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Identifying Values to Express Emotions with a Non-Anthropomorphic Platform

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Abstract Social environments are intricate spaces where people behave in ways that lead to their acceptance in social groups. In a similar way, robots that interact with humans on daily bases are expected to be accepted by people. This creates the necessity to make robots with high social presence that let humans to feel comfortable with robots presence. The straightest way is through imitation of humans' characteristics, such us body shape, behaviors and social characteristics. As a consequence many social robots have been built with anthropomorphic embodiment, which could include features to express emotions. Although anthropomorphic embodiment may support robot acceptance in interactive tasks, there are robots that not need to have anthropomorphic characteristics to fulfill their tasks. As a consequence, features not related with anthropomorphic embodiment should be exploited to support robot acceptance. This paper presents an experiment made to understand the contribution of angular and linear velocity, body orientation, and movement direction on humans' perception of emotion. Therefore, a non-anthropomorphic platform was used in the experiments to let participants to focus on the desired features. Moreover a Likert questionnaire was used to measure participants' perception for different treatments. The Krippendorff's alpha agreement was used to create a top 10 table for each of the emotions listed in the questionnaire. The obtained results suggest values that could guide the implementation of the considered emotions in social robots.

Keywords Human-Robot Interaction · Emotion Expression · Experiment · Non-anthropomorphic Platform · Emotions Expression with Non-anthropomorphic Platform

1 Introduction

Social environments are intricate spaces where people behave in ways that lead to their acceptance in social groups. Similarly, studies in social robotics have shown that robots acceptance increases when robots project a high social presence [22]. The straightest way is through imitation of humans' characteristics, such us body form, behaviors and social characteristics. This has inspired most researchers to focus on how express emotions and mental states exploiting anthropomorphic features, and in many occasions relying just on faces. However emotions and mental states are not just presented through facial expression, but also by body postures and other features [20]. Nonetheless in psychology has been a clear tendency to study the role of human face in emotion projection [17], [25] and mental states. This trend has been followed by robotics community, where anthropomorphic faces (e.g., [18], [5]) and bodies (e.g., [4], [21], [13]) have been widely used to convey emotions. Nevertheless, in many situations the presence of anthropomorphic elements would be out of place and not justified by the main robot's functionalities. Most of the current and future robotics platforms on the market will not require anthropomorphic faces

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or limbs. In some cases, like, for instance, in floor cleaning robots, anthropomorphic characteristics could even be detrimental to robot's task accomplishment. This generates the necessity to study other mechanisms that could help to project emotions, which could give people an idea about the robots' state, and engage the user in long term relations.

The amount of works studying non-anthropomorphic features in robotics (e.g., [38, 29, 40, 34]) remains still small in comparison to those that exploit anthropomorphic features. Moreover, these works do not prescribe any specific range of values for the characteristics to be used to express the implemented emotions. For example, Suk and collaborators [33], in their study, give specific values for acceleration, curvature, but their connection to specific emotions is not given. Rather, they gave a relationship between their features and values in terms of valence and arousal. Another possibility is the use of professional human actors to study how they convey certain emotions. However, a direct mapping between humans and robots is not possible [39, 4] due to robots' physical capabilities. In addition, the significance of the agreement obtained from the studies that used human actors is on discussion [**?**]. As a consequence determine precise values to project emotions in non-anthropomorphic platforms is required.

In order to get a better understanding of other features and values that could be used to convey specific emotions, this paper presents an experiment that was designed to identify specific values for some movement features that could be used to express the following emotions, selected among the ones suggested by Ekman as basic [17]: happiness, anger, fear, and sadness. The considered features are: oscillation angle, linear and angular velocity, direction and orientation, identified as independent variables. The perceived emotions and their intensities were considered as dependent variables. It is to be observed that it was given the possibility to the subjects to provide their evaluation of emotional intensity for more than one emotion for each experience. The experiment took place in Politecnico di Milano during June and July of 2015, where students from diverse departments were asked to participate without any economical retribution. Krippendorff's alpha agreement [27] (α) was used to evaluate the agreement among the participants for each treatment. For each of the four emotions was generated a top 10 list based on alpha agreement and perceived intensity. The results suggest that fear is perceived when the robot is looking at the subjects while moving far from them fast. Sadness is associated to slow velocities with slow angular velocity and small oscillation angle. Anger is attributed to fast velocities, both angular and linear, small angle of oscillation and the robot facing the subjects while approaching them.

This paper is organized as follows. The next section introduces previous studies done in human emotion and robot emotions projection. Section 3 introduces the robotic platform and the software used in the experiment. The experiment's design is explained in section 4. Finally sections 4 and 5 present the study done and the obtained results.

2 Related Work

Although it is not possible to apply a direct mapping from human studies to robots [39, 4], human studies provide guidelines about possible features and values that could be used to generate emotional motion.

2.1 Human Studies

Emotion plays an important role in human-human interaction, and can be expressed through diverse channels such as body gestures and poses, body movements, face expressions. Given the complex structure of human face, where more than 43 muscles act, face configurations are considered as a primary channel to express emotion. As a consequence, many works have focused on facial expression, mainly, but not only, influenced by the work done by Ekman [17]. However, the role that body plays in emotion projection was recognized, too, and started to be studied [20, 43]. Nevertheless, the amount of works related to body expression of emotions is still small compared to studies about facial expression.

Analysing some of the few works that have studied human body expressiveness, it is possible to recognize two different methodologies to create the data base of movements to be assessed during the experiments. Applying a first methodology, human actors (either professionals, or amateurs) are asked to walk straight from point A to point B conveying specific emotions [12, 32, 43]. Each trial is recorded and later shown to each subjects that have to classify all the sequences. The second methodology uses virtual agents [37, 42] to generate the very same set up for the experiments; the agent's movements are generated from the data recorded from human actors.

The work done by Wallboot [43] has been used as a reference by others. It addressed the question: *Are specific body postures indicative of emotion or are they only used to indicate the intensity of the emotion?* To answer this question, he recorded 224 videos for joy, happiness, sadness, despair, fear, terror, coldness anger, hot anger, disgust, contempt, shame, guilt, pride, and boredom, and showed them to the subjects. His results reaffirm that movement and body postures are indicative of intensity for some emotions. But at the same time, these two characteristics seem to be enough to identify other emotions.

Complementary studies using virtual agents have been performed by Kluwer and collaborators [11], who studied the contribution of postures and angle view in the interpretation of emotions. They generated 176 static positions for happiness, anger, disgust, fear, sadness and surprise. Each image was later rendered from three different angles (front, left, and above and behind left shoulder) producing a total of 528 images. All the participants were exposed to all 528 images and were asked to label the image with the emotions that best represent it. Their results show that five out of six emotions were quite well recognized independently from the angle of view., while disgust was for some postures confused with fear.

The main drawback of all these projects is the use of video recorded sequences, which misses the impact related to a complete physical experience. For instance, it is clearly different facing an angry robot really rushing against us, or looking at a video where this happens.

2.2 Robotic Studies

As a direct consequence of the abundance of works in face elicitation in humans, most of the works done in Human-Robot Interaction (HRI) have focused also on faces. One of the most well-known expressive robots is Kismet [5], a robotic face able to interact with people and to show emotions. The face had enough degrees of freedom to portray the basic emotions suggested by Ekman [17] (happiness, surprise, anger, disgust, fear, and sadness), plus interest. Despite the complex system behind Kismet, the emotion's projection evaluation was done using videos with a very limited number of participants. Similar approach was followed by Li and Chignell [31], who used videos of a teddy bear robot to study the contribution of arms and head movement to express emotions. In same direction Destephe and collaborators [14, 13] studied the attribution of emotion to a robot's gait using a virtual representation of the platform WABIAN-2R. More recently Knight and Simmons [26] used Keepon and NAO platforms to study the possibility to project inner states with just head movements. Although use of videos has the advantage to cover a major number of participants, the lack of interaction with the real platform make these works lose the impact that a robot could generate on the participants.

The use of real platforms to study emotion projection could be dived in two lines: using anthropomorphic and non-anthropomorphic platforms. In the first case, these works are characterized by the use of cue positions to project desire emotions [36]. In some cases, special attention has been taken to determine head's angle and arms position contribution in specific emotions [6]. Nevertheless, current humanoid platforms cannot generate smooth gaits, which limit the study of body movements. To overcome this limitation, some researchers have reduce the human appearance (e.g. eliminating limps and facial expressions)to increase platform mobility and study new mechanisms to project emotions [18]. Pushing forward the reduction on anthropomorphic features, Saerbeck and Christoph used a Roomba platform to study the contribution of curvature in a trajectory to conceive emotional states [38]. Similarly Lourens and Barakova [3] implemented a set of behaviors to determine the emotion perceived from diverse movements, which were selected from the work done by Camurri et al. [9]. Continuing with her research on how robotics' behaviours are interpreted by people, Barakova and collaborators [23] created a closet in which lights could be manipulated to convey pre-defined behaviours. The robot's behaviours were defined using the Interpersonal Behaviour Circle (ICB) [30], which is based on two dimensions (dominance-submission and hate-love). Their findings suggest that electronic systems can elicit a type of reactions different from the one expected by theories of interpersonal communication.

Other approaches have tried to get a better understanding of the contribution of diverse features to express emotions through movement. For example, Suk and collaborators payed a particular attention to speed, smoothness, granularity of movement path and volume of a non-bioinspired object [33]. Their results suggest that arousal increases as speed increases and that there is not any clear tendency for smoothness. On the other hand, granularity is positively correlated with pleasure and arousal, while volume is negatively correlated with pleasure and positively correlated with arousal. Alike, Tan and collaborators [41] have studied the contribution of velocity, fluidity, direction and orientation of a small box. Their results suggest that direction is directly correlated with dominance, but that fluidity does not influence the perception. While flat orientation is related to positive valence, leaning position are related with negative valance. Finally the velocity is correlated with valence, arousal and dominance.

Due to the popularity that quadrocoptors have received in the last years, Sharma and collaborators [40] used a quadrotor to study how different Laban's effort [28] parameters could impact on the perception of affection. A professional Laban certified actor was asked to generate 16 different paths, for each one changing one of the four Laban's parameters (space, weight, time, and flow). Each generated path was recorded using the Vicon motion-tracking system. Continuing with the use of quadrocoptors, Cauchard and collaborators [10] studied how flight paths could project personal traits and emotional attributes. All these works present a very nice starting to point to identify features and values that could be used to project emotions in robotics, which could help in coordinating humans and robots [34]. However, all of these works not give a price guideline to elicit precise emotions, which from our previous case studies could lead to the misinterpretation of movements emotions [2]. For example people could confuse an implementation of *Happiness* with *Anger*.

3 The System

The system used in the experiment is composed by a non-anthropomorphic platform and software architecture that enrich robot's movements with emotion. The robotic platform was envisioned to be as simple as possible to limit the influence of shape on the study of the desired characteristics.

3.1 Hardware and Mechanical

A holonomic platform was built to be used in the experiment. This type of platforms are characterized by the possibility to move in any direction without the necessity to have a specific orientation, i.e., they are free to move taking any desired orientation. Therefore, it was possible to imitate movements that are done by humans. For example, people do not have constaraints in movement, and can take any direction in any moment. The platform has a diameter of 25 cm and height of 25 cm. Figure 1 shows the platform's blue prints and the real platform. Robot's frame of reference, in which all the velocities are going to be calculated, is depicted by the two black arrows. Therefore, as it could be observed, to make the robot move forward a velocity along the y axis is selected by the control system.

3.2 Software

To guarantee that the correct robot's velocity for each motor could be achieved, a PID controller was implemented. PID's set point is established by a higher level controller that could receive two different types of commands. The first commands are robot's velocities ($< V_x, V_y, \omega >$), given in robot's reference frame. The second command is a set point ($< x, Y, \theta >$) to be reached, given in the world reference frame. This world frame of reference is set every time the system is reset or boot. For example, if the robot finishes a trajectory and then it is reset, the new frame is going to be in the robot's current position.

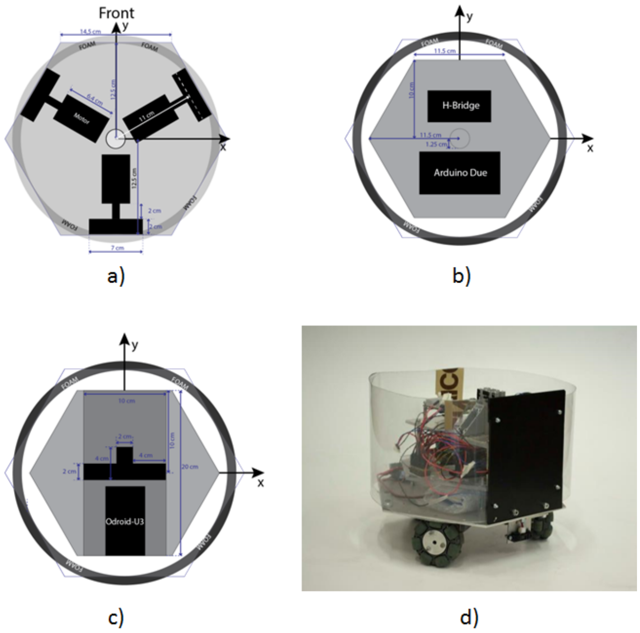


Fig. 1 Design of the platform. a) Base platform, this layer is used to carry the batteries. The two black arrows represent robot's frame of reference. b) First layer, which includes Arduino and the H-Bridges to control the motors. c) Second layer with Odroid-U3 and the mechanical structure to support the upper part. d) Lateral view of the robot.

4 Experimental Design

The experiment was designed to get a better understanding about the contribution linear and angular velocity, oscillation angle, direction, and orientation can give to the expression of *Happiness*, *Anger*, *Sadness*, and *Fear*, which are four out of the six emotions considered by Ekman [17] as basic emotions, which are characterized to have short duration, cultural universal [15], derive from evolution [7], and could influence cognition and action [8]. Moreover, these four emotions here selected are overlap with emotion schemas [24].

4.1 Independent Variables

The definitions of the selected independent variables are reported here below.

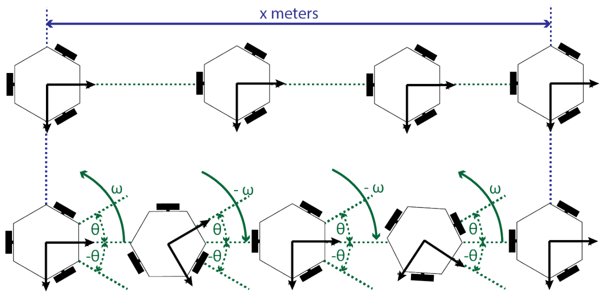


Fig. 2 Example of the features used in the experiment. x represents the displacement in meters, ω is the angular velocity (rad/s) and θ the oscillation of the body around its center (rad). The upper sequence depicts a movement based only on linear velocity, while the bottom one shows a sequence with angular and linear movement. The two black arrows in the robot's middle depict robot's frame of reference.

– **Angular velocity** is the rotational velocity (ω) of the robot with respect to its center.
– **Oscillation angle** is the maximum extension of the robot's rotation around its center in the oscillating movement (θ).
– **Linear velocity** is the rate of change of the position of the robot (V).
– **Direction with respect to participant's perspective** is the angle generated from the participant's point of view with respect to the robot's trajectory (D).
– **Orientation of the body with respect to participant's perspective** is the robot's body orientation with respect to the robot's trajectory (ϕ).

The three first variables are depicted in Figure 2. The robot's frame of reference is drawn to show that it could move straight while it is rotating. It is important to highlight that linear velocity is respected when the robot is also oscillating.

Independent Variables values

Specific, discrete values were selected for all independent variables, to make the experiment feasible. First, a simple test to evaluate when significant changes could be perceived was performed on a small sample of independent subjects. Based on this test, specific values for oscillation angle, and angular and linear velocities were selected. The values for the remaining two variables were selected to verify the impact of direction and orientation. This goes in accordance to our observations in previous case studies [19], in which people had a better recognition of fear when the robot was moving far. The chosen values are shown in Table 1.

To get a better idea about the Direction and Orientation values, in Figure 3 are reported all possibilities for these two variables.

Table 1 Values for each of the independent variables in the experiment.

Variable \ Possibilities	First	Second	Third	Fourth
Angular Velocity (rad/sec)	0	1	2	3
Oscillation Angle (rad)	0	0.087	0.175	0.349
Linear Velocity (mm/sec)	0	200	500	900
Direction (rad)	0	π	$\frac{-\pi}{2}$	
Orientation (rad)	0	π		

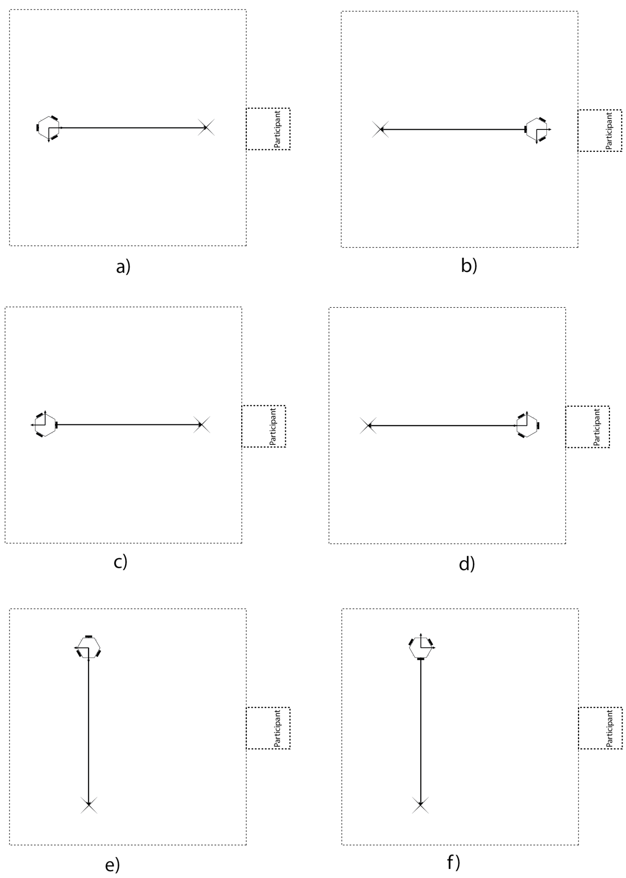


Fig. 3 Combination of direction and orientation. The crosses symbolize the final position. The robot represents the initial position with its orientation, which is represented through the robot's frame of reference. The dashed big square represents the robot's movement zone, while the small one on the side represents the subjects' zone. a) Direction = 0 and Orientation = 0. b) Direction = 0 and Orientation = π. c) Direction = π and Orientation = π. d) Direction = π and Orientation = 0. e) Direction = $\frac{-\pi}{2}$ and Orientation = 0. f) Direction = $\frac{-\pi}{2}$ and Orientation = π

Treatments, meant as desired combination of independent variables to compare [35], were generated from the combination of independent variables' values for a total of 384 combinations. Treatments that would not add any significant information to the experiment were removed, such as treatment with $\theta = 0$ and $\omega \neq 0$, which reduced total amount of treatments to 195.

4.2 Dependent Variables

Two dependent variables were determined, and they are described below.

- **Emotion** is the feeling perceived by the participants from the robot's movement. From previous experiences [19] , it was decided to ask the participants to select an emotion name in a list including the four emotions intended to be expressed, two mental states that could be misinterpreted from these emotions, and the option of "other". The two states of mind included as confounding terms are tenderness and excitement, which correspond to low and high arousal states.
- **Emotion's intensity** indicates the emotion intensity as perceived by the subject. This variable is measured on a Likert scale, ranging from 0 to 10, where 0 means that the corresponding emotion is not perceived by the subject and 10 that the emotion is highly perceived by the subject.

4.3 Participants

It was decided that each subject had to be exposed to twenty over 195 possible treatments. Each presentation lasted from 10 to 15 minutes. This was decided because each subject was a volunteer, so the time dedicated to the experiment had to be kept limited. The twenty treatments were selected picking a number without replacement from 1 to 195. A total of 980 answers were collected, guaranteeing a minimum of 5 trials for each treatment.

The experiment was performed at Politecnico di Milano, involving subjects with different backgrounds. A total of 49 volunteers were involved: 12 females and 37 males. The average age of the subjects was 25.28, with standard deviation of 2.8, with a minimum age of 20 and maximum of 32. The subjects' country of origin and their backgrounds are shown in the Table 2 and Table 3, respectively.

The information from each subject was collected using a web-based form. To maintain anonymity, no personal information that could be used to trace the subject back was collected. The procedure used with each subject is described here below.

Table 2 Subjects' Country of origin.

Country	Counting
Albania	1
Bosnia	1
Brazil	2
Colombia	4
Germany	1
Greece	1
Iran	5
Italy	33
Moldova	1

Table 3 Subjects' Background.

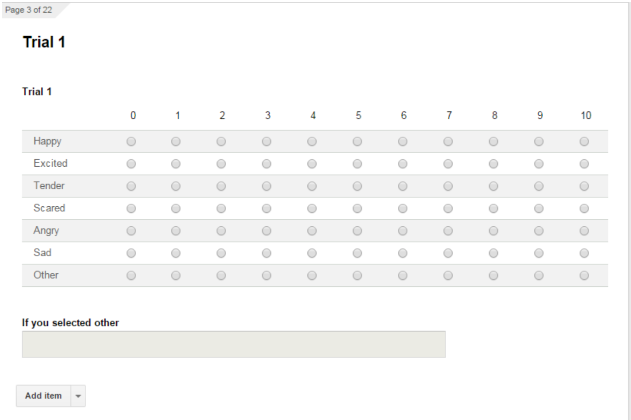
Career	Counting
Aeronautical Engineering	1
Architecture	1
Social assistance	1
Automation	1
Bio-medical Engineering	5
Computer Science	33
Electronic Engineering	2
Mechanical Engineering	2
Nursery	1
Pedagogical Science	1
Tourism	1

1. The subject was asked to fill out the following information:
   - Sex
   - Background
   - Age
   - Country of origin
2. The robot was shown to the participant and the experiment procedure explained.
3. An example of the questionnaire was presented and a sample movement of the robot shown.
4. The subject was exposed to a specific movement sequence according to the following steps:
   (a) The subject is exposed to the movement generated by a configuration of values.
   (b) The subject could use as much time as needed to select values for intensity of the different terms in the questionnaire.
   (c) After the subject had completed his/her selection about the current movement, the robot is positioned to the new starting point, and the sequence is repeated from step 1.(a) for the rest of movements.

The order of the options listed in the questionnaire changed for each question to prevent any kind of bias. Figure 4 shows an example of the questionnaire used.

4.4 Setup

The experimental setup and dimensions are shown in the Figure 5. The crosses symbolize possible starting


Page 3 of 22

Trial 1

Trial 1

	0	1	2	3	4	5	6	7	8	9	10
Happy											
Excited											
Tender											
Scared											
Angry											
Sad											
Other											

If you selected other

Add item

Fig. 4 Example of the questionnaire used in the experiment.

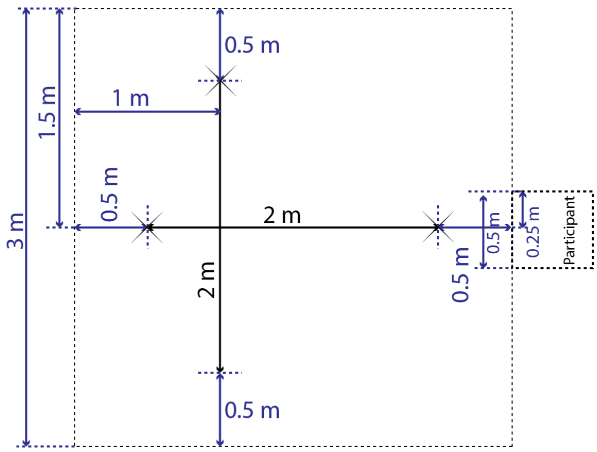


Fig. 5 Setup for the experiment. The crosses symbolize the possible starting points.

points, which were selected depending on the direction's value, as it is showed in Figure 3.

5 Results

A table with subjects' answers was generated for each treatment. Table 4 is an example of the generated tables.

For each table, mean, standard deviation, and median were calculated. It was not possible to use ANOVA test over the data because the assumption of normality is not satisfied in the collected data. This was checked using the Shapiro-Wilk Test. Additionally, a contingency table for each emotion was generated in each treatment, as it is depicted in Table 9, where the intensity for the rest of emotions is calculated as their mean of their intensity, including the option "other". Therefore a total of seven tables for each treatment were created. For all these tables, Krippendorff's alpha agreement [27] (α) was calculated, which is a reliability coefficient to measure the agreement among different participants. Unlike other coefficients (e.g., $Kappa$), α is a generalization of several known reliability indices, and it applies to any number of observers, any number of categories, any type of data, incomplete or missing data, large and small sample sizes.

This calculation was done using the R's package *irr*. To improve contingency tables' interpretation, it was decided to just register emotions' alpha and intensity values greater than zero. The α for each treatment is shown in Figure 6. As it could be observed, this table does not provide any information about the interpretation for each emotion. Therefore, it was decided to create top ten raking of treatments from the contingency tables of each emotion. This ranking is generated considering the following items in the respective order:(i) the mean intensity of the respective emotion, (ii) the alpha agreement of contingency table for the respective emotion, and (iii) the alpha agreement for the specific treatment. From the resulting tables 5, 6, 8, and 7, it is possible to notice:

- *Fear* was the only emotion that had six over ten movements obtaining both general and specific alpha agreement over 0.41, which is the lower bound for moderate agreement [1]. Also, it was mostly selected (eight over ten) when $direction = \pi$ and $orientation = \pi$. The angle and the angular velocity attributed six over ten times were 0.087 and 2, respectively. So it seems that people perceive the movement as a fear expression when the robot is looking at them and moving far from them fast.
- *Sadness* was mostly attributed to linear velocities of $0mm/s$ (two over ten) and $200mm/s$ (eight over ten), and angular velocities of $0rad/s$ and $1rad/s$, with higher predilection of the second (eight over ten). It seems that people attribute sadness to slow velocities with slow angular velocity and small oscillation angle. Regarding the other two features, there is not any defined pattern that could lead to make a generalization.
- *Happiness* is attributed to different values of the independent variables. But it is the only emotion that is highly perceived when the linear velocity is 0 with four over ten. However the oscillation angle for these four cases is equally divided between the values 0.174 and 3.49. So it seems that happiness is mainly attributed to fast angular velocities and big oscillations angles. Specific agreement among the other features is not present.
- *Anger* is highly perceived with an angle of 0.087 (seven over ten) and with linear velocities over $200mm/s$. It seems that people attribute anger to fast velocities, both angular and linear, small angle of oscil-

Table 4 Example of the table generated for each experience. This table corresponds to the experience with $ID = 1$.

Sex	**Background**	**Age**	**Country of Origin**	**Happy**	**Excited**	**Tender**	**Scared**	**Angry**	**Sad**	**Other**	**Explain**
Masculine	electronic engineering	29	Iran	0	2	8	0	0	0	0	
Feminine	Computer science	25	Italy	0	0	6	0	0	8	0	
Masculine	Computer science	24	Italy	0	0	0	8	0	7	0	
Feminine	Pedagogical Science	26	Italy	0	0	0	0	0	0	7	Dubbioso
Masculine	Computer science	24	Italy	4	8	0	0	0	0	0	

lation and the robot facing the persons while approaching them.

6 Conclusions and Further Work

This paper presented an experiment made to understand the contribution of angular and linear velocity, body's orientation, and movement direction on humans' perception of emotion expression by a non-anthropomorphic platform. The emotions covered in this experiment correspond to four of the ones enlisted by Ekman [16] as basic emotions: *Anger*, *Happiness*, *Fear* and *Sadness*. To study the contribution of the desired features, a non-anthropomorphic, holonomic platform was used. The experiment was conducted at Politecnico di Milano, and involved 49 participants, each exposed to 20 over 195 movements, selected randomly for each participant. The Krippendorff's alpha agreement [27] was used to calculate the consensus about the interpretation of each treatment. Using alpha and the average emotion intensity attributed to each movement a top 10 movement table for each of the emotions was created.

The values obtained in this experiment could be used to express emotions in non-anthropomorphic platforms. It is still needed to cross validate the values and to determine what values from the top ten could more accurately express the desired emotion. It is important to mention that is not expected to have a 100% of correct emotion recognition by the participants. As it has been observed in previous work in humans and robots, it is not possible to get a 100% of correct recognition. This cross validation would help to reduce the number of feature combinations to the ones with higher possibility of identification. Moreover, additional experiments should be done to obtain analogous values for changes in shape and in different platform's size.

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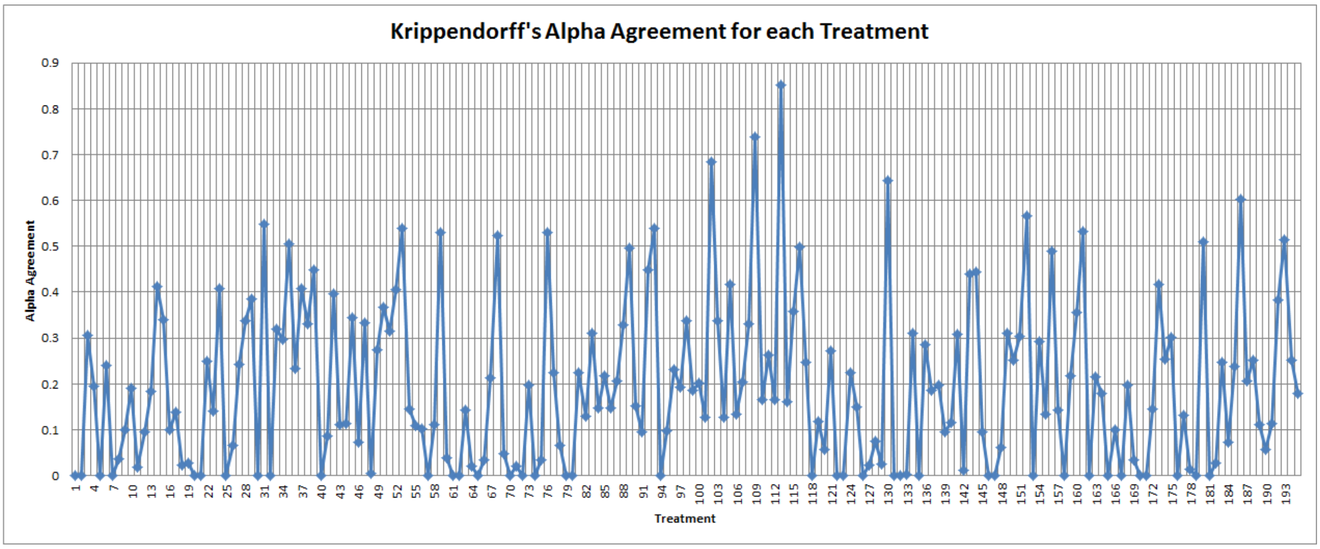

Fig. 6 Alpha values for each movement.

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Table 5 Top 10 attributions for Happiness. This tops table was generated by ordering the results from highest to lowest first by Happy mean, then by Happy alpha, and finally by Movement alpha.

Features					Alpha								Mean						
Direction (rad)	**Orientation (rad)**	**Linear V. (mm/sec)**	**Angular V. (rad/sec)**	**Angle (rad)**	**General**	**Happiness**	**Excitement**	**Tenderness**	**Fear**	**Anger**	**Sadness**	**Other**	**Happiness**	**Excitement**	**Tenderness**	**Fear**	**Anger**	**Sadness**	**Other**
0	0	500	3	0.349	0.38	0.71	0	0	0	0.13	0	0.13	6.8	3	2.6	0	1.4	0	1.4
$-\frac{\pi}{2}$	0	0	2	0.174	0.53	0.71	0	0	0	0	0	0	6.8	3.8	2	0	0	0	0
0	0	900	3	0.174	0.33	0.22	0	0.13	0	0	0	0	6.6	2.6	0.6	0	1.6	0	0
π	π	0	3	0.349	0.21	0.21	0	0.13	0	0.23	0.34	0	6.6	3.6	1.4	2	0.8	0.4	0
π	0	900	3	0.349	0.48	0.11	0.72	0.12	0	0.76	0	0	6.4	6.8	1.2	4	0.2	0	0
0	π	0	2	0.349	0.34	0.71	0	0	0.13	0.47	0.23	0	6	1.4	3.2	1.6	0.4	0.6	0
π	π	0	2	0.174	0.31	0.12	0	0	0.61	0	0	0.13	6	4.8	4.8	0.4	0	0	2
π	0	500	2	0.349	0.43	0.11	0	0	0	0.13	0	0	6	0	3.4	0	0.6	0	2
0	0	500	1	0.174	0.24	0.11	0	0	0	0	0	0.13	6	4	4.2	0	2.2	0	1.2
π	0	200	3	0.349	0.28	0.22	0	0	0	0	0	0	5.8	0.8	3	0	0	0	1.4

Table 6 Top 10 attributions for Anger. This tops table was generated by ordering from highest to lowest first by Angry mean, then by Angry alpha, and finally by Movement alpha.

Features					Alpha								Mean						
Direction (rad)	**Orientation (rad)**	**Linear V. (mm/sec)**	**Angular V. (rad/sec)**	**Angle (rad)**	**General**	**Happiness**	**Excitement**	**Tenderness**	**Fear**	**Anger**	**Sadness**	**Other**	**Happiness**	**Excitement**	**Tenderness**	**Fear**	**Anger**	**Sadness**	**Other**
0	0	0	2	0.087	0.19	0	0.13	0.13	0.13	0.22	0	0	3.2	1.4	1.2	1.8	6.4	0	0
0	0	900	2	0.087	0.29	0.13	0	0.76	0.13	0.21	0	0	1.6	3.8	0.2	1	6.4	0	0
$-\frac{\pi}{2}$	0	900	0	0	0.60	0	0	0	0.13	0.73	0	0	0	1.6	0	1.4	6.2	0	0
0	0	900	3	0.349	0.44	0	0	0	0	0.12	0	0	3	5	0	2.8	6.2	0	0
$-\frac{\pi}{2}$	0	200	3	0.087	0.41	0	0	0	0	0.11	0.47	0	0	4.8	2.6	0	5.8	0.4	0
π	0	500	3	0.087	0.44	0.13	0	0	0	0.43	0	0	0.8	2.6	0	1.4	5.2	0	0
0	0	200	3	0.087	0.13	0.13	0	0	0	0	0	0	1	0	0	2.4	5.2	0	1.8
0	0	900	1	0.087	0.54	0	0.16	0	0	0.16	0	0	2.4	6.4	0	0	5	0	0
0	0	900	0	0	0	0.13	0	0.13	0.13	0	0	0.13	1.6	3	1	1.6	5	0	1.8
π	0	500	2	0.087	0.30	0.13	0	0	0	0.21	0	0	1	1.8	0	3.4	4.8	0	0

Table 7 Top 10 attributions for Fear. This tops table was generated by ordering from highest to lowest first by Fear mean, then by Fear alpha, and finally by Movement alpha.

Features					Alpha								Mean						
Direction (rad)	**Orientation (rad)**	**Linear V. (mm/sec)**	**Angular V. (rad/sec)**	**Angle (rad)**	**General**	**Happiness**	**Excitement**	**Tenderness**	**Fear**	**Anger**	**Sadness**	**Other**	**Happiness**	**Excitement**	**Tenderness**	**Fear**	**Anger**	**Sadness**	**Other**
π	π	900	2	0.174	0.85	0	0	0.15	0.83	0	0	0	0	0	1.2	9.6	0	0	0
π	π	900	1	0.087	0.73	0	0	0.15	0.79	0	0.79	0	0	0	0.6	9.6	0	0.2	0
π	π	500	3	0.087	0.41	0.13	0	0	0.75	0	0	0	2	3.4	0	9	3.6	0	0
π	π	500	2	0.174	0.33	0.24	0.24	0	0.34	0.24	0	0.25	1.33	1.5	0	7.83	0.66	0	1.66
π	π	500	2	0.087	0.68	0	0	0	0.72	0.13	0	0	0	0	0	7.8	0.6	2.20	0
π	π	200	2	0.087	0.44	0.13	0.13	0	0.66	0	0	0	1	1	1.2	7.6	1.6	0	0
$-\frac{\pi}{2}$	0	0	2	0.087	0.35	0.35	0.13	0	0.22	0	0	0	0.4	1.2	0	7.4	3	0	0
0	π	900	3	0.087	0.53	0	0	0	0.30	0	0	0	0	0	0	7	2.20	0	0
π	π	500	3	0.349	0.20	0.13	0.13	0	0.16	0.34	0	0	1.8	1.6	0	6.8	0.4	2.4	0
π	π	200	2	0.174	0.53	0	0	0.13	0.71	0.13	0.13	0	0	0	1	6.6	0.8	1.2	0

Table 8 Top 10 attributions for Sadness. This tops table was generated by ordering from highest to lowest first by Sadness mean, then by Sadness alpha, and finally by Movement alpha.

Features					Alpha								Mean						
Direction (rad)	**Orientation (rad)**	**Linear V. (mm/sec)**	**Angular V. (rad/sec)**	**Angle (rad)**	**General**	**Happiness**	**Excitement**	**Tenderness**	**Fear**	**Anger**	**Sadness**	**Other**	**Happiness**	**Excitement**	**Tenderness**	**Fear**	**Anger**	**Sadness**	**Other**
π	0	200	1	0.349	0.64	0	0	0	0	0.13	0.73	0.13	0	0	0	0	1.2	7.4	1.6
0	π	0	1	0.349	0.39	0	0	0.13	0	0	0.22	0	0	0	1.8	0	0	7.2	3.2
0	0	200	1	0.349	0.18	0.13	0	0	0	0.13	0.11	0	1.6	2	5.4	2.6	1.6	6	0
$-\frac{\pi}{2}$	0	200	0	0	0.10	0.13	0.29	0	0	0	0	0	0.8	0.4	1.8	0	0	6	3.2
π	π	200	1	0.349	0	0	0	0.13	0.13	0.14	0	0	0	0	0.6	1.4	1.2	6	2.4
0	π	200	0	0	0.27	0.13	0	0	0	0	0.21	0	1.2	0	3.4	1.8	0	5.8	0
$-\frac{\pi}{2}$	0	0	1	0.087	0.14	0	0.13	0.13	0.13	0	0.21	0.13	0	2	2	1.2	0	5.8	1.6
0	π	200	1	0.349	0.40	0	0.13	0	0	0	0.57	0.13	0	0.8	3	3	0	5.6	0.6
π	π	200	0	0	0.32	0.69	0.69	0	0	0	0.16	0	0.2	0.2	1.2	3.2	0	5.4	0
0	π	200	1	0.087	0.36	0	0	0	0	0	0.16	0	0	0	3.6	3.6	0	5.4	0

Table 9 Contingency table formula used for each emotion and experience. Where k is the kth experience, j is jth emotion for the kth experience, n is the total number of participants, and $Value$ is the intensity given by a participant.

Participant	Desire Emotion	Other Emotions
1	$Value^1_{k,j}$	$\frac{\sum_{i=1}^{i<=7 \wedge i \neq j}(Value^1_{k,i})}{\sum_{i=1}^{i<=6 \wedge i \neq j}(1)}$
2	$Value^2_{k,j}$	$\frac{\sum_{i=1}^{i<=7 \wedge i \neq j}(Value^2_{k,i})}{\sum_{i=1}^{i<=6 \wedge i \neq j}(1)}$
...	...	...
n	$Value^n_{k,j}$	$\frac{\sum_{i=1}^{i<=7 \wedge i \neq j}(Value^2_{k,i})}{\sum_{i=1}^{i<=6 \wedge i \neq j}(1)}$

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