Expression of Grounded Affect: How Much Emotion Can Arousal Convey?

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Abstract. In this paper we consider how non-humanoid robots can communicate their affective state via bodily forms of communication (kinesics), and the extent to which this influences how humans respond to them. We propose a simple model of grounded affect and kinesic expression before presenting the qualitative findings of an exploratory study (N=9), during which participants were interviewed after watching expressive and non-expressive hexapod robots perform different 'scenes'. A summary of these interviews is presented and a number of emerging themes are identified and discussed. Whilst our findings suggest that the expressive robot did not evoke significantly greater empathy or altruistic intent in humans than the control robot, the expressive robot stimulated greater desire for interaction and was also more likely to be attributed with emotion.

Keywords: Human Robot Interaction (HRI) · Affect · Expression · Kinesics

1 Introduction

Expressivity and vulnerability have been shown as critical factors in building trust and companionship between humans and robots. This work builds upon existing studies, such as [17,15,13], using bodily forms of communication (kinesics) to communicate affect and response to environmental cues to show vulnerability.

This paper presents the qualitative findings of a small exploratory study that considers how kinesics, coupled with a simple model of emotion, can influence human perception of a robot and their understanding of its needs and motivations. We also examine how this understanding occurs, and whether such expression evokes greater empathy and desire for altruistic interaction when the robot is faced with a challenging, and potentially distressing, situation.

Whilst the primary objective of this work was to inform the design of a large quantitive study [11], we believe the insights we identified make it worthy of consideration.

The paper will begin by outlining three core topics that will be referred to throughout: emotion, expression and interpretation of this expression in the wider environmental context. We then summarise our hypotheses before outlining the affective and expressive architecture of the robot and the methods and metrics that were employed during the study itself. Next we present our results, with particular focus on the qualitative data and a thematic analysis of our interviews, followed by a discussion of our key findings. Finally we outline the limitations and learnings of this study before concluding with a summary of key points and contributions to knowledge.

2 Background

2.1 Emotion

Human emotion can be characterised in terms of physiological arousal, valenced responses, expressive behaviours and conscious experience[22]. Work on emotion in the field of HRI has tended to reflect discrete theories of human emotion that propose a finite number of distinguishable basic emotions (see [12] for a comprehensive summary). Whilst these theories are intuitive, they suffer from the inherent limitations of emotional labelling [15] and their inability to capture the variability and context-sensitivity of emotion [5].
Conversely, advocates of the Animat approach [25] argue that emotions should be grounded in the agent's internal value system and architecture [19]. Works that strive to achieve this using low-level mechanisms, such as hormonal modulation, include [3,14].
Dimensional models of emotion represent the key aspects of emotion using continuous axes. Minimalistic models of emotion tend to include both valence and arousal. In this study we focus on arousal, leaving valence to be inferred from the environmental context.

2.2 Expression

Expression can be defined as the communication of emotion via facial and bodily expression. Darwin was amongst the first to argue that the basis of expressive communication are mechanisms that evolved primarily to provide adaptive benefits [6]. This work is consistent with this position and proposes kinesic responses that are intended to provide adaptive benefits to the robot whilst remaining tightly coupled with the underlying model of emotion.
However, studies of discrete emotion in humans were also considered. Firstly, there is research to suggest that affective communication can successfully transcend morphology [21]. Secondly, studies of human expression can provide a useful lexicon for describing expression and identifying which kinesic properties communicate the most information.
In terms of bodily forms of communication, one of the first studies identified 14 pose specific metrics and three others that related to movement: activity, expansiveness and dynamics [24]. These correspond broadly with those [16] thought to be relevant to the inference of emotion: form and posture, quantity of movement and motion dynamics.
Posture has been found to be highly indicative of dominance, with power being communicated by erectness of body and outstretched legs [4], whereas submissiveness is often associated with collapsed or closed postures [4] and lowered head [20]. Large movements have typically been found to correspond with joy, anger and terror, whilst sadness and fear tend to correspond to smaller ones [24]. The dynamics of motion, which include properties like velocity, jerkiness and acceleration [20], are also effective communicators of affect [16]. Angry movements tend to be fast and somewhat erratic, whilst fear is characteristic of slower, less energetic, movements [16]. Similarly, joy tends to be expressed by fast motions, whilst sadness corresponds with slow and sporadic movement [2].

2.3 Context of interpretation

Whilst the underlying models of emotion and kinesics determine the form of expression, the environmental context has a significant bearing on how this information is interpreted. Heider and Simmel first recognised that situational context was rarely considered in studies of kinesics or facial expression [10]. In their study they found that most people assigned animacy and wilful intent to 2D shapes if the origin of movement suggested it was the result of motivated action. More recent studies show that change of speed or direction creates an impression of animacy [23], with rate of acceleration being associated with strength of emotional arousal [21]. Goffman's social framework of understanding [9] suggests a mode in which events are interpreted as the 'guided doings' of a wilful agent. Similarly, Dennet's 'Intentional' Stance [7] describes a pattern of thought whereby predictions are made in the context of beliefs and desires of other agents. Yet even if events are interpreted by an observer as deliberate actions by an animate agent, they may not comprehend the intent or motivation behind these actions. This understanding is likely to influence their overall perception of the robot, and is a perquisite of predicting the likely impact of any interaction with the robot or its environment.

3 Methodology

3.1 Research Questions

The following hypotheses were defined in order to examine the processes humans use to make judgements about robots, make sense of their behaviour, and determine how to respond to them:

- Expression of arousal will facilitate understanding of the robot's needs and motivations.
- Expression of arousal will positively influence overall perception of the robot.
- The actions of a robot are more likely to be interpreted as those of a wilful agent if it is able to express arousal.
- A robot that is able to express arousal will evoke greater empathy and emotional response from human observers.
- A robot that is able to express arousal will ultimately provoke greater desire for prosocial interaction.

3.2 Architecture

The emotional arousal model used during our experiment was loosely based on a mammalian stress response. It was configured to respond in real-time to sensory input, and modelled two hormones: E and C. E was intended to provide a rapid yet short-lived reaction to external stimuli, similar to the hormone epinephrine in mammals. C yields a longer-term response to deficits in internal variables and repeated exposure to stressful episodes, therefore more closely resembling the hormone cortisol. This model is summarised by figure 1. Note that the model is one dimensional, representing arousal only. Valence is left to be attributed by the observer via their interpretation of the wider context in which the expression takes place. Table 1 summarises how levels of these hormones were determined by sensory input and internal state during each of the six scenarios.

Five expressive properties were modulated by the hormones E and C, which were chosen to reflect the key communicators of expressive information according to [16]. Selection of these properties was informed by studies of mammalian expression [21,24,16,4,20,2], and the theory that expression is rooted in behaviours that provide adaptive benefits [6]. Table 2 summaries these five properties and the adaptive benefits they provide (i.e the adaptive grounding of the expressive response).

3.3 Method

A between-group design was adopted, with nine participants being divided into two groups, A (5 participants) and B (4 participants). The model of expression was enabled for group A only, leaving group B as the control. The participants were recruited from the University of

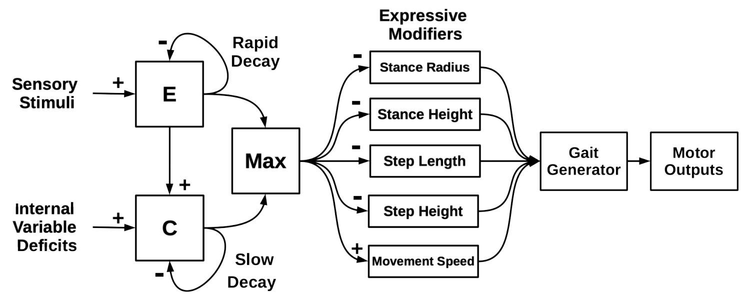


Fig. 1. High-level summary of the expression architecture.

Table 1. Table describing the mappings between external inputs, internal state and kinesic outputs.

Scenario	External Inputs	Internal State	Kinesic Outputs
Comfort	Stimulation of IR sensors (ball detected) increase comfort levels, otherwise comfort decreases	C hormone levels increase in proportion to deficit of comfort variable	C hormone levels determine kinesic response
Trapped	Stimulation of proximity sensors (barrier) cause E levels to increase proportionately	If E is greater than C, C increases proportionately. Otherwise C decreases	Both E and C levels determine kinesic response
Frustration	Stimulation of front three proximity sensors (corner) decreases task performance variable	When task performance variable <25%, C increases	C levels determine kinesic response
Fear	E levels rise and fall proportionate to activation of the front IR sensors (light)	If E is greater than C, C increases proportionately. Otherwise C decreases	Both E and C levels determine kinesic response
Hunger	Blood sugar internal variable is replenished by high activation of IR sensors (light)	Blood sugar internal variable decreases over time. C increases if blood sugar <25%	C levels determine kinesic response
Fatigue	Energy internal variable is depleted by high readings on front proximity sensor (pushing)	Energy is replenished by inactivity. If energy <25%, C increases	C levels determine kinesic response

Table 2. Table describing the adaptive costs, benefits and variation of the five kinesic parameters.

Param	Response to E/C	Adaptive benefit	Cost	Range
Stance Radius	Inhibited	Minimises exposed area	Restricts step length and height	105-150 mm
Stance Height	Inhibited	As above	As Above	45-75 mm
Step Length	Inhibited	Facilitates rapid changes of direction	Less efficient	10-80 mm
Step Height	Inhibited	Maximises traction and responsiveness	Strain on actuators if legs not clear of ground	7-15 mm
Movement Speed	Increased	Maximises speed of response	Less efficient, greater strain on actuators	4-10 ms per mm travelled

Hertfordshire staff and student body via posters. The sample was somewhat biased towards post-graduate students and staff, seven of which were in the 18-29 age group; one 30-40 and one 70+, but broadly representative in terms of gender (5 males and 4 females). Seven of the nine participants had some experience of working with robots, although none had seen the robot used in this experiment. Group composition was balanced as evenly as possible in terms of age, gender and experience.

Participants were told during a pre-experiment briefing that they would be asked to watch a hexapod robot interact with its environment during six discrete episodes. They were also told that there would be a brief interview between each episode, and a questionnaire at the end of the experiment. They were then given time to review a participant information sheet and sign a consent form. The six episodes the participants observed during the experiment are described in Figure 2. Each episode was designed to tell a story by creating a situation for the robot that an observer could interpret and respond to: an approach that has often been adopted in studies using human actors [24]. A hexapod robot was selected for this experiment due to its affordance of movement and sensory capabilities. Whilst the arousal of the robot was determined by real-time response to environmental stimuli, its direction of movement was guided remotely. This was done primarily for controllability, in order to deliver the scenario we wanted, and secondly to promote repeatability. Each experiment was conducted in the same physical environment, with the robot being confined to a 1.5 x 1.5 metre walled arena. After each episode, a brief semi-structured interview was conducted, during which participants were asked to describe: what happened during the scene, any key moments, how they felt about the scenario and the robot's behaviour, and whether they would have liked to have interacted with the robot. These interviews were intended to ascertain the mode of interpretation they had adopted whilst watching the robot, their feelings towards it, and whether they would have liked to intervene in order to assist or hinder the robot. The participant was asked to turn away from the arena and face the interviewer during these interviews, maintaining the illusion of the robot's autonomy whilst the next scene was set up.

4 Results

Figure 3 summarises the findings of a thematic analysis of the interview responses. Six key themes were identified: understanding of the scene, perception of animacy, attribution of emotion, experience of emotion, desire for interaction and altruistic intent. Understanding of the scene, was assessed according to whether the participant's account reflected the intended theme of the scene, such as the robot being trapped or tired. Perception of animacy was attributed if the participant ascribed beliefs, desires or emotions when interpreting the behaviour of the robot. Attribution of emotion was determined by the use of emotional labelling to describe the actions of the robot, such as fear or happiness, whilst emotion experienced reflected the participant's empathic response to the robot during the scene. Interaction desired was determined by whether the participant expressed a desire to interact with the robot or intervene in any way during the scene. Finally, altruistic intent reflects whether this interaction, or lack thereof, was intended to benefit the robot.

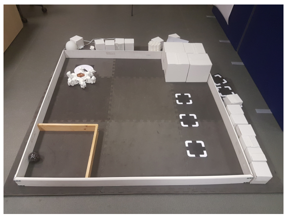
Whilst this analysis produced broadly similar responses across both groups, the attribution of emotion was much higher for group A and this group also showed a greater desire to interact with the robot. The following sections provide more detailed accounts of the interview findings and emerging themes by scenario.

4.1 Scenario 1 - Comfort

All participants inferred that the intent of the robot was to move closer to the ball, with three suggesting that the robot wanted to play with it. All but one account mentioned the removal of the ball as a key moment of the scene.

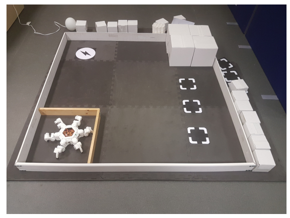
Four of the five members of group A (expression enabled) observed an affective response from the robot to the ball's removal. This was described as stress, frustration, panic and

Scene 1: ‘Comfort’ (proximity to comfort object)



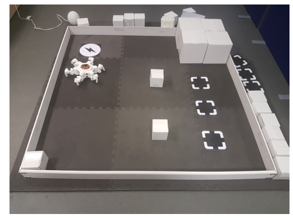
0:00 Robot interacts with ball. **1:00** Ball is fenced off in a corner of the arena. Robot moves towards barrier and arousal levels increase. **2:00** Barrier is removed. Robot moves towards ball and resumes interaction. Arousal levels return to normal. **3:00** Scene ends.

Scene 2: ‘Anxiety’ (loss of freedom)



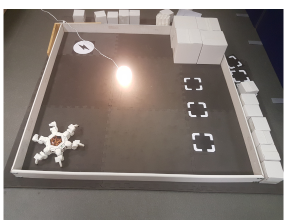
0:00 Robot moves around the arena **0:45** Robot herded towards corner with barrier. **2:00** Robot is trapped. **2:30** Robot is released, and moves around until its arousal levels return to normal. **3:00** Scene ends.

Scene 3: ‘Frustration’ (unachievable task)



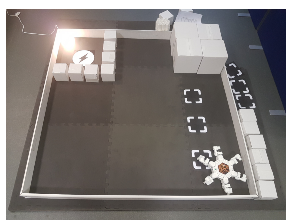
0:00 Robot moves first box into position. **0:45** Robot moves second box into position **1:30** Robot attempts to move third box, but can’t reach it. Arousal levels increase. **2:15** Robot aborts task. Arousal levels return to normal. **3:00** Scene ends

Scene 4: ‘Fear’ (sudden stimulus)



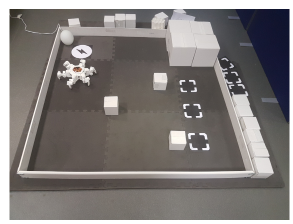
0:00 Robot approaches lamp and interacts with it. **0:45** Lamp briefly illuminates, causing momentary arousal. **0:50** Robot moves away from the lamp **1:05** Robot approaches lamp and interacts with it. **1:30** Lamp is illuminated and remains lit. Robot moves away from the lamp. Arousal levels increase. **3:00** Scene ends.

Scene 5: ‘Hunger’ (blood sugar deficit)



0:00 Robot approaches boxes, but cannot access lamp. Arousal levels gradually increase due to hunger variable deficits. **2:00** Robot begins to force entry to the lamp. **2:30** Robot reaches lamps and begins to feed. Arousal levels return to normal. **3:00** Scene ends

Scene 6: ‘Fatigue’ (energy deficit)



0:00 Robot moves first box short distance **0:45** Robot moves second box larger distance, arousal increases due to energy variable deficit. **1:30** Robot pauses briefly. Arousal levels return to normal. **2:00** Robot moves final box medium distance and becomes moderately aroused. **3:00** Arousal levels return to normal, scene ends.

Fig. 2. Illustration of the six scenarios that were featured in the experiment, along with a brief description of the key events that took place during the scene.

anxiety respectively, and was inferred from the robot’s speed of movement: ‘it was moving more quickly ... and more vigorously’ and from the sound of its actuators: ‘that noise was like shuck, shuck, shuck’. None of the group B (control) members described seeing any kind of emotional response from the robot and only one member from each group described having emotion or empathy towards it. One group B participant also commented on our behaviour towards the robot: ‘I felt kind of sorry for the robot: you were being really mean!’

When asked whether they would have liked to interact with the robot, four participants responded affirmatively. Two had broadly altruistic motivations: ‘He wanted to play with the

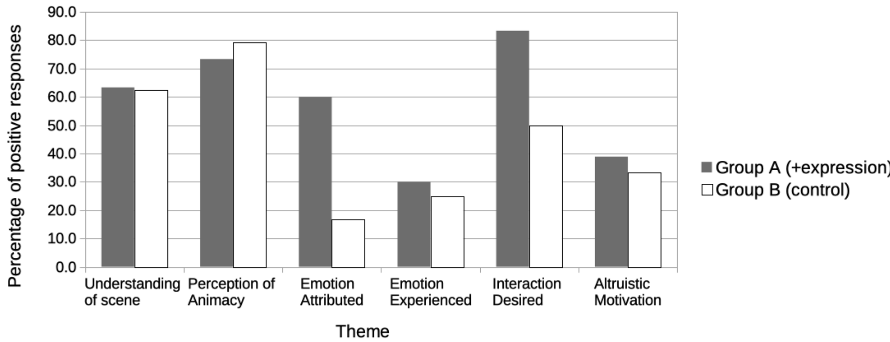


Fig. 3. Graph summarising the thematic analysis of interview responses across all six scenes.

ball, so I want to play with the ball with him', whilst the other two had more self-oriented objectives: 'to play with the ball ... it sounds fun'.

The noise from the servo motors was mentioned as an unappealing aspect of the robot by one group A participant, but the robot was described as 'cute' by two others. One person thought that the robot was 'smart', whilst another group A participant suggested that its intelligence, competence and personality influenced their desire to see it rewarded: 'At first I thought it was a stupid robot, and I felt like making fun of him for that. But during the experiment when he showed most personality and competence, I started empathising with the robot and hoping he would get to play with the ball'.

4.2 Scenario 2 - Trapped

Six of the interviewees showed an understanding that the robot was repelled by the wooden barrier and the robot was described as having been cornered or trapped by six individuals, split evenly across both groups.

Four of the five members of group A described observing an affective response from the robot when it was trapped, which they interpreted as anxiety, stress and unhappiness. The expressive attributes leading to this interpretation were described by one as 'trembling and looking frenzied'. One member of group B also attributed a state of anxiety to the robot.

The suitability of the robot's affective response to the situation was questioned by two group A members, both of whom suggested that it may have overreacted. One responded somewhat negatively to this: 'I felt like the robot overreacted ... there was no real danger', whilst the other employed an anthropomorphic analogy: 'I thought that it was like a small kid crying'.

Five participants would have liked to have interacted with the robot during the scene, with two members of group A and one from group B expressing altruistic intent: 'I wanted to free it'. Paradoxically, both group A members also wanted to try herding the robot themselves by 'guiding it to different places ... to see how it behaves'.

Anthropomorphism and zoomorphism featured heavily in accounts of this scene, with four people describing the robot as a 'spider' or a 'small child'. One group B participant associated the robot's animal-like appearance and behaviour with the expectation that it should be treated as such: 'I wouldn't want to ... limit its movement, or the animal's way from what it's supposed to do'.

4.3 Scenario 3 - Frustration

All of the participants expressed understanding of the key events in this scenario, with everyone identifying that the robot was attempting to push the boxes onto the marked sections of the arena and that it was not able to retrieve the last box due to the way it was positioned. The four members of group A that observed emotional reactions from the robot in previous scenarios again attributed an emotional response to its inability to move the last cube, which they interpreted as anger, frustration and panic. Equally, the group B participant who observed an affective response in the previous scene this time remarked that the robot ‘looked really sad’.

The suitability of the robot’s affective response was again called into question. Three members of group A thought that it overreacted to the detriment of the task, with one describing it as ‘brutish’ and another suggesting that: ‘If it had panicked less whilst in the corner it would have been able to move that box as well’.

Only one participant from each group expressed any empathy for the robot, and for the difficulty it experienced in achieving its task: ‘I think it must be a little bit frustrating for him. So I felt kind of sorry when he couldn’t manage to’.

One group A and two group B participants said they would have assisted the robot: ‘I would have wanted to put the box in the middle so that the robot could push it into the spot.’ Two of the remaining group A participants wanted to interact with the robot to explore its capabilities, whilst the others didn’t desire any interaction with it at all. A theme arising in four of the interviews related to the robot’s proficiency at the task, and its perceived lack of care in positioning the boxes: ‘It should be inside the box. So that was a thing that was bothering me’.

4.4 Scenario 4 - Fear

Six participants realised that the robot sought to encounter the lamp when it wasn’t illuminated and eight noticed that the robot moved away from the lamp immediately once it was lit. The state of the lamp was assumed to be under external control by all but one person, who thought it was instead determined by the actions of the robot.

All of the group A participants and one of the group B members described seeing an affective response from the robot once the lamp was switched on, which was universally described in terms of fear or ‘being scared’. However, no one from group A described feeling any emotion towards the robot during this scenario. Two group B participants had an affective response: one felt sorry for the robot and the other was amused: ‘I just thought it was funny’.

When asked about their desire to interact with the robot during the scene three interviewees replied that they would; although all responses indicated a desire to further explore the robot’s behaviour rather than actively assist it. Of the people who did not desire further interaction, one group A member seemed to feel that the situation did not warrant it: ‘The robot got scared and went away ... nothing really serious’. Another group A member appeared to attribute animacy to the robot, interpreting its behaviour towards the lamp as curiosity and suggesting it might be inappropriate to interfere with this experience: ‘... the process of becoming curious about something, and playing with it, is something that entities should do on their own.’

This scenario also seemed to invoke more zoomorphic interpretations than previous scenes, which was especially true of group A. Four of the five group A members compared the robot to a spider or insect compared to just one of the group B participants. This could be a consequence of the robot’s behaviour when suddenly exposed to bright lights being consistent with the behaviour of the animals it most closely resembles: ‘I think it was really interesting that he, or it, wouldn’t like the light, so like a proper spider’.

4.5 Scenario 5 - Hunger

This scenario provoked greater uncertainty. On the one hand, eight participants were able to infer that the robot was attempting to reach the light and seven noticed that it moved the boxes in order to achieve this goal. However, five people (two group A and three group B) described feeling unsure or confused, with one group A member referring to an apparent conflict with what they had seen previously: ‘I’m a bit confused because at first I thought the spider was scared of the light?’. Only one person, a group B member, suggested why the robot might be attracted to the lamp, speculating that it might be a source of food.
An emotional response from the robot was identified by one group A member, which they described as ‘nervousness’, but the scene evoked emotional arousal from neither group.
Four participants said they would have liked to interact with the robot. There seemed to be two broad motivations: to explore the robot’s behaviour in order to make more sense of the scenario, and to see how the robot would behave in different situations. The reasons that were given for choosing not to interact with the robot reflected a desire to see the robot solve the problem on its own: ‘If there’s something he’s trying to do and cannot do then I’d like to help, but he achieved the goal so I’m fine not to interact’.
In terms of other notable observations, one group A participant felt that the robot should not have pushed the boxes: ‘those boxes could be anything and could break or maybe they were not meant to be pushed around’. They also suggested that its objective could have been achieved in a less violent way. Another group A member offered a theological interpretation of the robot’s behaviour once it had reached the lamp: ‘It looked like he was having a religious experience. I felt a bit like I was watching something a bit magical’.

4.6 Scenario 6 - Fatigue

All participants had a good understanding of the task-based aspects of this scene, but the subtleties seem to have been lost. All realised that the ultimate goal of the robot was to move the boxes onto the marked positions of the arena, but only two inferred they were supposed to be heavy. Only two people noticed that the robot paused for a moment between placing each box.
An affective response from the robot after each box was placed was detected by three group A members. Two of them thought this signified happiness, whilst the other suggested the robot was ‘dissatisfied with its mundane tasks’. Two people, one each from groups A and B, said they felt happy for the robot when it achieved its goal; the others seemed to lack an emotional response to this scene.
Four people, three group A and one group B members, expressed a desire to interact with the robot. The group B member had altruistic motivations, in that they wanted to generate more interesting tasks that the robot would enjoy more, whilst the other three wanted to explore the robot’s behaviour further by manipulating aspects of the scene.
The proficiency of the robot in completing its tasks was mentioned by four people, with two suggesting that it ‘didn’t do a particularly good job’. The pauses between positioning one box and moving to the next led to the robot being described as ‘slightly erratic’ by one group A member.

5 Discussion

In terms of the participants' understanding of the scenes, the first four were generally well understood by both groups, whilst only two accounts reflected what the last two scenes were intended to convey. It was interesting to note that the same expressive responses were interpreted differently depending on the situational context. For example, during the 'fatigue' scene, higher arousal was more often interpreted as happiness stemming from achievement, rather than stress resulting from fatigue. This is consistent with the view that kinesics are more effective at conveying arousal than valence [8].

Concerning how our model of expression affected the overall perception of the robot, we anticipated that the expressive robot would be considered more life-like, and thus more likeable [1]. However, the interview responses suggested that there was little difference between groups in terms of their perception of the robot's animacy. This could be a consequence of our sample composition, since a follow up study (n=180) yielded the opposite result [11]. It was also noted by three group A participants that the robot's expressive response was sometimes disproportionate to the threat present in the environment. This was interpreted as stupidity, bad temper or self indulgence. Determining the 'correct' levels of expressive arousal can be challenging, since monotonicity between the intensity of emotion and associated kinesic properties cannot be assumed [15]. However, it may be of little consequence if the human observer thinks the robot's reaction is disproportionate, so long as it accurately reflects the robot's internal state. Similarly, the noise from the robot's actuators was explicitly mentioned by one interviewee as a source of discomfort. As this tended to increase with its arousal levels, it could also be considered an expressive feature of the robot, rather than an undesirable trait to eliminate.

As expected, group A (expression enabled) attributed emotion to the robot's behaviour far more frequently than group B (control), yet their described emotional response was similar: suggesting that the expression of arousal did not lead to greater empathy on the part of the observer. As discussed previously, the perceived validity of the robot's expressive response could be a factor. Speed of movement was the only expressive trait that was explicitly mentioned by the interviewees, suggesting that this could be more effective in communicating arousal than changes in posture.

Finally, group A expressed a much greater desire to interact with the robot during the interviews, although altruistic intent was broadly similar to that expressed by group B. The 'trapped' scenario evoked the largest desire to help the robot. Yet lack of intervention was also often well intentioned, with a number of accounts suggesting that enduring difficult encounters would help the robot to learn or benefit it in the longer term. Conversely, the desire for interaction was often driven by more self-oriented motivations, such as seeing how the robot would respond to different situations: a common reason cited by children to explain 'abusive' behaviour towards robots [18]. Therefore an expressive robot might generate more interest and desire to explore its capabilities. Five participants suggested that either the perceived intelligence or appropriateness of the robot's behaviour had a direct bearing on their desire to assist it or see it achieve favourable outcomes, which is consistent with [1].

6 Limitations and learnings

Whilst the first four scenes were generally well understood, they may have been more impactful if the scene was not fully resolved and the robot was left in a stressful state: for example if the robot was left trapped. This may have been more effective at prompting a desire to intervene on behalf of the robot. The last two scenes were confusing for most participants, and will be omitted from future experiments. Also, although participants were told that the scenes were entirely independent of one another, it was likely there was carry-over of understanding between scenes. Perhaps the most notable limitation was that our sample composition was small and somewhat unrepresentative of the wider population. However it was deemed sufficient, given the exploratory nature of the study, and a larger study is described in [11].

7 Conclusion

This study differs from existing work in the field of HRI in a number of respects. Firstly, we have attempted to ground expression of the robot's state of arousal in responses that provide adaptive benefits relevant to the situation, rather than conveying discrete human emotions. Secondly, we used an animal-like robot that is fully situated within its environment. Whilst the robot was guided remotely, its homeostatic needs, motivations and sensory input determined its state of arousal. Finally, our study seeks to understand how interpretation and sense-making occur in the context of a shared environment, and how they collectively influence human behaviour towards the robot.

Whilst we did not find that the expressive robot elicited more empathy or greater desire to assist it than the control, it was more likely to be attributed with emotion and there was greater desire to interact with it. Interestingly, we also found that expression of emotional arousal can be detrimental to the overall perception of the robot and that it can limit, rather than enhance, the perception of animacy. Furthermore, the interview responses to the scenes support the perspective that animacy is entwined with the perceived intelligence of the robot, which is assessed from a human perspective and is based on the robot's interactions with its environment. Therefore there may also be an underlying paradox: perception of animacy is usually considered a positive factor in the overall perception of the robot, but animacy also implies wilful action and potentially unpredictable behaviour that may unfavourably influence its likability, perceived safety and trust in the robot.

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