Real-Time Empathy: Facial Mimicry on a Robot

Laurel D. Riek
Computer Lab., Univ. of Cambridge
15 JJ Thompson Avenue
Cambridge CB3 0FD, UK

Laurel.Riek@cl.cam.ac.uk

Peter Robinson
Computer Lab., Univ. of Cambridge
15 JJ Thompson Avenue
Cambridge CB3 0FD, UK

Peter.Robinson@cl.cam.ac.uk

ABSTRACT
Expressing empathy is a key component of human social communication. One common way people convey empathy is via facial expression mirroring. It may be helpful for machines intended to interact with people to also convey empathy in this manner. We have thus created Virgil, an expression-mimicking robot. We hypothesize that if people feel like a machine is empathizing with them they will be more likely to rate the interaction positively. We conducted a pilot study to test our hypothesis, and through quantitative and qualitative analysis of our results found some support for it.

Categories and Subject Descriptors
I.2.9 [**Artificial Intelligence**]: Robotics – *Commercial robots and applications*; J.4 [**Computer Applications**]: Social and Behavioral Science – *Psychology, Sociology*

General Terms
Design, Experimentation, Human Factors

Keywords
Affective Computing, Empathy, Facial Expressions, Human-Robot Interaction, Social Robotics

1. INTRODUCTION
Expressing empathy is a key component of human-human social communication. It helps people experience and understand what others are conveying [7]. One level of empathetic understanding is known as *emotional contagion* [2, 3], where an observer mimics a target's behavior, and then that mimicry causes observers to experience an emotional state that is similar to that of the target [1]. One common way in which people convey empathy is through the use of facial expression mirroring. Such facial mimicking might include laughing, eyebrow raising, head nodding, etc. For machines that are intended to interact with people it may be helpful if they too are able to convey empathy in this manner.

Much work has been done with real-time facial expression mimicking on virtual avatars; Kang et al. [4] provide a survey. In robotics work has been done with regards to real-time conveyance of facial expressions, gaze, and head gestures on physical avatars, which are tele-operated robots intended to represent remotely located users; see Riek [6] for a survey of this work. Much work has been done on autonomous robotic platforms that have human-like or animal-like appearances that convey expressions in real-time; see Walters [8] for a thorough survey. Also, Nadel et al. compared how subjects respond to affective facial display on a robot vs. on a human [5].

We hypothesize that if people feel like a machine is empathizing with them they are more likely to rate their interaction positively. This hypothesis in inspired by results presented in the literature regarding human-human, human-robot, and animal-animal communication [4, 6, 7, 8].

To test this hypothesis, we created an expression-mimicking robot named Virgil (see Section 2) and implemented a pilot study, which is described in Section 3.

Through quantitative and qualitative analysis of our results (See Section 4), we find some support for our hypothesis. Interpretation of these results is presented in Section 5.

2. EXPRESSION MIMICKING ROBOT
2.1 Motivation
In psychology it is well understood that humans and some non-human mammals can convey empathetic responses via involuntary facial mimicry. This is mimicry that does not involve a cognitive dimension and is quickly processed, usually within one second or less [7]. In that vein, we have chosen to create a naïve facial mimicking robot that mirrors back some expressions a human makes to it in real-time.

Since the system is currently at the proof-of-concept stage, we are focused solely on aspects of facial expression that are relatively easy to track, such as head nodding and mouth open/close movement. According to Ross et al., simple open mouth faces are probably be sufficient to convey empathy [7], but we believe head gestures are also important for empathy conveyance.

Figure 1. The robot Virgil. It has 18 degrees-of-freedom.

2.2 Platform Description

We chose to use the Wowwee Alive Chimpanzee Robot, which we have named Virgil (see Figure 1). Practically, this robot was selected because it was inexpensive and easily modifiable. However, it was also selected because apes can be extremely empathetic creatures [7], and are thus a natural platform to use for facial mimicry.

Virgil has a total of 18 degrees-of-freedom (DOFs). Its eyes have 4 DOFs (up/down/left/right), eyebrows 2 DOFs (up/down), its lower jaw 2 DOFs (up/down), its upper lip 2 DOFs (up/down), and its head 8 DOFs (roll/pitch/yaw). Out of the box the robot can operate fully autonomously or be tele-operated via remote control.

We have modified Virgil to be fully controlled via an Arduino microcontroller.

2.3 Software

We created an interface to the Arduino microcontroller to allow Virgil to be controlled from a laptop using high-level commands. These commands include head, eye, eyebrow, jaw, and upper-lip control. We also implemented some more complex commands, such as looking suspicious (narrow eyes, turn head left), though did not use them in our study.

Originally we planned to track facial features from user and translate those features into fully autonomous control of the robot. However, we were unable to finish implementation of our system in time for publication.

3. METHOD

We ran a between-subjects pilot study with two groups. In the control group the robot acted in a completely random fashion ("demo mode"). In the treatment group, the robot mimicked mouth facial expressions and head gestures made by the subject in a manner to indicate the robot was listening to them speak. Subjects were randomly assigned to either the treatment group or the control group.

3.1 Subject Recruitment

Subjects were recruited via word-of-mouth. They were told they would be participating in a study where they would be talking to a robot. Subjects were told they would receive a £10 gift voucher to a local department store in thanks for their participation.

3.2 Setup

3.2.1 Physical Space

The experiment took place within the Computer Laboratory Usability Lab, which is a room meant to resemble a living room. It has tables, chairs, a carpet, and pictures on the wall. Virgil was placed on a table draped with a black cloth. A chair was placed approximately two meters away from the table for subjects to sit in and face the robot (See Figure 2).

The experimenter sat behind a one-way mirror in a separate room.

3.2.2 Robot Setup

For the random condition, Virgil was simply switched on. The robot has a default "curious" mode where it will remain in indefinitely. In this mode the robot will turn its head from side to side, move its lips, etc. Other times it will remain still. These behaviors are enough to give an impression of randomness.

For the mimic condition, Virgil was Wizard-of-Oz controlled (i.e., remote controlled) by the experimenter. The experimenter stood behind a one-way mirror watching the subject and robot interact and commanded the robot via a laptop.

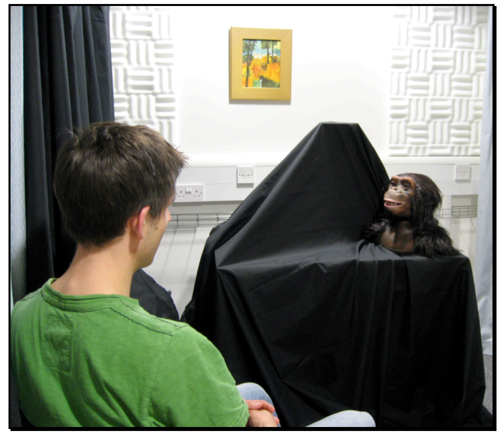

Figure 2. The experimental setup in the Usability Lab.

3.3 Materials

3.3.1 Instruction Sheet

We prepared an instruction sheet for participants that contained the following:

- A "Thank you" for participating
- An overview of the study ("This study requires you to talk to a robot. Please try to do so in a natural manner.")
- A description of the procedure ("You will be given two tasks, both of which involve talking to the robot. Then you will complete a short, paper-based questionnaire. Finally, you will be asked some open ended questions by the experimenter.")
- A note that they are free to withdraw from the study at any time without giving a reason for withdrawing.
- A note that all questionnaire responses will remain confidential, and that no personally identifying information will be published.

3.3.2 Robot Information Sheet

We prepared a robot description sheet that had a picture of the robot with a brief textual description of its capabilities. "Virgil is a Chimpanzee Robot. The robot is stationary but can move its head and mouth. It does not make any noise aside from its motors moving."

Subjects were given this sheet to help avoid them being shocked from seeing the robot for the first time.

3.3.3 Post-evaluation questionnaire

We created a post-evaluation questionnaire based on the Interactant Satisfaction Survey described by Kang et al. [4]. The questions are listed in Table 1. We used a 1-6 Likert rating scale; strongly agree (1) to strong disagree (6). All of the responses are positively biased with the exception of Q2, "I don't mind if I never get to interact with Virgil again."

Table 1: Modified Interactant Satisfaction Survey

Question No.	Survey Question
1	I think Virgil could be a friend of mine.
2	I would like to have a friendly chat with Virgil in the future.
3	Virgil is pleasant to interact with.
4	I don't mind if I never get to interact with Virgil again.
5	Virgil recognized my feelings and emotions.
6	Virgil expresses feelings and emotions appropriate for the situation.
7	Virgil responds appropriately to positive and negative emotions.
8	Virgil knows how to control its own feelings and emotions effectively.
9	Virgil handles others' feelings and emotions sensitively and effectively.

3.4 Procedure

3.4.1 Introduction

Subjects were met outside the usability lab. They were given the instruction and robot information sheets and asked to read them. They were then asked if they had any questions.

3.4.2 The Study

Following the introduction, subjects were brought into the usability lab and seated in the chair facing the robot. The experimenter left the room.

From an observation room the experimenter said verbally, "The first task will now begin. Please tell Virgil the route you took to the Laboratory today. For example, 'I left my house, took a left on Histon Road, etc.'"

Once the subject finished, the experimenter then told them (again from the observation room) to begin task two. "Next, please tell Virgil about your first memories of Cambridge – people you met, things you saw, foods you ate, etc. Please be as descriptive as possible."

3.4.3 Conclusion

Subjects were given the post-evaluation questionnaire to complete. The experimenter left the room.

Following completion of the questionnaire, the experimenter re-entered the room and interviewed subjects about their experience. All subjects were asked, "What were your first impressions of Virgil?", "How did you feel talking to the robot?", "Did you feel like the robot was an amicable conversation partner?", "Is there anything you'd like to add?" The experimenter also asked follow-up questions when appropriate to encourage subjects to elaborate.

Finally, subjects were asked their age, if they had seen the robot before, and if they knew about what the experimenter's research area was / what was being tested.

3.5 Measures

Because we were measuring attitudes toward the robot via an ordinal scale, we employed non-parametric statistical measures in our analysis.

We also reversed the raw data for question 4 ("I don't mind if I never get to interact with Virgil again.") to make all the ratings consistently positive. Thus, a "Strongly Agree" score was converted to a "Strongly Disagree" score, etc. Since we used a 6-point Likert scale, this conversion was possible.

4. RESULTS

Our hypothesis is:

(H1) People in the facial-mimicking group will rate their interaction with Virgil as more satisfactory than people in the control group.

Thus, our independent variable is the robot state (intentional facial mimicking vs. random), and our dependent variable is expressed satisfaction as measured by the Modified Interactant Satisfaction Survey (see Section 3.3.3).

4.1 Subject Demographics

Six people participated in our study. Two were male and four were female. Ages ranged from 20-50 (mean age: 29.3, $\sigma = 10.7$). All subjects were affiliated with the Computer Laboratory. Four people were research students and two were administrative staff. Two subjects had seen the robot before, but never when it was turned on.

4.2 Manipulation Check

No subjects we aware of the experimenter's hypotheses or research interests. One subject did know the experimenter was a Human-Robot Interaction researcher, but the subject was unaware of any specifics.

4.3 Control Condition Check

Before beginning our analysis it was necessary to ensure that there was a statistically significant difference between the control group and the intentional facial-mimicking group. To do this we combined all ratings per the two groups. This allows us 27 samples, thus permitting valid statistical measures to take place.

We performed the Wilcoxon Rank Sum Test (a non-parametric t-test) on the two groups. Our results indicate we can reject the null hypothesis, which is that the facial-mimicking group and control group rated their satisfaction with the interaction the same ($p < 0.000$, $\alpha = 0.05$, $W = 161.5$). Thus, there is a significant difference between the two groups.

4.4 Satisfaction Ratings

Next, we wanted to examine (H1) to see if there was a difference between the two groups in terms of expressed satisfaction. Because we only had six subjects, it was not possible to perform statistical analysis on the individual questions. However, since we were only interested in knowing if there was a general difference in the overall satisfaction levels between the two groups, we once again looked at the total combined ratings for each group. A visualization of these data is presented in Figure 3.

We performed a Mann-Whitney Test on the two groups, and found the mean ranking of the combined scores of subjects in the control condition was 37.02, and the mean ranking of subjects in the mimic condition was 19.98. ($p < 0.000$, $\alpha = 0.05$). Because we used a positively biased questionnaire where 1 is Strongly Agree and 6 is Strongly Disagree, a lower mean ranking actually means overall higher satisfaction. Thus, we find support for (H1), that people in the facial-mimicking group will rate their interaction with Virgil as more satisfactory than people in the control group.

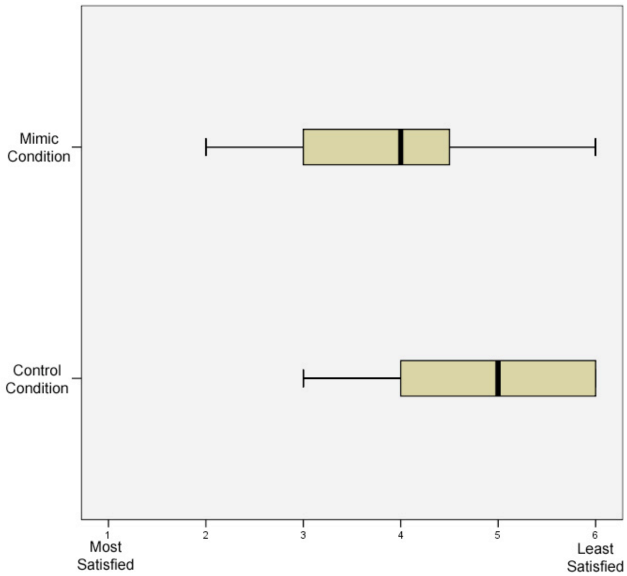

Figure 3. Combined satisfaction ratings for each group.

4.5 Qualitative Results

In addition to finding some support for (H1) quantitatively, the qualitative data lend further support. While it is difficult to classify one response as more extreme than another given individual differences in how people respond to questions, subjects in the control condition seemed to be more negative overall than subjects in the facial mimicking condition. Responses given about Virgil fit into four categories: conversation flow, response appropriateness, appearance, and sound.

We will use the following abbreviations for quote attribution: *FMC* for subjects in the Facial-Mimicking Condition and *CC* for subjects in the Control Condition.

4.5.1 Conversation Flow

Four subjects expressed dissatisfaction over the fact that the conversations with Virgil were one-sided.

"[The robot] has to speak back. [It felt like] a one-way conversation." *–FMC*

"When I converse with people I like to ask people questions and have them answer. I felt like I was rambling. Usually input from the other person helps fuel the conversation, rather than just me talking the entire time." *–FMC*

"I was embarrassed because I knew he wouldn't be speaking back" *–FMC*

"If it had the ability to talk back, react, say, "Mmm-hmm" [to show attentiveness], vocal sounds, etc, that would have helped [improve the interaction]." *–CC*

4.5.2 Response Appropriateness

All subjects commented on the appropriateness of responses from the robot. One response was quite positive:

"At one point he opened his mouth in surprise, which I thought was really cool – like he was showing surprise in reaction to something I said." *–FMC*

Three responses were even-keeled:

"It was trying to nod a little bit / open its mouth. It did so too extremely – not sure if it came at the right [time] in the conversation. But you definitely felt like you were speaking to something – rather than a box or a machine." *–FMC*

"Some facial expressions and head movements were positive, more like talking to a human. But when you got non-suitable expressions from the robot, it was quite surprising… some of the expressions were exaggerated and unsuitable for the context… It was like talking to someone with a mental disability." *–CC*

"To me it didn't seem like he was responding to what I was saying – not a close correspondence… He seemed to respond at times when I was speaking. I didn't find him threatening or disagreeable in any way." *–FMC*

And two subjects expressed very negative opinions regarding the appropriateness of responses:

"He did a weird thing where he opened his mouth / moved his nostrils [at the wrong time]." "His movements seemed negative - the first thing he did was look away from me. It is difficult to talk to someone when they do that." *–CC*

"[Talking to the robot] was a bit unnerving. I felt that he wasn't listening to a word I said. I was almost waiting for a response, but he wasn't listening." *–CC*

4.5.3 Appearance

All subjects remarked upon Virgil's appearance when asked about their first impressions.

"I felt a bit strange talking to a chimp at first, rather than something with a human face." *–FMC*

"It looks ok…. [it was] better than a robot with no eyes. I could make eye contact with its face. It was better than talking to a [robot that looks like] a metal box." *–FMC*

"Friendly enough, nice face. Still unnerving because of its lack of movement… I didn't find him threatening or disagreeable in any way." *–FMC*

"My first impression was quite negative – its initial expression was surprised. If this was a human you wouldn't meet them for the first time with that expression." *–CC*

"I think he looks quite scary." *–CC*

"Frightening figure." *–CC*

4.5.4 Sound

Two subjects remarked on the sounds of Virgil's actuators:

"I found the sounds of the motors distracting." *–FMC*

"It's a bit weird, the sound of the motors. I don't like talking on my own, and the sound of the motors while you're alone in a room is odd." *–CC*

5. DISCUSSION

We found some support for our hypothesis (H1), that people in the facial-mimicking group will rate their interaction with Virgil as more satisfactory than people in the control group. However, it is difficult to draw any definitive conclusions from this result given that we ran a pilot study with a small number of subjects. Furthermore, the qualitative data indicate that it was difficult for subjects to feel strongly engaged with the robot due to the fact that it didn't speak or make any sort of noises acknowledging their statements. (And, thus, it was more difficult to empathize with the robot as a conversation partner).

The fact that people expressed dismay that the robot didn't speak and didn't respond appropriately during the conversation may mean that people placed a burden upon the robot to be expressive in a human-like way because it was a three-dimensional entity (which would concur with Riek [6]). On the other hand, this expectation for human-like expression may just be due to the fact that people were placed into a conversational context. This effect warrants further investigation.

Because we are still at the proof-of-concept stage of our research we chose to mimic only two aspects of human facial expression on our robot – head movement and mouth movement. In the future we plan to extend Virgil's expressive repertoire, and will likely provide it with the opportunity to speak as well.

6. ACKNOWLEDGMENTS

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