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# Robots can defuse high-intensity conflict situations

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*Abstract*— **This paper investigates the specific scenario of high-intensity confrontations between humans and robots, to understand how robots can defuse the conflict. It focuses on the effectiveness of using five different affective expression modalities as main drivers for defusing the conflict. The aim is to discover any strengths or weaknesses in using each modality to mitigate the hostility that people feel towards a poorly performing robot. The defusing of the situation is accomplished by making the robot better at acknowledging the conflict and by letting it express remorse. To facilitate the tests, we used a custom affective robot in a simulated conflict situation with 105 test participants. The results show that all tested expression modalities can successfully be used to defuse the situation and convey an acknowledgment of the confrontation. The ratings were remarkably similar, but the movement modality was different (ANON $p < .05$) than the other modalities. The test participants also had similar affective interpretations on how impacted the robot was of the confrontation across all expression modalities. This indicates that defusing a high-intensity interaction may not demand special attention to the expression abilities of the robot, but rather require attention to the abilities of being socially aware of the situation and reacting in accordance with it.**

## I. Introduction

With the increased presence of robots employed in service jobs comes an increased rate of confrontations between humans and robots. This is often caused by errors made by the robots and results in blame being placed on them despite that they are rarely directly responsible. When humans respond to the errors of the robot it sometimes leads to physical confrontations and the robots end up being damaged. Humans often have a lower fault tolerance for robots as indicated by Young et al. 2008 and investigated by Tatsuya et al. 2006 and Nomura 2016 [1]–[3]. This poses a problem as current robots are clumsy, move slowly, and often fail to communicate properly. Each of these attributes could motivate humans to get annoyed with the robots and ignite high tension scenarios. It may also be difficult for people to navigate conflict situations as found by Kim and Hinds 2006 because the normal theories about blame as outlined in Malle et al. 2014 may be different for human-robot interactions [4], [5]. This paper aims to focus on using the expressive behavior of the robot to resolve such conflicts.

Hamill et al. 2006 stated that the relationship between service machines and humans resembles a master-slave relationship, and compared the roles of service robot interaction with historic examples of interaction with Victorian servants [6]. This could potentially enlarge any negative predetermined expectations to the social status between the user and robot during an interaction and could enforce expectations of how the robot should behave in confrontations. This view is also outlined in Bryson 2010 [7]. Eg. that the robot should blindly obey humans and accept any blame in such a situation.

We have identified five expression modalities available for robots to convey complex emotional information [8]. These can be summed up as follows: Movement, gestures, morphology, audio, and anthropomorphic reflection. While a substantial amount of research focuses on optimizing individual expression modalities, we have relatively little knowledge of how the synergies of different modalities can strengthen the ability to convey affective information and how effective individual modalities function across different contexts. Furthermore, the modalities may also differ in strength depending on the type of affective information conveyed by the robot. Eg. anthropomorphic features such as eyes might be better at conveying sadness while high volume audio might be better suited at conveying fear.

The research outlined in this paper is novel in that it uses a non-humanoid robot with simple implementations for each affective expression modality to convey acknowledgment of a conflict situation. The strategy for defusing a potentially threatening scenario is to convey that the robot accepts the blame and to match the intensity of the sender while keeping its attention on the sender [9]. Since the complexity in conveying an apologetic behavior and paying attention could demand using multiple means of expression [10]–[12], this paper also attempts to determine if any of the expression modalities are better suited than others to convey an apologetic behavior in this specific scenario.

Through the tests we performed, we found that although there were vastly different complexities in the actual physical implementations of expression modalities there was little difference in the affective impact they made on the par-

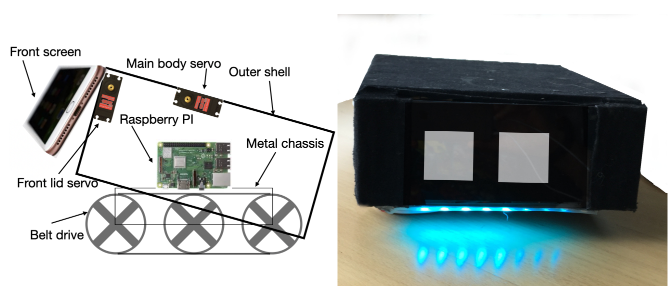


Fig. 1. The 'Affecta' robot used in the scolding reception experiments. The left image depicts the inner parts of the robot. The right image shows the led lights beneath the robot used to convey affective status using the morphology modality.

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ticipant. This underlines that high-intensity conflicts are a special scenario, and that by scolding the robot, people feel remorseful and in that state disregard the complexity, size, and type of the response.

## II. Conflict resolution

There has been relatively little research conducted on how the conflict resolution theory derived from human-focused psychology studies relates to human-robot centered conflicts. However, there has been some recent research performed on human stress reduction using robots. Hout 2017 investigates whether a robot could calm down stressed human participants after attempting to build a bond with the test robot [13]. The study found it difficult to quickly establish a bond between the robot and the participants and saw no positive effect of a soothing touch from the robot. In this project we attempt to convey affective information between participants and a robot, but with no physical interaction. In Birnham et al. 2016 they highlight that the responsiveness of a robot can make humans perceive it as more appealing and also influence the willingness to employ it as a companion in stressful situations [14]. The work outlined in this paper extends some of this research by placing the robot and the test participant on either side of a conflict situation.

We chose to adopt some of the main strategies derived from psychology research projects for resolving conflicts between humans and to apply those techniques as behaviors to the "Affecta" robot. When involved in a conflict, the actions that should be performed to resolve the conflict differ with the type of relationship established between the conflicting partners. Fincham et al. 2004 focused on married couples and different strategies for defusing conflict scenarios. A strategy where the parties avoided the argument, shows poor results for resolving the conflict [15]. Although it seems a feasible strategy for the robot to leave the high-intensity situation, ignoring the scolder and driving away could intensify and increase the rage level of him or her even further. There are indications that withdrawal from the conflict situation only works with internalizing the problems as outlined by Branje et al. 2009 [16]. A viable strategy for resolving the conflict is presented by Jessica Solis 2011, in which the actions for successfully disarming a conflict situation are [9]:

- Active listening.
- Autonomy promotion and expression (respecting and acknowledging the views of the other participant of the interaction).
- Relational behavior (showing that you understand how the other participant is impacted).

We have attempted to use these concepts when designing the conflict-resolution skills of the robot by directly mapping those abilities to the following behavioral traits:

- Active listening -> Paying attention to the scolder and giving active feedback during the interaction to let the scolder know that the robot is paying attention.
- Autonomy promotion and expression -> Showing remorse and conveying a behavior that shows the robot is impacted by the scolding and that it changes the mood of the robot.
- Relational behavior -> Matching the intensity level of the scolder to convey that the robot has understood the level of irritation/angriness the scolder is trying to communicate.

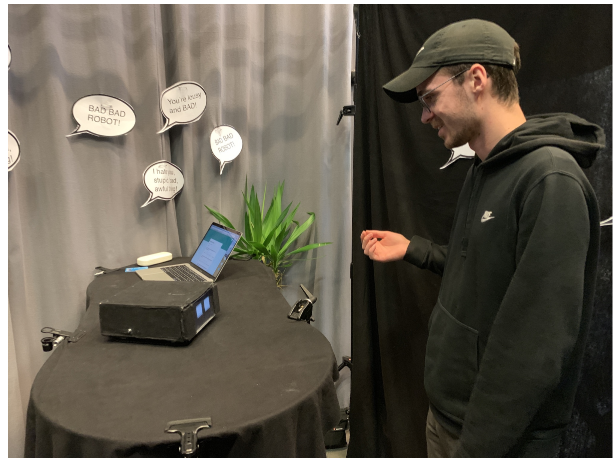


Fig. 2. The main test setup. The aim was to make the test participants feel comfortable with scolding the robot.

It is challenging to design conflict resolution behaviors that would work across different cultural boundaries. Among others, Murray et al. 2000 found that conflicts vary among individuals, communities, societies, and vary among ethnic groups [17], [18]. It is a high complexity area to generalize from and in this paper, we acknowledge that the behaviors and expression modalities that the "Affecta" robot employs may not (to similar effect) expand to different types of users with different cultural and social backgrounds.

## III. Three affective subsystems

The robot had three subsystems to handle the scolding reception. These subsystems handled the following tasks:

- Conveyed keeping attention to the sender.
- Attempted to determine the user's affective state and current level of intensity for that state.
- Expressed affective states. In this scenario, a state that could be interpreted as being remorseful was conveyed.

Besides the three subsystems, the robot also used artificial sounds to match and alter the naturally occurring noise that the robot emitted. It played a sound to cover the servo and DC-motor noise in an attempt to strengthen the affective interpretation of the robot [19]. The hardware and software overview can be seen in Figure 3.

### A. Physical aspects

The 20x20x10cm Roomba-sized robot weighed 2.8kg. It consisted of a belt-driven differential drive system with a square exterior body. The robot was constructed on a pre-made metal chassis as seen in the right picture of Figure 1. A mobile phone was mounted on the front panel of the robot and it was used to display various types of affective

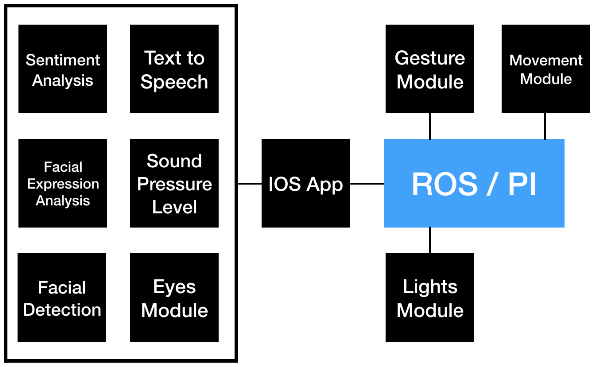


Fig. 3. The software overview of the 'Affecta' robot altered for conflict scenario handling. The system consisted of two independent software platforms running on a raspberry pi and a mobile phone respectively. The raspberry pi hosted a ROS application with independent modules for Bluetooth communication (with the IOS platform), gesture handling, general movement, and lights signaling. The mobile IOS application had individual modules (left box) that handled measuring the participants' intensity level. This included text-to-speech using the "Siri" Apple API, sound pressure level measurements and sentiment analysis using a pre-trained neural network running on IOS neural engine API.

information. For the usage outlined in this paper, the phone screen was used to display the animated eyes of the robot. The robot controller consisted of a raspberry pi 3b+ running "Robot Operation System" (ROS) as outlined by Quigley et al. 2009 [20]. The robot worked as a Bluetooth peripheral and advertised a single writeable Bluetooth service.
An IOS app running on the phone made a Bluetooth connection to the robot and sent control signals to the robot chassis. The robot had three individual subsystems running as ROS nodes controlling motor + servos, lights, and Bluetooth communication listeners. The servos on the robot allowed it to tilt both its entire body and the front panel phone holder upwards. Figure 1 shows the 'Affecta' while Figure 3 depicts the software architecture.

### B. Lights

The lights used by the robot were colored led strips and they were designed to match the sender's intensity level. The light colors and behavior progressed from green, blinking green, cyan, blinking cyan, deep blue, to blinking deep blue. The blue color was chosen because we felt it represented the emotion sadness. Valdez and Mehrabian 1994 also found that blue-green, and green were the most arousing colors which match the intended affective status for the robot [21]. Initially, we used the standard color-progression from green over yellow to red, as people are accustomed to interpreting the signals these colors represent. However, in this context for the initial test calibration rounds, the participants interpreted the robot as being faulty rather than expressing an affective state. This makes sense as both yellow and red usually means "Error" (complying with the machine directive required for companies to be able to sell a product). In our setting, the participants seemed to better understand the green -> cyan -> blue progression.

### C. Movements

The movements of the robot were designed to be expressive. The robot can handle various speeds and movement patterns. In the tests, the least intensity movement employed by the robot was a smaller shivering movement (each belt drive would switch between backward and forward three times) where the robot did not move from the starting position. This was meant to portrait a small acknowledgment of the sender's actions and was meant to align with a close-proximity interaction as mentioned in Bethel and Murphy 2008 [22]. The expressive movements for the next intensity level was a squirming movement backward 20cm at 180 degrees from the starting position and orientation. The movement amount (length and turning degree) was chosen to fit the test context in the best possible way. In the test, the robot was placed on a small table, and larger movements might have made the robot fall off the edge of the table. Increasing the intensity level made the robot move swiftly backward to emphasize that the robot was scared of the scolding. The physical aspects of moving backward also illustrated that the robot was being forced backward.

### D. Gestures

The gestures of the robot were limited by the physical aspects of its construction. Both the main body and the front panel that held the mobile phone only had a single degree of freedom. The body could be tilted upwards to an angle of 14 degrees and the front lid could be titled up to 20 degrees. The amount of movement here was the maximum amount the outer shell on the robot could be tilted without touching the belt drive. This amounted to a nodding gesture for both the front lid that held the eye display and the main robot body. While the degrees of freedom for gesturing were limited, the movement amplitude could be customized and used to display varying intensity levels. The scolding reception gestures spanned across smaller movements with the main body to wider body movements.

### E. Audio

The audio modality was used by the robot for two purposes. It was used to cover some of the natural noise that the robot made, and it was used as the main expression modality to convey affective information. Eg. DC-motors, servos, and robot wheels all make a sound that can change how the robot was perceived. In previous work (Frederiksen & Stoy 2019) we used audio to mitigate the negative aspects of naturally occurring robot noise [19]. Niedenthal 2007 also found that alignment between the body movement and the voice pitch can make it easier to convey emotions [23]. Following the same approach for this robot's naturally occurring audio, it was attempted to augment the natural sounds of the robot and to change how the noise was perceived into something more organic that could support an anthropomorphic interpretation of the robot. The expressive audio of the robot was inspired by the pitch changes found in human voices as they express remorse, sound sincere, or apologize. We aimed at replicating some of those sound characteristics by sampling human voice and used vocoder and midi instruments to change the sampled audio. The midi instruments also allowed the robot's expressive sounds to replicate the same pitch curve. For the tests in this paper the robot used nine different increasingly intensive sad noises. With the increasing intensity levels the changes in each sound were increased pitch changes, volume, and gain.

### F. Anthropomorphic reflection

As a way to use anthropomorphic features the robot displayed animated eyes on the phone mounted on the front panel. The eyes were also employed as a way to inform the scolder that the robot was paying attention. We omitted the mouth on the display following Pollmann et al. 2019 [24]. The robot tracked the position of the scolder's face in relation to the front of the robot, positioned the eyes so it appeared the robot was looking at the scolder, and followed the scolder with its eyes. The eyes were also used by the robot to make it appear as a living character and they blink randomly for that effect. Blinking and eye movements were also used to make the robot more pleasant to interact with as mentioned in Riek 2009 [25]. Using non-blinking starring eyes could have had the unwanted result of appearing inanimate or dead and thereby distract the test participants. To express a state of being sad or apologetic the robot used simple animations for the eyes. For the minimal intensity, the eyes were formed as simple white squares. As the intensity level of the scolder increased, the shape of the eyes was changed towards an upside-down U-shape. Towards the maximum intensity levels, the robot also used eyebrows and they tilted downwards as the intensity increased even further. Small stick eyebrows and simplistic square eyes were also used in Bennet et al. 2013, in which it was found that even very modest facial features were needed to successfully convey emotions [26]. While the other modalities of the 'Affecta' robot changed in steps, the animation of the eyes was fluent. This was because changing the eyes and brows in steps could have been perceived as unnatural movements for the biologically inspired facial features we attempted to replicate. This again could impose a negative effect on how the robot was perceived by the scolder. However, the eye positions were changed in discrete steps to mimic rapid eye movements in humans. Figure 1 shows the eyes of the robot.

### G. Conveying keeping attention

The robot paid attention to the sender by correcting its orientation and eye positions. These constant small adjustments also worked as to gain the attention of the scolder by providing salient stimuli as outlined in Knudsen 2007 [27]. The direction and servo positions were controlled by the IOS app on the mobile phone. The app used the built-in phone camera to run facial recognition and to track the position of the scolder. The position of a tracked face was used to determine the directions of the orientation. E.g. if a user's face was tracked at the upper and outer right side of the image (from the robot's perspective) the robot tilted the body upwards and turned towards the user. For the tests in which the eyes were not engaged, the attention was conveyed using the orientation of the main body.

## IV. Determining the user's affective state

To be able to react dynamically to the user's current affective state, the robot constantly measured the sound pressure level of the sender's voice and used the calculated level to output an estimated current intensity level. (a simple integer between 0 and 10). If the level exceeded a predetermined threshold, the robot would initiate a speech to text function. This functionality used the "Siri" API provided by "Apple" for use in IOS applications to translate the spoken words into a text representation. The same functionality could be gained from any of the voice assistants mentioned in Hoy 2018 [28]. The service returned a text string with the contents of the sender's spoken sentences. The robot then proceeded by using sentiment analysis on the sentence using a recurrent neural network trained on a dataset extracted from the website Epinions.com [29]. The network attempted to determine on a sentence level whether the input sentences were positive, neutral, or negative. The epinions.com dataset contained 664824 different reviews of consumer products and each review had an associated score. If the sentences were classified as positive, it decreased the overall intensity level. If the sentences were classified as negative, the measured intensity level was increased. A neutral sentence would not change the detected intensity level. This sentiment analysis was also used as a way to stop the robot from reacting to loud noises alone. In the first few calibration test rounds, we quickly discovered that people tried to trick the robot into reacting by shouting something positive to it. As a result, we made it so that the robot does not react to anything but negative sentiment sentences.

The robot also recorded video using the front-facing mobile phone camera. It captured the scolder's face and a sub-image was created containing only that. This image was then processed to determine the current emotion of the human in the interaction by looking at his or her facial expressions. Ten times per second, a deep convolutional neural network processed these images in an attempt to determine if the user was angry, neutral, or happy. The network used in this process was created by Levi 2015 but was converted to coreML to make it run on the IOS App [30]. When the neural network classified the facial expression of the sender as "angry" the intensity level was increased by 2. The resulting intensity level was a number between 0 and 10 and this number was used by the robot to adjust the intensity of its affective expressions. # Method 105 human observers participated in a simulated conflict interaction with the robot. The participants were aged from 3 - 50+ with the majority (37%) being between 20-30 years old. The gender distribution was 56% female and 44% male participants. Although there was some variation in the age of the test participants (ranging from 3 to 50), from a cultural perspective the participants were a homogeneous group - all having similar western European social and cultural backgrounds.

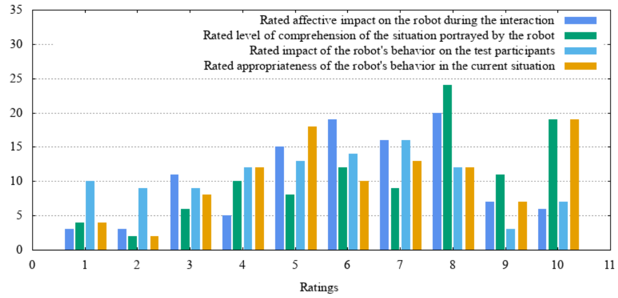


Fig. 4. The distribution of ratings for the questions across all modalities.

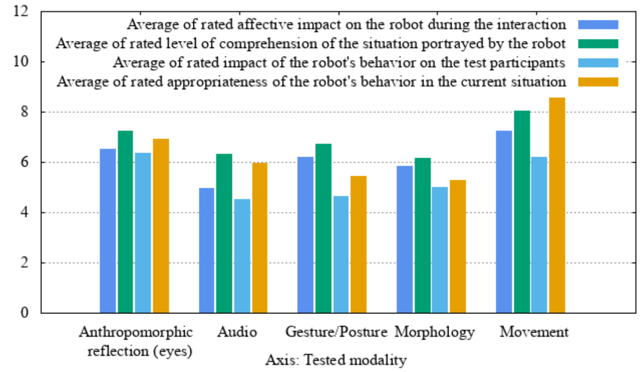


Fig. 5. The average ratings for each question grouped by expression modality.

The impact of every expression modality was investigated subsequently through five rounds of testing. Each round included 20 participants one at a time experiencing a single expression modality. Before each test started, each test participant was introduced to the following pre-test narrative: "The robot is a delivery robot. For the fifth time in a row, the robot has failed to deliver what you have ordered and this time the robot has also caused some destruction to your front door. The robot understands what you tell it, and it understands if you speak or yell, and how you look while you interact with it. Feel free to scold the robot as you see fit." After that introduction, each participant went through the following steps:

1. The test participant would attempt to scold the robot as long as he or she wanted to.
2. The participant was asked to rate on a scale from 1 to 10 how big an impact the scolding had made on the robot, with 1 being "it had no impact at all" and 10 being "It had a big impact on the robot being scolded".
3. The participant was asked to rate on a scale from 1 to 10 to what degree the robot had understood that it was being scolded, with 1 being "it did not understand at all" and 10 being "It understood completely".
4. The participant was also asked to rate on a scale from 1 to 10 how big an impact the robot's behavior had made on him or her, with 1 being "very little impact" and 10 being "very large impact".
5. The participant was also asked to rate on a scale from 1 to 10 how appropriate the robot's behavior was in this specific situation, with 1 being "The behavior was inappropriate" and 10 being "very appropriate".
6. Finally, the participants were asked to state their age and gender.

The test facility was a specially constructed room which allowed the test participants to remain isolated from other people as they scolded the robot. The walls of the test facility room contained small posters with simple negative phrases to act as an inspiration to the scolders. Because scolding the robot required the users to use loud voices, negative sentiment words, or similar high-intensity behavior, this would often lie outside the comfort zone of the participants. To help them get started, we would often scold the robot with them until they were ready to scold the robot alone. The participants interacted with the robot one at a time, and the robot would remain on a raised table to get as close as possible with the scolders. The test room and physical setup can be seen in Figure 2.

## V. Results

### A. Impact on the robot vs. on the human participants

Figure 4 shows the rating distribution for each of the questions from the questionnaire. In the following section, we group ratings from one to ten into five rating groups from low (1-2), to low-mid (3-4), with center medium (5-6), across high-mid (7-8), towards high ratings (9-10).

The questions regarding whether the robot was impacted by the scolding and whether it conveyed an acknowledgment of the scolding were rated high-mid with average / std. deviation being respectively 6.15/2.21 and 6.88/2.52 across all expression modalities. The high-mid ratings indicate that across all expression modalities, most people agree that the robot was impacted by the conflict and that they perceived it as if the robot was acknowledging it was experiencing a conflict scenario. In the question regarding the affective impact on the humans in the interaction as seen in Figure 4, the results show a high-mid "7" being the most selected option out of ten.

### B. Similar results across modalities

The averages of the resulting answers for each modality as seen in Figure 5 were relatively similar to each other with an overall variance between them of 0.71. Although the results are similar, the value for the movement modality contains the highest ratings of all the groups regarding the questions about the robot acknowledging the situation (avg:8.05, std. dev:2.02) and rated appropriateness for the robot's actions (avg:8.2, std. dev:1.31). In an ANOVA test comparing all modalities for the questions on the impact on test participants and impact on the robot, the movement category differed from the other modalities with a statistically significant p-value below .05 (.016957 and .043285) compared to the p-value without the movement category at 0.122357 and .089831.

For the tests regarding how well the robot had understood that it was being scolded, the variance of the average

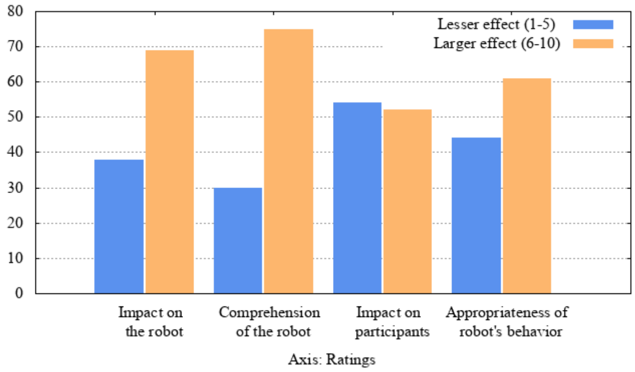


Fig. 6. The grouped distribution of ratings for each question. The blue color shows the test participants who though the robot had a lesser effect on them. The red color shows the test participants who though the robot had a larger effect on them.

results were 0.60, with the movement modality rated as the most impactful modality with an average rating of 8.05 (std. dev:1.93). The second highest-rated affective expression modality for this question was the anthropomorphic reflection with an average rating of 7.25 (std. dev: 2.53).

### *C. Lesser vs. larger affective impact*

To clarify to what extend the test participants found that the robot had an effect on them, we polarized the collected answers into two groups: Those that thought the robot had a lesser effect on them (They rated 1 - 5), and those who felt the robot had a larger effect on them (they rated 6 - 10). The size of the two groups for each question can be seen in Figure 6. The graphs highlight that the majority felt the robot had an effect on them across all questions except regarding the impact on the test participants.

Summing up the results there are three main findings:

- There is little difference to ratings of complex vs non-complex implementations.
- there is little difference between the outlet of the expression as all modalities were rated above average.
- There is little difference between the ratings for the affective impact on the robot and on the human who interacts with the robot.

## VI. Applying the findings

Based on the results, we can state that each affective expression modality of the robot successfully conveyed an understanding of being scolded by the sender in the interaction. The high ratings on all modalities as seen in Figure **??** show that even low complexity implementations such as status lamps can have a large affective impact as a response to incoming stimuli. It should be noted that since the participants were a culturally homogeneous group, and the results are dependent on the cultural and social attributes of the users, it may be difficult to achieve similar results with a group from a different social or cultural background.

As some of the modalities were limited by physical aspects that were hard to circumvent (E.g. a physical morphological response and larger gestures are difficult to expand and enlarge beyond the physical limitations of a small-sized robot), it could seem unfair to compare the ratings of each modality. However, the results from the scolding experiment indicate that normal intuition regarding the hierarchy of expression modalities may not apply to this context. It is interesting that the ratings in Figure 5 are quite high and close to each other on all modalities despite differences in the complexity of their implementations. As previously stated, the physical and contextual limitations made some of the expression modalities stand out as being very simplistic. E.g. the morphological expression modality consisted of a blinking status led strip. Even that modality was rated as highly impactful by the participants and shows that the robot managed to generate some form of empathy despite it not being optimally shaped as outlined in Riek et al. [31].

Some modalities also naturally attract more attention than others. Anthropomorphic features such as eyes are high saliency objects that immediately grab attention in an interaction such as outlined by Birmingham et al. 2009 [32]. With the full focus of the test participants, one might assume that this modality would receive a relatively higher rating than other lesser pronounced features. However, this is not evident in the resulting data. These counterintuitive results can be seen as an effect gained from the high-intensity context in which the interaction takes place - that by scolding the robot, people feel remorseful and in that state disregard the complexity, size, and type of the response. This indicates that there might be opportunities in aligning the engineering aspects of the affective expression features of the robot with the emotional aspects of the context. By considering the intensity of the interaction during the design phase of affective robots and by dynamically aligning the expression modalities with the measured intensity level of interaction, it may be possible to expand the general expression abilities of future affective robots.

We chose to use a simple non-humanoid robot in these tests. Using a different type of robot could sway the results in a different direction. Using a humanoid robot could perhaps make it easier to make test participants view the robot from an anthropomorphic angle. This makes the findings even more interesting as the robot we used did not rely on cuteness or human features to convey affective information [33]–[35]. Our initial assumption was that the difference in affective impact on the robots and the affective impact of the humans would be large. However, as these two affective states were rated relatively similar (in Fig. 5), it can be argued that for conflict scenarios it does not matter where the emotion is interpreted as residing.

Some participants refused to interpret the robot in an anthropomorphic manner and focused strictly on the technical aspects of the robot instead. E.g. some participants stated that the robot could not make an emotional impression on them as they viewed the robot solely as a physical construction consisting of a black square box with lights attached to it. However, high-mid to high ratings were given by these participants despite them refusing to interpret the robot from an anthropomorphic angle. They still considered the interaction as affectively impactful but for different reasons. This is a topic we did not investigate further in our tests. However, this may be an opportunity for further studies in Human-Robot conflict Interaction scenarios.

## VII. Conclusion

This paper investigated the potential ability of robots to defuse conflict interactions using five different affective expression modalities to convey acknowledgment of a received scolding. This was accomplished by modifying the expressive behaviors and technical expressive implementations of an affective robot designed for the purpose. The results showed that all modalities were usable in the context and that they worked to similar effect. Although the implementation of several modalities was relatively simplistic, there were no major measurable drawbacks in their rated affective impact. The ratings were also similar for the affective impact interpreted from the robot behavior and the impact on the humans in the interaction. The robots managed to convey an emotional impact from the interaction and the results indicate that defusing a conflict interaction may be feasible simply by detecting the intensity and reacting with any available expression modality. The results further highlight the effect of placing humans and robots in high-intensity interaction scenarios and indicate that the context and objective of the interaction may be a viable catalyst for enforcing an anthropomorphic interpretation of robot behaviors.

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