Calamaro: Perceiving Robotic Motion in the Wild

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ABSTRACT

We present our study of *Calamaro*: a robotic platform designed to investigate the impact of emotive motion on people, and its deployment in an extensive field study in a busy public space at the University of Calgary campus. Our paper details the design of the *Calamaro* robot, the field study conducted with it, including hundreds of observers and 88 participants, and our quantitative and qualitative findings. The paper provides a thorough discussion of the implications of our results on the design of robotic emotive motions, and reflections on the deployment of robotic interfaces in field studies.

Author Keywords

emotive motion; robot interaction in-the-wild; HRI

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e. g. HCI): Miscellaneous

INTRODUCTION

Motion is a powerful channel of expression and as robots begin to take on increasingly personal roles in our daily lives it is expected that their inherent motion capabilities will become an important method for people to be able to communicate and interact with them in socially intuitive and easily understandable ways. In this paper we explore the concept of *emotive motion* as a design tool for social human-robot interaction research (HRI) by exploring how low-level style and characteristics of robotic movement (e.g. slowly, smoothly, sporadically, etc.) affect people's social and emotional interpretations of them when deployed in the public space.

The essence of life and liveliness is intimately linked to the concept of motion. From an etymological perspective, the Latin word *anima* refers to the concepts of "soul", "life", "spirit", and "vital principal" and from this root we encounter the words *animal* ("living creature") and *animate* ("to impart life"). Intuitively, we gain that same impression from the world around us: things that are moving, changing, and reacting are seen as somehow "alive" whether they are biological creatures or not.

Besides simple liveliness, motion is also a powerful channel for emotional expression. For thousands of years, humans have been expressing emotions through theatre, dance, and gesture; conveying frustration, sorrow, jubilation, and an entire spectrum of powerful emotions using only the movement of our bodies. In contrast, a person who is entirely motionless (e.g. their chest not even breathing) are quickly presumed to be in distress, injured or deceased. In the world of film, master animators have demonstrated for decades that there is emotional power to be expressed in *how* characters move, above and beyond the specific gestures of *what* those characters are doing [1].

Arguably, motion is also one of the primary differentiating features between robots and other computerized agents. Unlike virtual agents, robots are capable of moving through their environment: gesturing, reacting, exploring, communicating, and affecting their surroundings in very dynamic, physical ways. Whether a robot's purpose is to serve, create, explore, or destroy, it is this ability to move, interact, and affect the same physical world that we, as humans, live in which distinguishes them from almost all other forms of modern technology.

This paper presents the evaluation of *Calamaro* (Figure 1) a robotic platform designed specifically for the study of *emotive motion*, which we deployed in a field study in a busy public space gathering finding on the impact of emotive motion as well as on the challenges of running HRI studies in-the-wild.

RELATED WORK

The importance of pursuing HRI research challenges in-the-wild, and of understanding how social HRI experiences change when they move from the laboratory into the "real world" has been highlighted by several HRI researchers. A few examples include in-the-wild observations of a robotic conference attendee, and a robotic receptionist [2], in the field observations of robot guides in a train-station [3], and in a building [4], and observations of androids deployed in public spaces [5,6].

HAI '14, October 29 - 31 2014, Tsukuba, Japan

http://dx.doi.org/10.1145/2658861.2658891

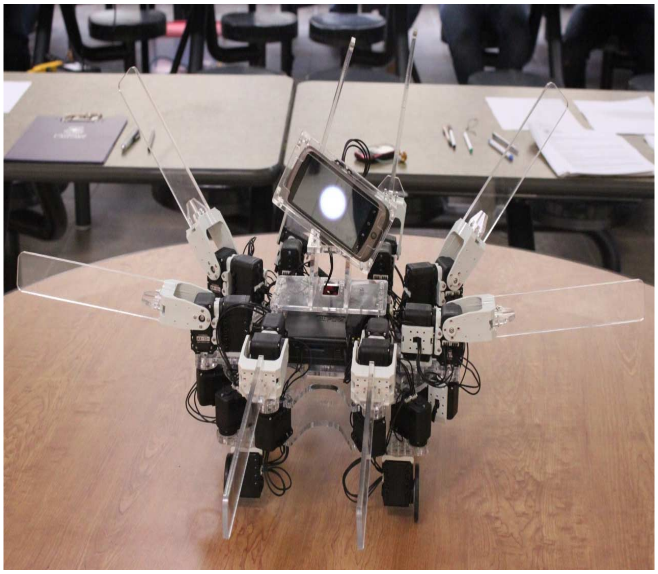

Figure 1 - The *Calamaro* prototype with its eight arms

Emotive motion is arguably inherent to all robotic interfaces, with seminal work on the affective capabilities of moving, non-living, abstract objects dating to the 1944 experiment by Heider and Simmel [7]. Emotive motion was explicitly explored in several recent HRI efforts: for example, Hoffman and Breazeal's robotic desk lamp assisted its human partners with what was perceived as intelligent and often emotive actions through simple physical gestures and movements [8]. Mutlu et al. projected a collection of abstract moving geometric shapes onto a display with the intent of eliciting specific emotional responses such as happiness, nervousness, or fear by animating the displayed shapes according to designated patterns [9]. In [10] the authors demonstrated how motion paths could be used to express different robot personalities and intents. A study by Saerbeck and Bartneck [11] investigated emotive motion by asking participants to rate their emotional responses to robotic motions with different acceleration and curvature. Nomura and Nakao studied how age and cultural differences affect the interpretation of robotic emotive motion [12], and the Stem project [13] used movements by an abstract robotic-stick for emotive expression. Takayama et. al. proposed to employ animation principles in HRI motion design [14], and recent efforts mapped emotive motion to future, actuated, semi-robotic mobile phones [15,16]. The *Calamaro* effort presented in this paper can inform these HRI research threads through its focus on exploration of robotic *emotive motion* via an extensive field study.

CALAMARO

Our goal was to design a robot with semi-zoomorphic attributes which is capable of a range of engaging *emotive motion*s and can be deployed in the field. Rather than seclude our participants in a serene and reflective but practically unnatural lab environment we wanted to take an in-the-wild approach. Our motivation was to pursue a greater sense of how our findings might generalize to robotic *emotive motion* in daily life.

The prototype we designed, *Calamaro* (Figure 1) is named after the singular of the Italian word "calamari" (a food recipe involving squid). In line with our original design goal, this articulated robot has visual appearance which is vaguely animalistic (e.g. an octopus) while still being heavily robotic. *Calamaro* has multiple distinct appendages, including wheeled legs, a 3-axis "head", and eight individual arms with three degrees of freedom each. *Calamaro*'s movements were designed to allow us to explore a spectrum of *emotive motion* themes relating to the speed, repetition and coordination of its appendages.

Calamaro was programmed to perform a set of 5 motion sequences using a combination of 3 different motion styles. In between each motion, the robot returns to a neutral position where its head is facing forward and all of its arms are evenly spaced around it, leveled, and pointing outwards like the spokes of a wheel. We attempt to describe each of the five *Calamaro* motions as clearly as is possible in text as follows:

1. *Simple Breathing* – *Calamaro*'s arms would begin laid out flat in an evenly spaced circle around its body. They would then rise to +25°, fall to -25°, and then return to level. At the same time, the robot's head would rise and fall slightly. The desired impression was that *Calamaro* was taking a deep breath and then exhaling slowly.

2. *Defensive Cage* – The robot would look once from side to side, roll backwards, and then raise its arms around itself; turning them about their axis so as to form a defensive wall around the perimeter of its head and body. Once "caged", *Calamaro* would look around again before lowering its defensive wall and returning to its neutral position. The desired impression was that *Calamaro* was guarding itself against some threat in front of it; as a boxer raises their hands to block incoming punches.

3. *Table Tap* – First, the robot would align all of its arms so that the four arms on its left side pointed directly left, all parallel, and the four arms on its right pointed directly to its right, also all parallel. It would then look over and down to its right and tap the table with its right arms and then return the arms to level. It would then repeat this tapping motion on its left side and then return to the neutral position. The desired impression was that *Calamaro* was "checking" the feel/sound of the table next to it.

4. *Ebb and Flow* – Similar to "Table Tap", but more closely resembling a smooth dancing manoeuvre. Without aligning its arms, *Calamaro* would roll sideways to the right while lowering its right arms and raising its left arms. Its head would roll into the slide and briefly dip down. It would then repeat this move to the left; lowering its left arms, raising its right, and dipping its head down and to the left before returning to its neutral position. The desired impression was

that *Calamaro* was suavely sliding from side to side, as if dancing.

5. *Prairie Chicken – Calamaro* arranges its four rear arms like the tail feathers of a turkey or peacock; sticking straight up into the air behind the robot's head. The remaining four front arms (two pairs of two) are arranged like "wings" to the front and sides of its body. The robot then rolls forward while rocking all of its arms side to side repeatedly before retreating. The desired impression was that *Calamaro* was presenting an aggressive display and challenging the observers in front of it; much as a real bird might try to intimidate an opponent and scare it away.

The content of *Calamaro*'s five motion patterns was not the primary focus of our research of *emotive motion*. Instead, we designed our experiment to study three simple "styles" under which these five motions would be performed. Each "style" had two attributes which were systematically combined in a 2 x 2 x 2 schema of conditions. Each motion sequence was scripted in such a way that there was only one sequence of steps for each and it was the combination of the different style conditions that would dictate how those steps were interpreted. *Calamaro*'s three styles of movements are described below:

A. *Fast or Slow* – A given sequence of motion steps would be interpreted and performed either quickly or more slowly. Each condition was just as smooth as the other, with only the time taken for each step being elongated or shortened.

B. *Sequential (Mechanical) or Simultaneous (Organic) – Calamaro*'s motion sequences consisted of discreet gestures. In the Sequential condition, these individual gestures would be performed separately, one after the other. (E.g. Raise arms, then turn head, and then roll forward.) In the Simultaneous condition, all of the distinct gestures would be performed at the same time. (E.g. Raise arms while turning head and rolling forward.) This style distinction also extended to individual gestures involving multiple motor axes working in unison and was especially evident with arm gestures. (E.g. either each of the eight arm motors would move one after the other until all of the arms were "raised", or the arms would all rise at the same time.)

C. *Repeating or Non-Repeating* – In the Repeating condition, once a complete motion sequence was finished, *Calamaro* would perform the same motion again and again. (E.g. Breathing, breathing, breathing...) In the Non-Repeating condition, *Calamaro* would randomly select a new motion each time. (E.g. Breathing, Defensive Cage, Prairie Chicken...).

During interactive sessions *Calamaro* cycles between motion styles approximately every half hour, ensuring that during a study participants interacting with *Calamaro* viewed only one type of motion style.

STUDY

The study was conducted in a crowded public space at the food court area of the University of Calgary campus, in three different sessions with over 12 hours of *Calamaro* interaction, and hundreds of observers and participants. The *Calamaro* robot was placed in the center of a large, round, 150cm diameter wooden table (Figure 2). Attached to the front and mounted on stands to either side of the table were three large information posters describing that a research study was being conducted and that the study area was being recorded via both video and audio.

Two experimenters were present with handheld audio recorders to interview passing visitors who expressed interest in the robot. In order to maintain some element of serendipity, these interviewers specifically avoided soliciting interest in the study and did not actively approach any passersby. If however someone chose to stop and examine the robot or speak with the interviewers, these people were then approached and questioned about their thoughts and impression of *Calamaro*. These people were classified as Category 1 participants.

Generally the participants would immediately begin a dialog with the interviewer. Otherwise, the interviewers would eventually prompt Category 1 participants with open-ended questions such as "*What do you think of the robot?*", "*What do you think it's doing?*", or "*Why do you think it is doing that?*" The interviewers would then ask more focused questions such as "*What can you say about the way the robot is moving?*" or "*Do the robot's motions remind you of anything?*"

Figure 2 - *Calamaro* deployed at the University of Calgary's food court

When answering questions posed by the participants, interviewers would attempt to avoid biasing the participants; often by deflecting the participant's inquiries back at them. For example, if a participant asked "*What is the robot for?*" the interviewer would respond with "*What do you think it's for?*" Depending on how persistent a participant would be with their inquiries, interviewers would eventually defer to email addresses displayed on the information posters and assure the participant that their detailed questions would be answered at a later time. The purpose of this was to avoid revealing the purpose of the study to the general population. We wanted to avoid having new participants arrive, having been briefed by their friends, with a pre-conceived focus on the robot's motions.

After being interviewed, the Category 1 participants were invited to fill out an additional questionnaire that asked more specific questions about their emotional interpretation of the robot and its motions. These survey sheets also included a section asking the participants for consent to a) analyze their survey results and/or b) use their un-blurred recorded video footage for academic publications. If these people chose to fill out a questionnaire sheet, they were then classified as Category 2 participants and were led to one of the nearby cafeteria seats where one of the experimenters would explain and administer the survey.

Having had an opportunity to observe and interact with *Calamaro*, Category 2 participants were presented with the Bartneck, et al. "Godspeed Questionnaire Series" Likert-scale style questionnaire [17]. The participants were asked to rate how applicable they felt different pairs of emotionally descriptive adjectives were to the robot and its motions. The Godspeed Questionnaires allow participants to reflect on concepts such as anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots; all of which relate to *emotive motion* and its impact on social HRI. For each participant, the order of each individual adjective pair was randomized, as was the ordering of all adjective pairs within the list (e.g. the order of the first, second, third, word pairs would differ randomly between participants.) Having completed the questionnaire, Category 2 participants were thanked and then allowed to depart.

RESULTS

The *Calamaro* study was conducted over the course of three sessions on separate days. Each session lasted from 11AM in the morning until 3PM in the afternoon; covering the high-traffic lunch hours of each day for a net total of 12 hours. Over the course of these three study sessions, hundreds of people observed *Calamaro* from afar; either watching it while walking through the food court or while sitting and eating. Of these, many dozens of people stopped to closely inspect the robot and talk with the experimenters about the study (Category 1). Of these, a total of 88 participants (70 male, 18 female) completed our written survey (Category 2). The average age of our Category 2 participants was 24.59 (standard deviation of 7.42). Part of the written survey was demographic and asked participants to describe their professional or academic background. We grouped their responses into four major categories: robotics oriented (e.g. mechanical/electrical engineering, computer science), technical but non-robotics oriented (e.g. chemistry, astronomy), non-technical but creative (e.g. artists, musicians, teachers), and non-technical non-creative (e.g. secretary, plumber). (Figure 3)

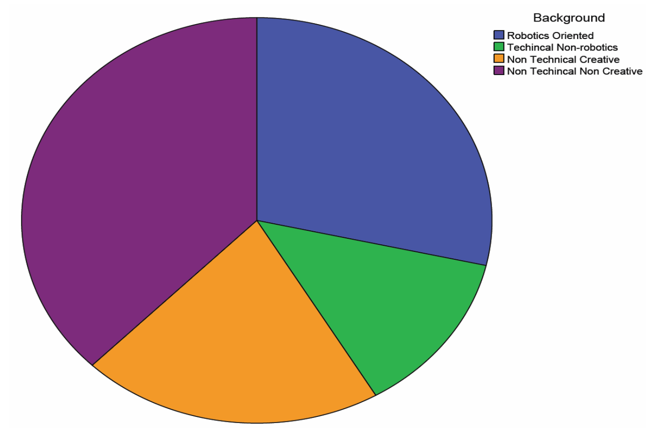

Figure 3: participants' demography

Quantitative Results

We performed an analysis of variance (ANOVA) on our collected survey data and found multiple main effects and 2-way interactions between our movements style conditions. We chose to run a factorial analysis of variance (ANOVA) because we were interested in comparing the different conditions of movement, speed and repetition. A covariance analysis was not conducted as there were no significant correlations found between the data and the demographic data we collected.

Main Effects

1) Comparing the simultaneous (organic) condition to the sequential (mechanical) condition, the following main effects were observed:

a) Participants rated the robot as significantly more natural under the organic movement type condition ($M = 3.26$) than under the mechanical movement type condition ($M = 2.59$) averaged over speed and repetition. $F(88) = 4.95$, $p = .029$.

b) Participants rated the robot as significantly more organic under the organic movement type condition ($M = 2.50$) than under the mechanical movement type condition ($M = 1.83$) averaged over speed and repetition. $F(88) = 5.41$, $p = .023$

c) Participants rated the robot as significantly more interactive under the organic movement type condition ($M = 3.16$) than under the mechanical movement type condition ($M = 2.95$) averaged over speed and repetition. $F(88) = 5.25$, $p = .025$

d) Participants rated the robot as significantly more kind under the organic movement type condition (M = 3.82) than under the mechanical movement type condition (M = 3.33) averaged over speed and repetition. F(88) = 4.43, p = .039

2) Comparing the repeating condition to the non-repeating condition, the following main effects were observed:

a) Participants rated the robot as significantly more relaxed with repetition (M = 3.80) than without repetition (M = 3.08) averaged over speed and movement type. F(88) = 4.46, p = .038

b) Participants rated the robot as significantly more calm with repetition (M = 4.12) than without repetition (M = 2.82) averaged over speed and movement type. F(88) = 22.52, p = .000

Two-way Interactions

1) There were two-way interactions between movement style and repetition:

a) For the fake/natural pair, participants rated the robot as more fake under the mechanical movement condition (M = 2.50) than the organic movement type condition (M = 3.79) when there was no repetition, t = 4.47, p = .026. There was no significant difference in ratings found when there was repetition between the mechanical movement type (M = 2.67) and organic movement type (M = 2.72) conditions.

b) For the mechanical/organic word pair, participants rated the robot as more mechanical under the mechanical movement type condition (M = 1.53) than the organic movement type condition (M = 2.67) when there was no repetition, t = 4.10, p = .002. There was no significant difference in ratings found when there was repetition between the mechanical movement type (M = 2.13) and the organic movement type (M = 2.33).

c) For the unfriendly/friendly word pair, participants rated the robot as less friendly under the mechanical movement type condition (M = 3.63) than the organic movement type condition (M = 4.22) when there was no repetition, t = 2.15. The effect of movement type was not the same for all levels of repetition as with repetition, the participants rated the robot as more friendly under the mechanical movement type condition (M = 4.19) than the organic movement type condition (M = 3.61).

d) For the anxious/relaxed word pair, participants rated the robot as more relaxed when repeating under the mechanical condition (M = 4.27) than when not repeating under the mechanical condition (M =2.75), t = 4.40, p = .001. There was no significant difference found in ratings under the organic movement type condition with repetition (M = 3.33) or without repetition (M = 3.41).

2) There were two-way interactions between speed and movement style:

a) For the mechanical/organic word pair, participants rated the robot as more mechanical under the mechanical movement type condition (M = 1.56) than under the organic movement type condition (M = 2.83) when the speed was slow, t = 3.90, p = .001. There was no significant difference in ratings found between the mechanical movement type (M = 2.10) and organic movement type (M = 2.17) when the speed was fast.

b) For the foolish/sensible word pair, participants rated the robot as more foolish under the mechanical movement type condition (M = 3.08) than under the organic movement type condition (M = 4.39) when the speed was slow, t = 4.35, p = .002. There was no significant difference in ratings found between the mechanical movement type (M = 3.42) and organic movement type (M = 3.03) when the speed was fast.

3) There were two-way interactions between speed and repetition:

a) For the ignorant/knowledgeable word pair, participants rated the robot as more ignorant with repetition (M = 2.78) than without repetition (M = 3.62) when the speed was slow, t = 2.76, p = .042. There was no significant difference in ratings found between the with repetition condition (M= 3.67) and the no repetition condition (M = 2.82) when the speed was fast.

b) For the agitated/calm word pair, participants rated the robot as more agitated with repetition (M = 4.50) than with no repetition (M = 2.11) when the speed was fast, t = 7.52, p = .000. There was no significant difference in ratings found between the repetition condition (M = 3.75) and no repetition condition (M = 3.53) when the speed was slow.

Qualitative Results

Over the course of the three separate sessions of the *Calamaro* study, a number of interesting interaction themes emerged. These are summarized as follows:

A Sense of Entitlement

An unforeseen consequence of this new study environment was a distinct "sense of entitlement" from many of the passersby. Often the very first question the experimenters received from many people was "*Ok, so what's this about?*", "*What's the story here?*", or "*Ok, give me the spiel. What's going on?*" followed by the participant crossing their arms and waiting for an explanation. Unlike a more classical ethnographic field study (where the experimenters are almost completely hidden and attempt to never interfere with the population they are studying), our study was designed (and our ethics clearance necessitated) that the experimenters be present and visible at all times during each session. Together with the large, highly visible information posters, this turned the experiment into more of a "kiosk" or "information booth at a convention" experience than a "natural encounter with a robot in-the-wild"-style experience as we initially intended.

Hands-on Interaction

While we felt a true "robot in-the-wild" experiment would be even more interesting, we learned over the course of preparing and mounting our *Calamaro* study that it would also take a tremendous amount of preparation and safety precautions (for both the participants and the robot) that we do not think would have been feasible given the resources available to us, in retrospect. *Calamaro* is a relatively fragile robot and, even with the experimenters present, the robot often came close to being man-handled and physically abused by the public participants to the point of being broken and needing to be repaired. It appeared that these hands-on participants were generally interested in testing *Calamaro*'s strength out of a natural sense of curiosity.

On one hand, it is highly likely that the current *Calamaro* prototype would not have survived for very long if participants were allowed free-reign of their physical interaction with it. This is primarily because the available motors and control programming did not account for extreme motor loads. *Calamaro* simply interpreted its motion scripts and performed its movements unthinkingly. If one of *Calamaro*'s motors were to become obstructed, it would continue to push against the obstacle until either the blockage was removed or the motor overloaded and shut down. While rare, the nearby experimenters worked to avoid this scenario by asking particularly hands-on participants to treat the robot more gently and discouraged aggressive handling.

On the other hand, we find it interesting that so many participants at least asked if they could touch and interact with *Calamaro*. Despite its unfamiliar appearance, unknown purpose, and often rapidly moving appendages, relatively few people appeared to be afraid of the robot. Instead, most participants seemed more to be intrigued, curious, or entertained by *Calamaro* and hence their desire to see just how closely they could interact with it.

We feel that this level of comfort arose out of two possible factors: 1) The "information booth" appearance of the study area; complete with waiting "information attendants" (e.g. the nearby experimenters with microphones). 2) The small, pet-like size of the robot, its lack of physically intimidating presence, and its relatively slow locomotion speed. One could easily "escape" from the robot, if necessary, so people may have felt bolder when approaching it.

The Effect of Background Training, and Self Selection

As could be expected the academic or professional background of a participant often greatly affected the tone of their interview responses. Technically oriented individuals, particularly those with engineering backgrounds or work involving robotics, approached *Calamaro* by comparing it to their own work or analysing its construction. E.g. "*So what did you use for the controller?*", "*How powerful are the motors?*", "*If it doesn't have any sensors, then it's just a toy.*"

Alternatively, there were numerous non-technically oriented participants for whom *Calamaro* was an entertaining curiosity. These participants were more likely to ask about the robot's name, refer to it as "*Calamaro*" or "he" as opposed to "it", and generally treated is as something with character rather than just as a machine. These participant's inquiries were more often directed towards the nature of the study and the experimenters' motivations.

Regardless of their technical background, all of the *Calamaro* study participants were self-selected. That is, participants decided to stop by the *Calamaro* food court table and join our study due to their interest in the robot. By negation, we assume that our study may be missing a subset of the population that had little interest in the robot and thus decided not to stop-by and participate. This self-selection bias is an interesting challenge for the design of future in-the-wild HRI studies, which may look for ways to "force" interaction with the robot, or seek mechanisms that will enable input also from people that decided against interaction with the robot.

Public vs. Private Reflection

Unlike usability lab settings *Calamaro*'s in-the-wild settings generated a unique atmosphere and challenges. First and foremost, we felt that the internally reflective comments from *Calamaro* participants was of low quality. When asked about their impressions of the robot participants were generally quick to respond, as if being quizzed for a known answer, rather than pausing to reflect and present their own well-formed thoughts. Part of this might be attributable to the high-pace nature of the public food court: people are either there to study, eat or are passing through on their way to different destinations. Some of the most popular comments from all of our participants were variations on "*That's cool!*" or "*That's impressive!*"; commenting on the robot and the study itself rather than their thoughts on the specific qualities of the robot's motions or visual characteristics. That any robot at all was moving and gesturing in the middle of the food court was more noteworthy and more unexpected than details about the robot itself or its motions.

Group Reflection

Unique to the *Calamaro* study was the possibility for participants to reflect as a group. A number of groups (e.g. sports teams, groups of colleagues out for lunch, student club members, conference attendees, etc.) stopped to observe the robot and were subsequently interviewed as a whole. Individual comments would be proposed, reiterated, added-to, or countered by other members of the collective. Often this would lead to the formation of consensus (E.g. "*Yeah, you're right... it does kind of look like an octopus.*"). We question whether this apparent group-think also had the effect of suppressing some of the less popular or more esoteric responses.

In other cases, in particular a group of robotic engineers and their non-engineer friend, the deliberation led to subtle conflict: a set of engineering graduate students that were working on a search-and-rescue robot for the University were particularly critical of *Calamaro*. They immediately regarded the robot as a machine with no intelligence or emotive impact and, once they recognized the relative simplicity of the robot's mechanics and control technology, were visibly unimpressed with *Calamaro*'s technical aspects as well.

However, a single non-engineering-oriented member of the group who claimed to have no understanding of how either *Calamaro* or the search-and-rescue robot worked clearly expressed a dissenting opinion and drew laughs and mild indignation from his friends. This participant then went on to explain that, because *Calamaro* actually "worked" (e.g. continued to move and perform without outside intervention for dozens of minutes at a time, despite his not having been told what the robot's "purpose" was), he was far more impressed with *Calamaro* than with his companions' more advanced, more capable, and more expensive platform that constantly suffered from technical problems which prevented it from consistently "working". "Reliability" was a characteristic that we had so far not considered in our experimental designs. Similar statements were also made by other participants with technically-oriented backgrounds. They complimented us on how well *Calamaro* appeared to be functioning and expressed exasperation over how difficult it often was to keep robot prototypes in good working order; especially when operating "in the field".

DISCUSSION

Running *Calamaro* as a field study was an attempt to bring some "real world legitimacy", or external validity, to our exploration of *emotive motion*. Although we encountered unexpected challenges in terms of how we were able to mount our study and publicly portray our robot, we gained important insights into both different *emotive motion* characteristics, the differences between conducting controlled laboratory studies and experiments in-the wild, and how that difference in setting affects emotional interpretations of social robots.

Impact on the Design of *Emotive motion*

The statistical analysis of our *Calamaro* survey results reveal that the more repetitious segments of the motion were perceived as being calmer and more relaxed. We believe that regardless of the complexity or duration of a robot's motion pattern, once an observer has perceived it to have fallen into a predictable pattern, a sense of expectedness and calm arises.

Robot motion that is smoother and more complex (e.g. simultaneous coordination of multiple appendages) was generally interpreted as more natural, more organic, more interactive, more friendly, more intelligent, more calm, and more kind; all of which can be viewed as beneficial traits when attempting to design pleasant social interactions between humans and social robotic agents. In contrast, "typical" robotic motion (e.g. jerky, linear, rigid, sequential, and repetitious) may be failing to take advantage of the expressive power of *emotive motion*.

We view these themes as our most important experimental results: The quality and style of a robot's motions, regardless of that robot's purpose or visual form, carried with it an important emotional weight and should be a deliberate focus when designing social human-robot interaction scenarios.

Impact on Social HRI Study Design

Our study proved an eye opener for us on the realities of deploying a robot into a busy public space, with little ability to gain personal and reflective interaction between the robot and participants. Social HRI researchers should be prepared for the practical challenges of bringing their robot prototypes out of the safety of the lab and into the unpredictable chaos of public spaces.

Most current robots are often relatively fragile and largely helpless devices which require constant supervision and regular maintenance. However, if social robots are to become the ubiquitous, daily experience that many envision they will become, then they must be capable of dealing with overzealous humans (and potentially overt vandalism), mechanical failure, complex and dynamic public environments, and many other challenges.

Even in the semi-controlled scenario of an academic field study, researchers must be aware of the unique social interactions (e.g. group consensus, time pressures, public expectations) that are simply not possible to emulate in a laboratory setting.

CONCLUSION AND FUTURE WORK

In this paper we discussed the development of our *Calamaro* robot prototype and its deployment in a field study. The study's results revealed some of the unique influences and challenges that rise when running HRI studies in-the-wild, and that can affect the design of robotic *emotive motion*. Our initial investigations into the expressive capabilities of *emotive motion* remain far from exhaustive, and much future work is called for.

In the short term a thorough, grounded-theory analysis of the *Calamaro* study video data could perhaps uncover some more interesting, if subtle, trends. We would also like to redesign *Calamaro* in a more locomotive fashion: although our current prototype has wheels, due to safety concerns about it accidentally rolling off the table *Calamaro*'s locomotion was extremely limited during our field study. This is a major limitation since locomotion is another entire aspect of motion that we did not really address in our current set of studies. We would also like to evaluate an interactive *Calamaro*: although some participants still thought the robot was able to react to their presence and actions, *Calamaro* never exhibited true interactivity. Adding an interactive layer could allow us to explore the role of interactivity in emotive motion with the *Calamaro* platform.

Through movement, humans and robots can express both powerful and subtle emotions. As robots continue to advance in complexity and capability, it is predicted that they will play increasingly larger roles in our daily lives, and that it will becoming increasingly important that robots will be able to communicate and interact naturally with their human counterparts. Robotic *emotive motion* will play an important role in the design of such future robotic agents and we hope that our *Calamaro* effort will help with additional insight on this research direction, and will add to the accumulated experience of running HRI studies in-the-wild.

ACKNOWLEDGMENTS
We thank the HAI'14 reviewers for their helpful comments, and NSERC Discovery Grant for enabling our research.

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