and spontaneous, are shown in figure 8.

Survey Results Beyond providing us insight for our inferences in our discussion, we found no significant result for likability, intelligence, gender, or race and the performance of behaviors before or after the Nao performed them. Our lack of results here can be partially explained by lack of sufficient sample size for questions such as demographic analysis.

5. DISCUSSION

Our results yield two main findings about inducing mimicry in humans through robots that support both of our initial hypotheses. **RESULT 1.** *Humans who do not spontaneously demonstrate a behavior prior to observing a robot do so perform that behavior more after observing a robot perform it.* **RESULT 2.** *Humans who spontaneously demonstrate a behavior prior to observing a robot do so perform that behavior less after observing a robot perform it.*

Interpretation of Mimicked Behaviors Our results support our first hypothesis H1. For both the strict and loose definitions of hands on hips, participants significantly put their hands on their hips more after seeing the Nao do so. This presents very strong evidence for a robot’s ability to induce mimicry. For the hands behind back behavior, the strict definition was only marginally significant while the

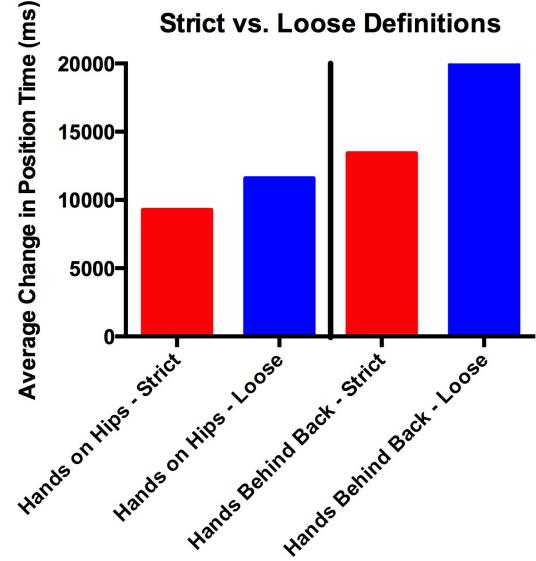


Figure 9: Strict vs. Loose Definitions

loose definition was statistically significant. This makes sense as the loose definition focuses on the population who put neither hand behind the back, meaning no part of this group even partially performed the behavior spontaneously. Because the loose group focuses on people who in no way perform the behavior spontaneously, their potential for mimicry is maximized in the after period. The differences between strict and loose definitions can be seen in figure 9.

[IS THIS LEGITIMATE]? As far as why the strict definition of hands behind back was only marginally significant while the strict definition of hands on hips was statistically significant, the difference in significance can possibly be explained by the nature of the behaviors themselves. Hands on hips is a more stable behavior in that occurrences of it are longer in duration than the sometimes short burst of hands behind back. This is best captured by the sample size of strict hands on hips vs. strict hands behind back (34 vs. 30). Essentially, there are less participants who by chance or very quickly or casually perform a hands on hips behavior spontaneously. This is especially true with one hand behind back, which is why the loose definition helps to bring hands behind back into statistical significance (the loose definition separates the populations of spontaneous vs. non-spontaneous more thoroughly).

Spontaneous Performers Mimic Less Our results support our second hypothesis H2. This was a surprising yet exciting result of our study. Participants who spontaneously performed hands on hips or hands behind back prior to the Nao doing so actually performed that behavior *less* after the Nao did. While we cannot conclude why this would happen we can make inferences, especially with the help of our survey responses. Several responses noted spontaneous participants saying that when they saw the Nao first put its hands on its hips or put its hands behind its back, they thought the Nao was mimicking their behavior. Such a thought process makes sense when we recall that the spontaneous partici-

pants had performed that behavior already at some point before ever seeing the Nao do so. The fact that several participants were trying to figure out the purpose of the study only further pushed them to attribute the Nao’s behavior as the Nao mimicking them (albeit in the wrong direction). This stands in contrast to several non-spontaneous participant responses who correctly identified the purpose of the study and did not confuse the direction of mimicry since they had never performed it up until that point. With this idea in hand that participants thought they were being mimicked, we can go back to psychology literature to look for explanations. Mimicry research in psychology has shown that mimicry can lead to socially cold feelings or the feeling that something is “off”. In particular, an inappropriate amount of mimicry arouses suspicion in the party being mimicked [3], [14], [19], [23]. This can possibly explain why there is a decrease in performance of hands on hips or hands behind back for spontaneous participants. Another possible explanation is that humans view the Nao as a member of a social outgroup. It is possible that viewing the Nao as a member of an outgroup makes participants who think the Nao is mimicking them feel that the mimicry is inappropriate [11].

There are several caveats to consider with the theory that participants had a negative reaction to being mimicked. Previous studies showed positive human reactions to being mimicked by a digital avatar when head posture was mimicked [2], which seems contradictory to our possible explanation. In that study, however, the mimicking was done on a delay and participants were not aware of the mimicry [2]. In our study, participants saw what they thought was an explicit attempt at mimicry. The explicit attempt fits more appropriately with the psychology research that discusses problems with “inappropriate” amounts of mimicry.

Within the surprising finding for spontaneous performers of the behavior is that the loose definition saw smaller decreases than the strict definition. For hands behind back, the loose definition had such a smaller decrease that it even moved the loose definition for spontaneous participants from statistically significant to marginally significant. This can possibly be explained by the fact that our cutoff for spontaneous vs. non-spontaneous was 0. This means that participants who barely performed the behaviors before the Nao did, even for only 1000 milliseconds, were counted in the spontaneous group. These participants had such a low “before” time that they could easily have a higher “after” time. This could happen just by chance (particularly for hands behind back which had more small bursts of the behavior) or because the participants who performed the behavior for small periods in the “before” period did not take the Nao performing the behavior as an attempt at mimicry, silencing the concern of inappropriate mimicry. Fundamentally, this problem is more pronounced given the small sample size for the spontaneous group.

6. CONCLUSION

Understanding mimicry in human-robot interaction is an essential piece of designing social robots. In particular, mimicry needs to be actively considered in design paradigms and when analyzing the social impact of a robot. In light of this, we ran a study to observe the ability of a robot to induce mimicry in humans. Participants described paintings

while interacting with a robot that assumed the posture of either hands on hips or hands behind back. Based on an initial pilot, we identified two groups of people within our sample: those who spontaneously exhibited hands on hips or hands behind back and those who did not. Our study produced two findings. People who did not spontaneously exhibit a behavior, mimicked the robot doing the behavior. People who spontaneously exhibited a behavior, performed the behavior less after observing the robot do the behavior. We discussed possible explanations for our results and their caveats in the previous section.

Implications In light of our first finding we can conclude that robots can induce mimicry in humans. This opens a lot of new research possibilities and questions. Does the salience of mimicry in human-robot interaction move in the same patterns as it does in humans? For example, does having a goal to affiliate or similarity between partners induce greater mimicry in human-robot interaction as it does in humans [7]? Our second finding also raises concerns about building mimicry into human-robot interaction, especially in terms of having robots mimic humans. Perhaps there are certain prerequisites that must be fulfilled in a human-robot partnership before mimicry is considered appropriate. Lastly, this study raises issues for design of robots and their impact on humans around them. Just as we are wary of how other humans may mimic our actions, we must be wary of how robots may induce humans to mimic tasks, particularly if they are tasks we design robots to do specifically because we don’t want humans doing them.

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