Improving Human-Robot Interaction: Modifications of a Social Robot on Dimensions of Behavior and Appearance

Daniella Massa

June 9, 2022

Abstract

This study aims to measure how Human-Robot Interaction (HRI) can be improved via alterations to a robot's appearance and behavior. More specifically, the robot's appearance will be modified over two dimensions: its profile (the variety of facial expression it displays) and its gender (male vs female). The gender of the robot will be implemented through its voice generated by Amazon Polly. The robot's behavior will also be modified over two dimensions: its personality (welcoming vs unwelcoming) and its movement (smooth vs rigid). In this study, the participants were assigned to one of four conditions: (1) interacting with a welcoming male robot, (2) interacting with a welcoming female robot, (3) interacting with an unwelcoming male robot, or (4) interacting with an unwelcoming female robot. In order to achieve altering the robot's personality, a feedback mechanism was used during the interaction. Furthermore, participants that were assigned to the welcoming robot conditions had to option to engage in a portion of self-expressive conversation, whereas those who were assigned to the unwelcoming conditions did not. At the end of the interaction, participants were prompted by the robot to complete a task. The speed and success of this task completion was recorded. Additionally, the participants' negative attitudes and anxiety towards robot interaction were measured before and after the interaction.

Contents

1 Introduction

The field of social robotics consists of designing a robot that has the ability to follow implicit social rules and mimic human behavior [1]. Similarly, Human-Robot Interaction (HRI) involves monitoring how humans respond to interacting with a social robot [7]. Both of these fields are prominent areas for modern

research in computer science. With the expansion of social robotics and HRI research, robotic agents are now being implemented in a variety of real world settings: classrooms, business industries, restaurants, etc. [2][10][9]. However, in order for these robotic agents to work effectively within a given environment, it is imperative that they are designed in such a fashion that optimizes positive HRI. In other words, it is essential to discover what factors determine if a robot is universally likable. The purpose of this study is to analyze what modifications can be made to a social robot's appearance and behavior, in order to improve HRI. More specifically, this study aims to address how a robot's facial expressions, gender, personality, and movement style affect HRI. Although the experiments included in this study will be conducted within a controlled environment, the findings of this research will have a concrete impact, as they will be applicable to real-world scenarios that involve social robots.

2 Background and Related Work

2.1 HRI from a Psychological Perspective

Previous research has shown that Human Robot Interaction (HRI) differs from Human-Computer Interaction (HCI) in the sense that HRI involves a more personable and emotional interaction. To be more specific, authors Forlizzi and DiSalvo [3] found that humans tend to automatically associate robots with living creatures, and will interact with robots as such. In other words, people tend to develop strong affective and emotional attachments to robots. However, this is not the case with other technological agents, such as computers or tablets. Additionally, studies show that negative attitudes and emotions towards robots directly influence a person's behavior in a human-robot interaction. More specifically, Nomura et al. [8] determined that there are certain psychological factors which contribute to poor human-robot interaction. For example, a person who displays social anxiety, technophobia, or communication apprehension will likely experience more discomfort and anxiety when interacting with a robotic agent, and will behave in a more reserved manner.

2.2 Conducting an Analysis of HRI

Human-Robot Interaction can be evaluated over three main dimensions: visceral factors of interaction, social mechanics, and social structures. Visceral factors refer to a person's biological and instinctual response when interacting with a robot (i.e. a person's first impression). A robot's size, shape, speed, and patterns of movement can affect visceral factors. Social mechanics refer to higher-level communication techniques that occur during an interaction (i.e. gestures, facial expressions, tone of voice, etc.). By altering the higher-level communication techniques implemented within a robotic agent, the perceived disposition and personality of the robot is affected. Social structures refer to the setting the interaction takes place in (i.e. the cultural environment), and how this setting may influence the interaction. This category also refers to the impact a robot may have in a given setting (i.e. the emotional impact of a robot's presence on humans over time). These dimensions were developed by Young et al. [12]. For the purpose of the current study listed in this paper, HRI quality will be analyzed over the first two previously listed dimensions: visceral factors and social mechanics.

2.3 Task-Driven HRI

Studies have also demonstrated that HRI will improve if a robot's appearance, behavior, and social cues match its task/purpose. Goetz et al. [4] found that people preferred friendly robots for highly sociable tasks. Additionally, people tended to comply more with a robot whose demeanor matched the seriousness of a task. Further task-related HRI studies have analyzed how to generate a shared mental model between a collaborator and a robot during an interaction. More specifically, researchers Tabrez and Hayes [11] looked into enabling a system to detect disparity between the robot and the human collaborator, finding the source of the disagreement, and ensuring that the robot provides human-interpretable feedback to the user. Findings showed that participants found the robot to be more helpful/useful when it provided an explanation for why a failure/discrepancy may occur. Additionally, when the robot gave justifications for its actions, it

led to a more positive user experience in which the participant viewed the robot as more intelligent. On the flip side, when the robot did not provide detailed feedback in regards to discrepancies, the participants did not trust the robot and were more skeptical of its behavior.

2.4 Additional Contributing Factors in HRI

Studies have shown that there are additional factors that may cause HRI to go poorly. For example, Lee et al. [6] found that people are reluctant to interact with a social robot if the robot is taller than them. Moreover, Ho et al. [5] illustrated that a person's discomfort may increase if a robot's life-likeness appearance exceeds a certain threshold, but it does not display realistic human-like behavior (The Uncanny Valley Theory).

3 Methods

3.1 Materials and Participants

This experiment will be conducted on-campus at Union College, in the Collaborative Robotics and Computer Human Empirical Testing Laboratory (CRoCHET Lab). The robot that will be used in this experiment is a PeopleBot named VALERIE (see Figure 1). VALERIE is a differential-drive robot that has the ability to speak and display facial expressions. VALERIE's speech is developed using Amazon Polly. VALERIE's current facial expression designs include: neutral, happy smile, happy laugh, sad, scared, angry, disgusted, and surprised (see Figures 2 and 3). These expressions are rendered on the main screen via an HTTP server. VALERIE has the ability to execute speech and expression-display commands through message passing in a ROS interface, specifically by utilizing the rosbridge_suite package. Additionally, VALERIE can smoothly transition between facial expressions through a tween module, that individually animates the various components of the face (i.e. mouth, eyes, eyebrows, etc.).

Participants for this study will be gathered via demonstrated interest through the college's SONA system, and participation will be voluntary. Prior to engaging in the experiment, the participants will be asked to complete a demographic questionnaire. The participants will also be asked to complete the Negative Attitudes Towards Robots Scale (NARS) and the Robot Anxiety Scale (RAS). After these forms have been submitted, the participants will be asked to schedule a date to meet in the CRoCHET Lab. This is where the bulk of the experiment will occur, in which the participant will interact with their assigned robot condition.

Figure 1: VALERIE Robot

3.2 Experimental Conditions

The participants will be randomly assigned to one of four conditions: (1) welcoming female robot, (2) welcoming male robot, (3) unwelcoming female robot, (4) unwelcoming male robot. The participants will not be made aware of these conditions, therefore a cover story will be used. The gender of the robot (female vs male) will be implemented via VALERIE's voice with Amazon Polly.

For the conditions that entail a welcoming robot, VALERIE will display friendly facial expressions, such as "happy smile" and "happy laugh". When the participant arrives at the CRoCHET Lab, the robot will move forward to greet them. During the interaction, VALERIE will ask the participant a variety of "ice-breaker" questions, such as "What are you studying at Union College?" VALERIE will also allow the participant to engage in self-expressive portion of the interaction, which will include more personal questions,

such as “Tell me about your favorite person”, “What are you most proud of?”, “What are you passionate about?”, etc. Additionally, the robot will utilize a feedback mechanism, in which VALERIE will react to the participants’ verbal response by saying “That’s so cool!”, “Can you tell me more about that?”, etc. This will further the effect of the robot’s welcoming appearance, as VALERIE will seem engaged and interested in the conversation during the interaction. At the end of the interaction, VALERIE will ask the participant to complete a task. This task will prompt the participant to hold the door for VALERIE so the robot can exit the lab, and the participant will be instructed to exit as well. Finally, VALERIE will say goodbye to the participant, and thank the participant for their engagement.

For the conditions that entail a unwelcoming robot, VALERIE will display unfriendly facial expressions, such as “angry” and “disgusted”. When the participant arrives at the CRoCHET Lab, the robot will not move forward to greet them. During the interaction, VALERIE will ask the participant the same list of ice-breaker questions as the welcoming conditions. However, during the interaction, VALERIE will not include the self-expressive portion of questioning, nor will the robot utilize the feedback mechanism. This will further the effect of the robot’s unwelcoming appearance, as VALERIE will seem indifferent and uninterested in the conversation during the interaction. At the end of the interaction, VALERIE will ask the participant to complete the same task as stated above. After this, VALERIE will say goodbye to the participant, without thanking them for their engagement.

Once the participant concludes their interaction with VALERIE, they will be asked to complete the Negative Attitudes Towards Robots Scale (NARS) and the Robot Anxiety Scale (RAS) a second time. Due to the fact that this study contains a repeated measure design, the order of the items on these scales will be randomized to eliminate practice effects. Additionally, the interaction will take no longer than fifteen minutes in order to eliminate fatigue effects.

3.3 Measures

The human-robot interaction in this experiment will be analyzed on three measures. The first measure is the participants self-report, via the NARS and RAS surveys. The total score for each survey will be calculated, and the difference between the scores (prior to interaction, after interaction) will be calculated. A statistical analysis of these scores will be conducted. The second measure is the task completion: whether or not the participant completed the task, and how long it took to complete the task. The third measure is observed behavior. The interaction portion of this experiment will be recorded, and the social behavior of the participants will be analyzed (i.e. body language that signifies discomfort). Any conclusions that are drawn from viewing the interaction will be cross-checked with another researcher.

NOTE: Ideally, the participants will not be informed of the fact that the interaction will be recorded, in order to eliminate the Hawthorne Effect (which is imperative to this study). However, I need to get human-testing and recording permissions through the Psychology Department (which I will accomplish over the summer).

After the experiment concludes, the participants will be debriefed from the cover story, and the true purpose of the experiment will be revealed. Additionally, the participants will be informed of the recording measure, in which they will have the option to either keep or delete their recording from the records. All records will be kept confidential.

4 Preparation

I have been collaborating with professor Kristina Striegnitz to essentially go over a VALERIE “crash course”: how to navigate the robot, how to send speech/facial expression messages, etc. More specifically, I’ve been working on familiarizing myself with VALERIE’s code, which utilizes the HTML, CSS, and Javascript languages. Additionally, professor Striegnitz and I conducted a study to verify the validity of our current facial expressions designs. Put briefly, we ensured that the rendered facial expressions are correctly identified/interpreted by humans,via a Qualtrics survey. I am in the process of performing a data analysis of the results from this study in a pandas DataFrame within Google Colab. Modifications to the facial expressions will be made as needed. I have also met with professor Catherine Walker in the Psychology Department to discuss NARS and RAS scales. Professor Walker has experience in conducting psychological experiments

Term	Course	Aims/Outcomes
Senior Fall	IDM 488*	Gather participants
		Conduct experiments in CRoCHET Lab
		Visualize Data
		Perform statistical analysis of results
		Draft Results section
		A Completed Experiment
Senior Winter	IDM 489*	Finalize Results section
		Update and complete entire thesis paper
		Additional visualization of project: i.e. draft poster for Steinmetz
		A Completed Capstone Design Project
		*Double Major Thesis Course

Table 1: Senior Year Thesis Timeline

that involve robots, and she previously designed a different scale to measure robot affinity. The NARS and RAS scales are adopted from a previous HRI study conducted by Nomura et al. [8]. However, I am interested in the possibility of designing my own scale, or combining items from multiple scales.

5 Work Plan

I will be spending 8 weeks over the summer on campus working with VALERIE. During this time, I will be able to gain important experience working with a social robot. More precisely, I will be working on adapting VALERIE's infrastructure to support task-driven interactions. I will also be looking at VALERIE's speech platform in more detail: I am curious to see if I can implement a gender neutral setting. During this time, I will be able to ensure that there are no bugs in VALERIE's software that need to be fixed, and I will see if any of the hardware components need to be adjusted. That way, once fall term begins, I can be confident that VALERIE will perform in ways that are necessary for this experiment.

Over the course of the summer, I will also be working on finalizing certain details of my experimental design. For example, the quality of the feedback mechanism will directly influence how "welcoming" VALERIE appears during an interaction; therefore I will need to precisely outline how to implement this mechanism. Furthermore, I am interested in modifying the current facial expressions to accommodate gendered appearances: i.e. designing the facial expressions to appear feminine vs masculine. This is something I plan to explore and test over the summer.

Additionally, I will continue searching for and reading articles that pertain to my thesis proposal. I will expand on my Related Work section, and modify my experimental design if needed. The summer will mainly consist of me getting organized: developing additional psychological scales that may be used in the experiment, drafting the participant interest form, getting approval for human testing, etc. By utilizing my time efficiently and working throughout the summer, I will be able to start my in-person experiment in the fall right away.

I aim to fully complete the experimental portion of my thesis in the fall. This entails gathering the participants, conducting the experiment, and collecting the results/data. I will ensure to update my thesis paper synchronously with performing the experiment, that way all of the writing is not left until winter term. A detailed description of my work plan is included in Table 1.

6 Conclusion

Overall, this research will expand on previous studies within the fields of social robotics, human-robot interaction, and social psychology. The findings of this research will have a concrete impact because they will be applicable to real-world scenarios that involve social robots (i.e. classrooms, restaurants, business, etc.). I am the right person to conduct this research because I am highly interested in, and passionate about,

social robotics and HRI. Moreover, my double major in Computer Science and Psychology has prepared me to conduct this research. In regards to computer science, I have previously taken a Robotics class, and I've been taking a practicum credit which consists of me working with VALERIE. Therefore, I feel confident that I have the knowledge and resources to properly design a social robot that is capable of handling task-driven interactions. Additionally, I will be able to adequately analyze human-robot interactions from a social psychological perspective. I have previously taken a Research Methods class, which taught me the correct methodology to design, analyze, and write a paper about a psychological experiment. Furthermore, conducting this thesis project will teach me a lot; it will deepen my understanding of social robotics and social psychology.

References

[1] Cynthia Breazeal, Kerstin Dautenhahn, and Takayuki Kanda. "Social robotics". In: *Springer handbook of robotics* (2016), pp. 1935–1972.

[2] Albert Causo et al. "Design of robots used as education companion and tutor". In: *Robotics and mechatronics*. Springer, 2016, pp. 75–84.

[3] Jodi Forlizzi and Carl DiSalvo. "Service robots in the domestic environment: a study of the roomba vacuum in the home". In: *Proceedings of the 1st ACM SIGCHI/SIGART conference on Human-robot interaction*. 2006, pp. 258–265.

[4] Jennifer Goetz, Sara Kiesler, and Aaron Powers. "Matching robot appearance and behavior to tasks to improve human-robot cooperation". In: *The 12th IEEE International Workshop on Robot and Human Interactive Communication, 2003. Proceedings. ROMAN 2003.* Ieee. 2003, pp. 55–60.

[5] Chin-Chang Ho, Karl F MacDorman, and ZA Dwi Pramono. "Human emotion and the uncanny valley: a GLM, MDS, and Isomap analysis of robot video ratings". In: *2008 3rd ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE. 2008, pp. 169–176.

[6] Min Kyung Lee et al. "The snackbot: documenting the design of a robot for long-term human-robot interaction". In: *Proceedings of the 4th ACM/IEEE international conference on Human robot interaction*. 2009, pp. 7–14.

[7] Robin R Murphy et al. "Human–robot interaction". In: *IEEE robotics & automation magazine* 17.2 (2010), pp. 85–89.

[8] Tatsuya Nomura et al. "Prediction of human behavior in human–robot interaction using psychological scales for anxiety and negative attitudes toward robots". In: *IEEE transactions on robotics* 24.2 (2008), pp. 442–451.

[9] Zengxi Pan et al. "Recent progress on programming methods for industrial robots". In: *Robotics and Computer-Integrated Manufacturing* 28.2 (2012), pp. 87–94.

[10] Yu Qing-xiao et al. "Research of the localization of restaurant service robot". In: *International Journal of Advanced Robotic Systems* 7.3 (2010), p. 18.

[11] Aaquib Tabrez and Bradley Hayes. "Improving human-robot interaction through explainable reinforcement learning". In: *2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE. 2019, pp. 751–753.

[12] James E Young et al. "Evaluating human-robot interaction". In: *International Journal of Social Robotics* 3.1 (2011), pp. 53–67.

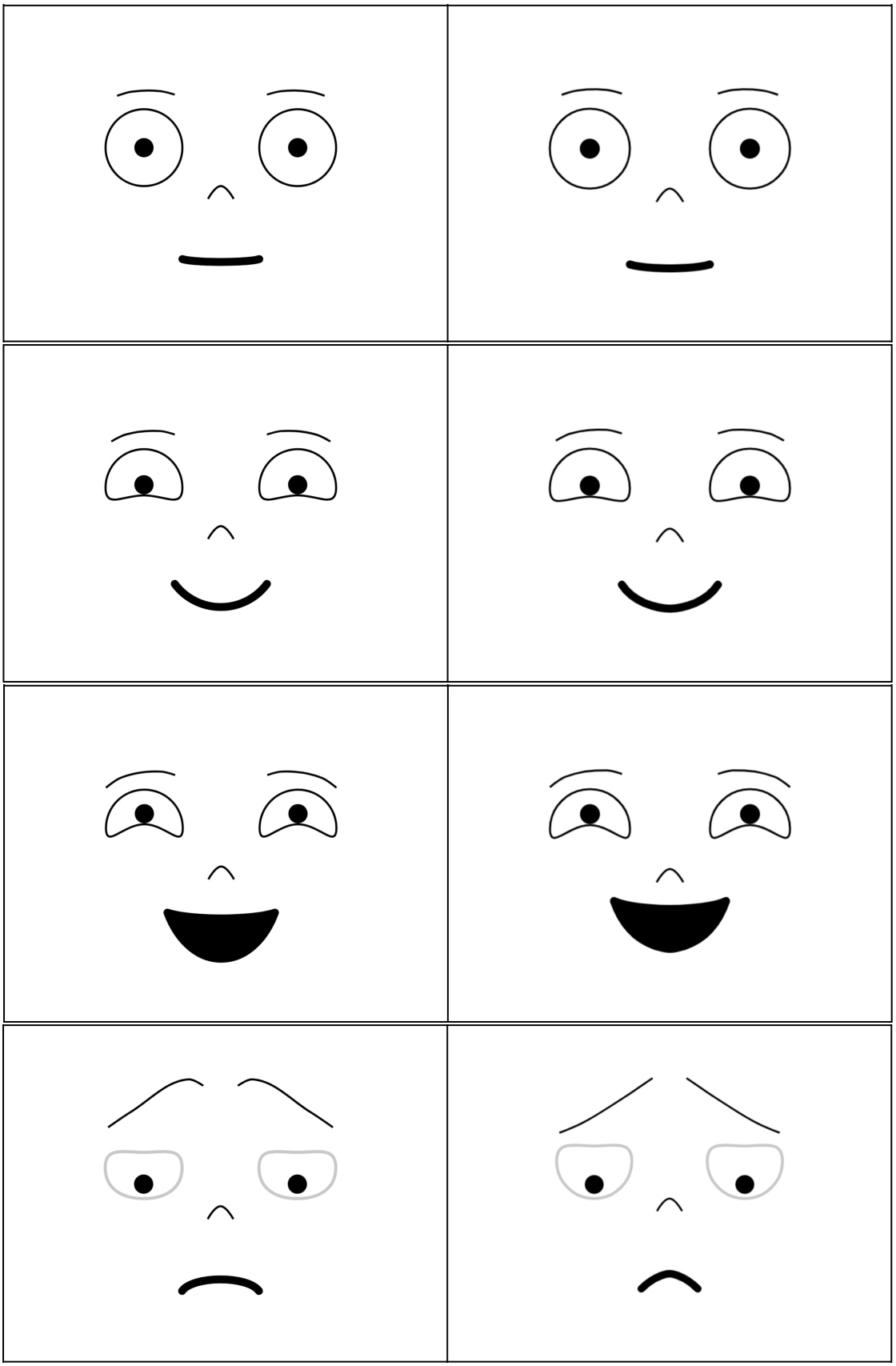

Figure 2: VALERIE Facial Expressions. Note that there are two images for each expression because the images are animated (start and stop positions). Expressions include (from to to bottom): Neutral, Happy Smile, Happy Laugh, and Sad.

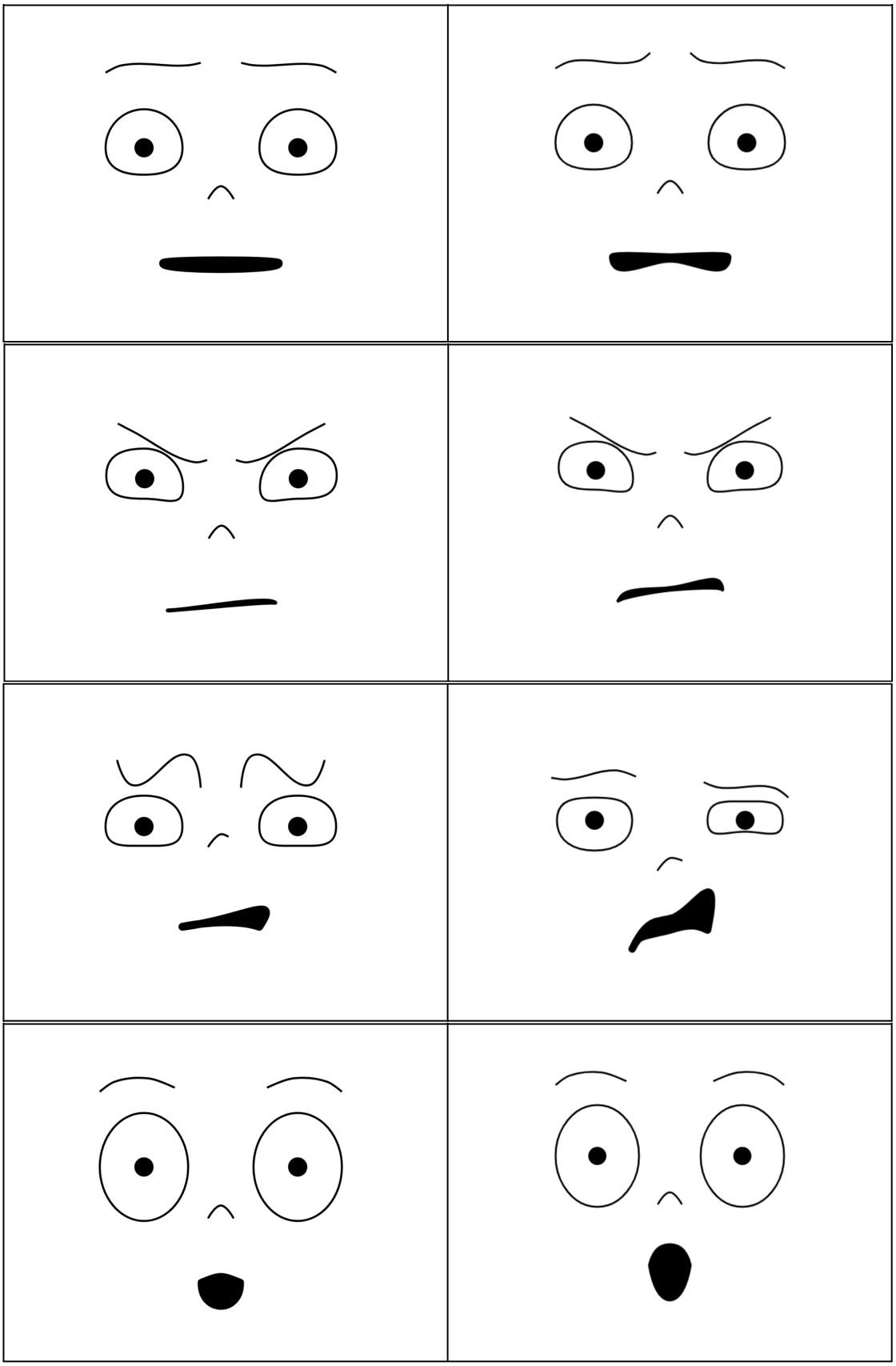

Figure 3: VALERIE Facial Expressions. Note that there are two images for each expression because the images are animated (start and stop positions). Expressions include (from to to bottom): Scared, Angry, Disgusted, and Surprised.