Cross Validation of Emotional Features with a non-Anthropomorphic Platform

Julian M. Angel-Fernandez[1] and Andrea Bonarini[2]

Abstract— **Robots should be able to express emotional states to interact with people as social agents. Emotions are a peculiar characterization of humans and usually conveyed through face expression, body language and voice. However there are cases where robots cannot have anthropomorphic shape, for example when they have to perform tasks, which require a specific structure. This is the case of home cleaners, package carriers, and many others platforms. Therefore, emotional states need to be represented by exploiting other features, such as movements and shape changes. This paper presents a case study, which studies emotion expression in non-anthropomorphic platform and how it is perceived by humans. This case study was design base on results obtained from a previous experiment, which was done to assess precise values for linear velocity, angular velocity, oscillation angle, direction and orientation that could be used to express happiness, angry, fear and sadness. Results of the case study show that people can recognize some emotional expressions better than others and that additional features should be added to differentiate some emotions. Additionally, it was done a small scene to verify if people prefer emotions with or without emotion.**

I. Introduction

Emotions and mental states are not just expressed through facial expression and voice but also by body postures and other features [1]. Many psychological studies have focused their attention on how emotions are conveyed through they face [2], [3]. Similarly, the robotics community uses anthropomorphic faces (e.g., [4], [5]) and bodies (e.g., [6], [7]) to convey emotions. In many situations 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 [5] or limbs [8]. For instance, floor cleaning robots are robots that do not have any anthropomorphic characteristics and still they accomplish their task. This generates the necessity to study other mechanisms that could help to convey emotions, which could give people an idea about the robots' state, and engage the user in long term relations.

However,the amount of works studying non-anthropomorphic features in robotics (e.g., [9]) remains still small in comparison to those exploiting anthropomorphic features. Moreover, these works do not give specific range of values for the characteristics used to expressed the emotions implemented. For example Suk and collaborators [10] in their study give specific values for acceleration and curvature, but their connection to specific emotions is not described. Rather, they established a relationship between their values and pleasure/arousal dimensions. This could help to select specific features to convey certain emotions, but it would be even better to know the precise range of values to be assigned to each characteristics to avoid misinterpretation with wrong emotions. These values could be used in social robotics to show emotions and as consequence increase their acceptance.

This paper is organized as follows. Section II introduce some previous works done in conveying emotion. Section III presents the platform used in the case study and the Emotional Enrichment System. Finally, sections IV and V presented case study's design and results.

II. Related Work

Some works in Human-Robot Interaction (HRI) uses videos to evaluate their implementations of emotions. One of the most well-known expressive robots is Kismet [5], a robotic face able to interact with people and show emotions. The face had enough degrees of freedom to portray the emotions suggested by Ekman [2] (*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 [8], 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 [7] studied the attribution of emotion to a robot's gait using a virtual representation of the platform WABIAN-2R. Knight and Simmons [11] used two platforms (i.e. Keepon and NAO) with different degrees of freedom to study the possibility to project inner states with just head movements. Although the use of videos has the advantage to cover a major number of participants, they loss the impact that is created from the interaction between the participant and the platform.

The use of real platforms to study emotion projection could be dissect in two tendencies: use of anthropomorphic and non-anthropomorphic platforms. In the first case, these works are characterized by the use of cue positions to project desire emotions [12]. In some cases, special attention has been taken to determine head's angle and arms position contribution in specific emotions [13]. 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 resemblance

[1]Julian M. Angel-Fernandez is a Research at Automation and Control Institute, Vienna University of Technology, Vienna, Austria julian.angel.fernandez@tuwien.ac.at

[2]Andrea Bonarini is a Professor at the Department of Electronics, Information, and Bioengineering, Politecnico di Milano, Milan, Italy, andrea.bonarini@polimi.it

(e.g. eliminating limps and facial expressions)to increase platform mobility and study new mechanisms to project emotions [4]. Reducing even more the anthropomorphism, Saerbeck and Christoph used a Roomba platform to study the contribution of curvature in a trajectory to conceive emotional states [9]. Similarly Lourens and Barakova [14] implemented a set of behaviors to determine the emotion perceived from diverse movements, which were selected from the work done by Camurri et al. [15]. Continuing with her research on how robotics' behaviours are interpreted by people, Barakova and collaborators [16] 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) [17], 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. Despite the type of platform used, these works offers an overview of features that could be used to express certain emotions but they not give precise values to implement the emotions.

Therefore, 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 [10]. 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 [18] 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 [19] used a quadrotor to study how different Laban's effort [20] 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 [21] 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 [22]. However, these works not give a price guideline to elicit precise emotions. This could lead to implementations that express a not desired emotion [23]. For example people could confuse an implementation of *Happiness* with *Anger*.

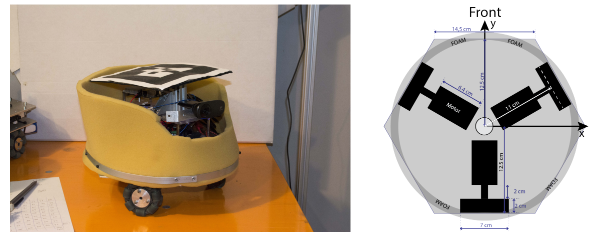

Fig. 1. Platform used in the case study (left), and holonomics's blue prints (right). The arrows represent robot's frame of reference.

III. System

A non-anthropomorphic robotic platform was created to no influence participants' perception. The robotic platform is holonomic and it was built using Odroid U3, Arduino Due, and 3 metal gear motors with 64 CPR encoders and omniwheels. The platform could be observed in Figure 1. The Arduino Due is in charge to be the interface between the hardware (e.g. motors) and Odroid, which host all the Emotion Enrichment System.

An Emotional Enrichment System was designed and implemented to automatize the process of emotion expression [24]. It modifies actions' parameters and adds additional actions to create the illusion of emotion expression in a robot. To achieve this, the system receives two messages. One message describes actions and the order in which they should be executed. These actions could be executed in parallel, sequentially or a combination of both. This kind of description enables the possibility to communicate several actions in one message. The other message informs the system with the desire emotion and its intensity. These two messages could arrive asynchronously and without any particular order. Every time a message is received, the system updates the robot movements to convey the desire emotion in the specific action.

IV. Case Study

The case study presented in this paper was done at Researcher's Night 2015 with two main objectives:

1) Cross-validate the findings obtained from a previous experiment [25]. This experiment was done to study the attribution of different linear and angular velocities, oscillation angel, direction and orientation of the platform to *Anger*, *Happiness*, *Sadness* and *Fear*. A total of 196 treatments were designed, but just 20 were presented to each participant. The questionnaire provided included the four emotions and two mental states (i.e. Excitement and tenderness).
2) Verify if participants would prefer scenes when the robot expresses emotions or rather moves without any emotion expression. To reduce scene variability was used two web-cams and eight Alvar tags to informed a Kalman filter to improve robots localization in the stage. AR tags were detected using the ROS package ar_track_alvar [26]. The distribution of the web-cams and the tags are depicted in Figure 2.

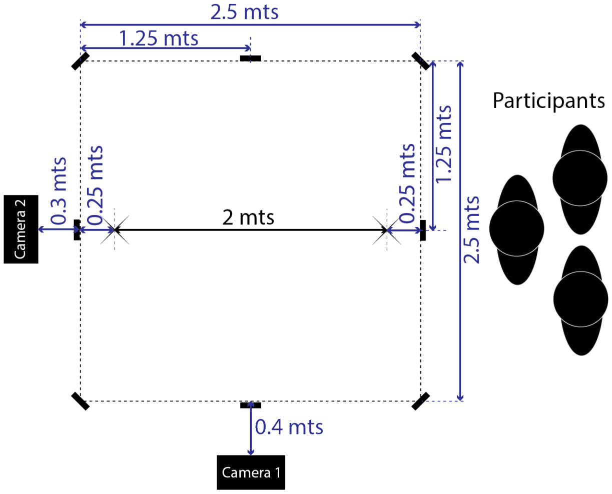

Fig. 2. Environment setup for the case study. The crosses represent the starting points.

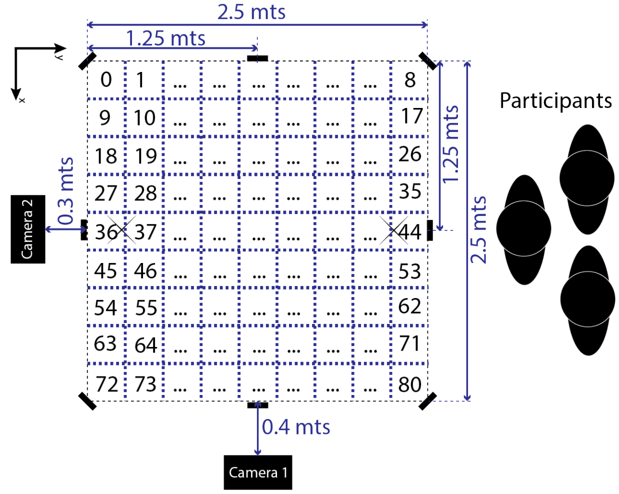

Fig. 3. Stage discretization used for the small scene. The blue squares correspond to the each zone, while the numbers correspond to the ID given to each zone.

TABLE I
PARAMETERS' VALUES SELECTED FROM THE EXPERIMENT.

Emotion	**Direction** (rad)	**Orientation** (rad)	**Linear Velocity** (mm/s)	**Angular Velocity** (rad/s)	**Angle** (rad)
Happiness-1	0	0	500	3	0.349
Happiness-2	0	0	900	3	0.174
Anger-1	π	0	500	3	0.087
Anger-2	0	0	900	1	0.087
Fear-1	π	π	900	2	0.174
Fear-2	π	π	500	2	0.087
Sadness-1	π	0	200	1	0.349
Sadness-2	0	π	200	1	0.349

A. *Emotion Description*

The parameters selected from the experiment to implement *Anger*, *Happiness*, *Sadness* and *Fear* are shown in Table I. As it could be observed, two treatments for each emotions were selected to be implemented. These treatments were selected considering: (i) the linear velocity should be greater than 0. In other words the robot should show some linear displacement. And (ii) it should be in the top 10 list of the emotion obtained in the experiment.

B. *Scene*

Stage discretization was used to give zones of movements instead of absolute positions. This idea was brought from human theatrical actors, who prepared their movements based on zones on the stage [27]. This allows them to adapt their position based on other actors and stage dimensions. Therefore, the stage was discretized in 9x9 matrix as is shown in Figure 3. Robot's movements are given in terms of the matrix positions to the Emotional Enrichment System. Robot's final position is calculated by the Emotional Enrichment System during execution. For instance, during the scene's preparation stage was 3 meters per 3 meters, but in the final presentation it was 2.5 meters per 2.5 meters.

Scene's description is the following: the robot starts in the middle of the stage to move to the upstage right (See [28]), close to the right wing. Then, the robot moves to upstage right center and rotates to $\pi/2$ left (See [29]). Next the robot moves to the right center. Then it goes to the center. When it arrives there, it turns full back and move backwards to downstage center with a full front orientation. There, it turns full back to move to center. Finally the robot turns to profile right and it does a step back; then it goes to the upstage center and then upstage right. The sequence of movements programmed to the robot are depicted in Figure 4.

The relation between emotion and movement is as follow: movements one to five do not express any emotion. Movements six to ten show fear. Movement eleven depicts happiness, and the remaining movements depict sadness. The actions describing this scene are executed by the Emotional Enrichment System and the emotion selection is done manually via a graphical interface.

C. *Study*

This case study was done during Researchers' Night, 2015. During a period of two days, people were asked to participate in this study, which was divided in to parts. The first one, each subject was exposed to two rounds of emotions. The two emotions and their other were generated randomly before hand. The second part, participants were explained that a small scene was going to be presented twice. Thus, they should to selected the one they like more. The order of the scenes (e.g. with or without emotion) were generated beforehand. The total number of volunteers was 256: 128 males, 126 females, and 2 that chose not to specify their gender. The average age was 27.29 years, with standard deviation of 16.58, minimum age was 4 and maximum 76.

V. RESULTS

This section reports the results obtained during two days for the two parts of the case study.

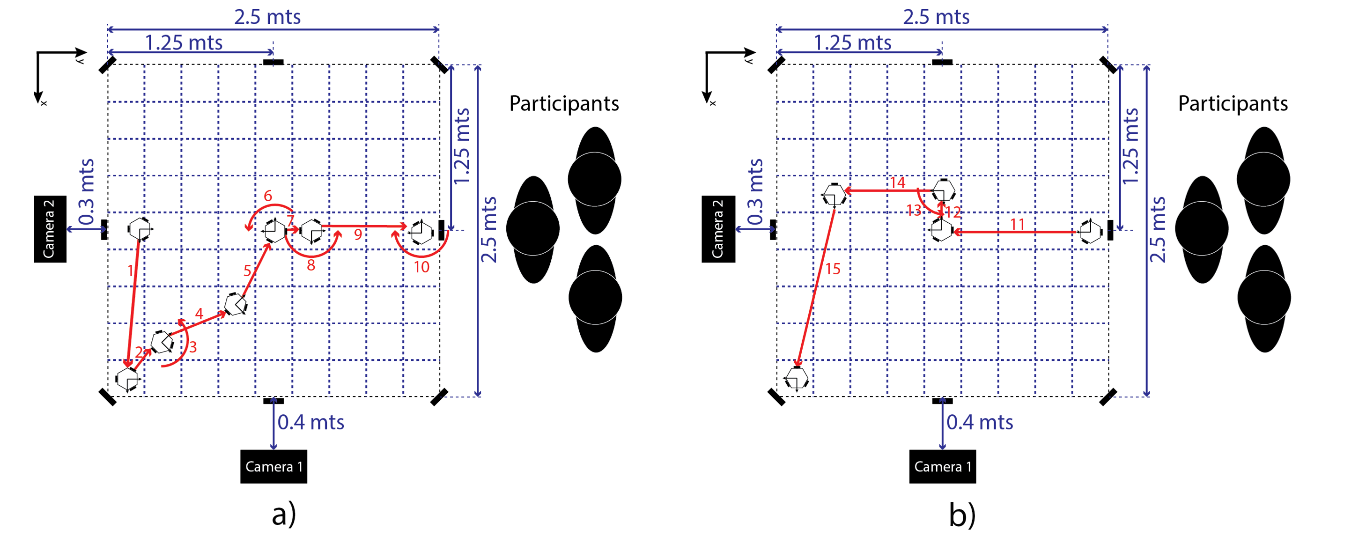

Fig. 4. Sequence of movements provided to the robot. The red arrows show the trajectory, while the numbers show the order among the movements. a) The first ten movements b) The last five movements

TABLE II
SUMMARY OF THE ANSWERS OBTAINED IN THE PRESENTATION OF EMOTIONAL MOVEMENTS.

Presented/Reported	**Happiness**	**Anger**	**Fear**	**Sadness**	**Excitement**	**Tenderness**	**Other**	**Total**
Happiness-1	8	16	7	4	16	4	7	62
Happiness-2	11	11	6	2	19	3	1	53
Anger-1	7	5	6	2	21	7	1	49
Anger-2	14	29	13	2	13	3	2	76
Fear-1	6	2	28	1	9	6	0	52
Fear-2	7	3	37	2	20	4	1	74
Sadness-1	3	5	17	14	5	16	5	65
Sadness-2	5	5	15	28	6	15	7	81

A. Part I: Emotion Recognition

The results obtained from the presentation of emotional movements are summarized in Table II.

It could be observed that both implementations of *Happiness* were confused with *Anger* and *Excitement*. In a similar way, Anger-1 was mostly confused with *Excitement*, which was voted twenty one over forty nine subjects. Anger-2 shows an improvement of perception from 10% to 38%, respect Anger-1. This implementation was perceived also as *Happiness*, *Fear* and *Excitement*. Both implementations of *Fear* had a high level of recognition 54 % and 50 % and mostly confused with *Excitement*, which was voted nine times for the first implementation and twenty times for the second implementation. Finally, the two implementation of *Sadness* were confused with *Fear* and *Tenderness*.

An analysis was done per groups, for each presented emotion. For each emotion it was considered how many subjects in each group recognized it, how many identified a different emotion, how many identified the considered emotion when presented another one, and how many subjects recognized an emotion different from the considered one when presented a different emotion. This lead to a table, which is known as contingency table, for each presented emotion, like the one reported in table III for Happiness-1.

TABLE III
EXAMPLE OF TABLE COMPILED FOR EACH EMOTION ON THE SUBJECTS WHICH HAVE BEEN PRESENTED EACH EMOTION (HERE HAPPINESS-1).

Presented/Reported	Happiness	Other
Happiness-1	8	54
Other	42	355

For each of the contingency table the classification accuracy and the no-information rate (NIR), i.e. the accuracy that had been obtained by random selection, are reported in Table IV. The results reveal that Sadness-2 is the only implementation that was correctly recognized among all implementations ($p < 0.05$).

Additionally, the positive predictive value, accuracy and a Pearson's χ^2 were computed for each table. The hypothesis used in the test were:

- H_0 = there is a difference in recognition between the implementation respect the others.
- H_1 = there is not a difference in recognition between one implementation respect the others.

The results are shown in table V. They show that there is significant evidence to conclude that Anger-2, both of *Fear* and *Sadness* are considered as a different implementation when they are compare with other implementations. While both implementations of *Happiness* and Anger-1 are considered as similar to the other implementations.

To determine if which implementations were perceived as

TABLE IV

CLASSIFICATION ACCURACY OF THE PRESENTED EMOTIONS BY THE SINGLE PANELS, COMPUTED AS MENTIONED IN THE TEXT, WITH CORRESPONDING 95% CONFIDENCE INTERVAL, NO-INFORMATION RATE, AND P-VALUE THAT ACCURACY IS GREATER THAN THE NIR.

Presented Emotion	**Classification Accuracy**	**95% CI**	**No-Information Rate**	**P-Value [Acc > NIR]**
Happiness-1	0.79	(0.75,0.82)	0.89	1.0
Happiness-2	0.81	(0.77,0.84)	0.88	1.0
Anger-1	0.8	(0.76,0.83)	0.88	1.0
Anger-2	0.89	(0.76,0.84)	0.83	0.95
Fear-1	0.79	(0.75,0.83)	0.88	1
Fear-2	0.78	(0.73,0.81)	0.83	0.99
Sadness-1	0.85	(0.81,0.88)	0.84	0.47
Sadness-2	0.85	(0.81,0.88)	0.81	0.035

TABLE V

ACCURACY, PRECISION AND RESULTS OF PEARSON'S χ^2 FOR EACH CONTINGENCY MATRIX WITH $\alpha = 0.05$ FOR THE CASE STUDY.

Presented Emotion	**Positive Predicted Value**	**Accuracy**	$\chi^2(1)$	**p-value**
Happiness-1	0.13	0.79	0.11	0.74
Happiness-2	0.21	0.81	3.7	0.054
Anger-1	0.1	0.8	$3.8e^{-29}$	1
Anger-2	0.38	0.81	34.4	< 0.001
Fear-1	0.54	0.8	36.2	< 0.001
Fear-2	0.5	0.78	35.8	< 0.001
Sadness-1	0.22	0.85	27.4	< 0.001
Sadness-2	0.35	0.85	72.9	< 0.001

different or similar, a Fisher's exact test was applied for ten different combinations of the implementations. Additionally, a Holm-Bonferroni correction was applied for multiple comparisons to get a better p-value estimation. The following are the hypothesis used in this test:

- $H_0 =$ there is a difference in the recognition of the two compared emotions.
- $H_1 =$ there is not a difference in the recognition of the two compared emotions.

The results are reported in Table VI. As it could be observed, both implementation of *Anger* were perceived as two different emotions ($p < 0.001$). Also shows that both implementation of *Happiness* were perceived as to Anger-2 ($p = 0.69$ in both cases).

Nevertheless, it is important no notice that the results were obtained using the lower part of the robot without any change in shape. Another important factor to highlight is the impact words listed in the questionnaire have on the perception rate. As it was expected, mental states Excitement and Tenderness were confused with emotions with similar arousal level. In this precise case the emotions Anger, Happiness and Fear were confused with Excitement, and Sadness was confused with Tenderness. Despite the bias generated by the two mental states listed in the questionnaire, the recognition rate of five out of eight implementations was over 35%, being the two implementation of *Fear* the implementations with the higher recognition rates (54% for the first and 50% for the second).

TABLE VI

PAIR COMPARISON AMONG ALL THE IMPLEMENTED EMOTIONS USING FISHER'S EXACT TEST FOR BOTH QUESTIONNAIRES WITH $\alpha = 0.05$ FOR THE CASE STUDY. THE * INDICATES THAT THE P-VALUE WAS ADJUSTED USING THE HOLM-BONFERRONI CORRECTION FOR MULTIPLE COMPARISONS.

Pair Compared	**p-value**	**p-value***
Happiness-1 vs Happiness-2	0.38	1.0
Anger-1 vs Anger-2	< 0.001	< 0.001
Anger-2 vs Happiness-1	0.137	0.69
Anger-2 vs Happiness-2	0.157	0.69
Fear-1 vs Fear-2	0.74	1.0
Sadness-1 vs Sadness-2	0.665	1.0
Fear-1 vs Sadness-1	< 0.001	< 0.001
Fear-1 vs Sadness-2	< 0.001	< 0.001
Fear-2 vs Sadness-1	< 0.001	< 0.001
Fear-2 vs Sadness-2	< 0.001	< 0.001

TABLE VII

ANSWERS OBTAINED FOR THE SMALL SCENE.

Gender	**With Emotion**	**Without Emotion**	**Total**
Male	84	43	127
Female	81	45	126
Total	165	88	253

B. Part II: Scene Preference

The results obtained form the small scene are presented in Table VII. From this data, two questions wanted to be answer:

1) Do people prefer scenes with or without emotions?
2) Has gender an impact in the preference?

To answer these questions the following hypothesis were created:

1) $H_0 =$ there is a preference towards scenes with emotions. H_1 there is a preference towards scenes without emotions.
2) $H_0 =$ there is an association between gender and the preference. $H_1 =$ there is not an association between gender and the preference.

A χ^2 test with one degree of freedom and $\alpha = 0.05$ was done to verify them. The results of the tests show that there is enough statistical evidence to accept that people prefer scenes with emotions ($p < 0.001$). On the other hand, the test shows that there is not association between gender and preference ($p = 0.85$).

VI. CONCLUSIONS AND FURTHER WORK

The case study presented in this paper was done to cross validate the findings in the experiment and verify whether the participants would prefer scenes when the robot expresses emotions or rather moves without any emotion expression. For each one of four emotions (i.e. Anger, Happiness, Sadness and Fear) studied in the experiment were selected a two set of parameters.The results show that both implementations of happiness were confused with anger and excitement, while one implementation of anger was just confused with excitement. Both implementations of sadness were confused with tenderness and fear. Both implementations of fear had a recognition rate over 50%. Scenes results show that people prefer scenes with emotional movements and there is not any difference in gender.

Additionally to the results already mentioned, there are words that could bias participants' perception. For instance happiness and anger were considered as excitement. This misinterpretation should not be a surprise given the fact that there is not a unique definition of emotion [30], [31], and each person would interpret a situation differently, so they will give a different label to the presented movement. Moreover a misinterpretation of Happiness and Anger could suggest that additional features (e.g. trajectory or shape) should be added to increase differentiation between these two emotions. For example, Venture and collaborators [32] had found out that in human bodies the recognition rate of anger and fear are increased when torso and head are downwards. On the other hand, they found that happiness perception is increased when the torso and head are move upwards. This example could bring some insight to possible body changes that could occur in non-human like bodies, but it should tested in this kind of platforms to confirm if the same impact is reached.

REFERENCES

[1] B. de Gelder, "Why bodies? twelve reasons for including bodily expressions in affective neuroscience," *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, vol. 364, no. 1535, pp. 3475–3484, 2009.

[2] P. Ekman, *Emotions Revealed : Recognizing Faces and Feelings to Improve Communication and Emotional Life*. Owl Books, Mar. 2004.

[3] A. Kleinsmith and N. Bianchi-Berthouze, "Affective body expression perception and recognition: A survey," *Affective Computing, IEEE Transactions on*, vol. 4, no. 1, pp. 15–33, 2013.

[4] S. Embgen, M. Luber, C. Becker-Asano, M. Ragni, V. Evers, and K. O. Arras, "Robot-specific social cues in emotional body language," in *Proceedings of the IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN'12)*. USA: IEEE Computer Society, September 2012, pp. 1019–1025.

[5] C. Breazeal, *Designing Sociable Robots*. Cambridge, MA, USA: MIT Press, 2002.

[6] A. Beck, A. Hiolle, A. Mazel, and L. Cañamero, "Interpretation of emotional body language displayed by robots," in *3rd ACM Workshop on Affective Interaction in Natural Environments*, 2010, pp. 37–42.

[7] M. Destephe, T. Maruyama, M. Zecca, K. Hashimoto, and A. Takanishi, "Improving the human-robot interaction through emotive movements: a special case: walking," in *HRI*, 2013, pp. 115–116.

[8] J. Li and M. H. Chignell, "Communication of emotion in social robots through simple head and arm movements," *I. J. Social Robotics*, vol. 3, no. 2, pp. 125–142, 2011.

[9] M. Saerbeck and C. Bartneck, "Perception of affect elicited by robot motion," in *Proceedings of the 5th ACM/IEEE International Conference on Human-robot Interaction*, ser. HRI '10. Piscataway, NJ, USA: IEEE Press, 2010, pp. 53–60. [Online]. Available: http://dl.acm.org/citation.cfm?id=1734454.1734473

[10] T.-J. NAM, J.-H. LEE, S. PARK, and H.-J. SUK, "Understanding the relation between emotion and physical movements," *International Journal of Affective Engineering*, vol. 13, no. 3, pp. 217–226, 2014.

[11] H. Knight and R. Simmons, "Laban head-motions convey robot state: A call for robot body language," in *Robotics and Automation (ICRA), 2016 IEEE International Conference on*. IEEE, 2016, pp. 2881–2888.

[12] A. Robotics, "Nao," http://www.aldebaran-robotics.com/en/.

[13] L. Brown and A. M. Howard, "Gestural behavioral implementation on a humanoid robotic platform for effective social interaction," in *Robot and Human Interactive Communication, 2014 RO-MAN: The 23rd IEEE International Symposium on Robot and Human Interactive Communication*, Aug 2014, pp. 471–476.

[14] E. I. Barakova and T. Lourens, "Expressing and interpreting emotional movements in social games with robots," *Personal and Ubiquitous Computing*, vol. 14, no. 5, pp. 457–467, 2010. [Online]. Available: http://dx.doi.org/10.1007/s00779-009-0263-2

[15] A. Camurri, I. Lagerlöf, and G. Volpe, "Recognizing emotion from dance movement: comparison of spectator recognition and automated techniques," vol. 59, no. 1-2, pp. 213–225, 2003. [Online]. Available: http://linkinghub.elsevier.com/retrieve/pii/S1071581903000508

[16] L. Hiah, L. Beursgens, R. Haex, L. P. Romero, Y. Teh, M. ten Bhömer, R. van Berkel, and E. I. Barakova, "Abstract robots with an attitude: Applying interpersonal relation models to human-robot interaction," in *IEEE International Symposium on Robot and Human Interactive Communication, IEEE RO-MAN 2013, Gyeongju, Korea (South), August 26-29, 2013*, 2013, pp. 37–44.

[17] T. Leary, *Interpersonal Diagnosis of Personality: Functional Theory and Methodology for Personality Evaluation*. Ronald Press Company: New York., 1957.

[18] H. Tan, J. Tiab, S. Šabanović, and K. Hornbæk, "Happy moves, sad grooves: Using theories of biological motion and affect to design shape-changing interfaces," in *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, ser. DIS '16. New York, NY, USA: ACM, 2016, pp. 1282–1293. [Online]. Available: http://doi.acm.org/10.1145/2901790.2901845

[19] M. Sharma, D. Hildebrandt, G. Newman, J. E. Young, and R. Eskicioglu, "Communicating affect via flight path: Exploring use of the laban effort system for designing affective locomotion paths," in *Proceedings of the 8th ACM/IEEE International Conference on Human-robot Interaction*, ser. HRI '13. Piscataway, NJ, USA: IEEE Press, 2013, pp. 293–300.

[20] R. Laban and L. Ullmann, *Modern educational dance*, 2nd ed. Praeger New York, 1968.

[21] J. R. Cauchard, K. Y. Zhai, M. Spadafora, and J. A. Landay, "Emotion encoding in human-drone interaction," in *The Eleventh ACM/IEEE International Conference on Human Robot Interaction*, ser. HRI '16. Piscataway, NJ, USA: IEEE Press, 2016, pp. 263–270. [Online]. Available: http://dl.acm.org/citation.cfm?id=2906831.2906878

[22] J. Novikova and L. Watts, "Towards artificial emotions to assist social coordination in hri," *International Journal of Social Robotics*, vol. 7, no. 1, pp. 77–88, 2015. [Online]. Available: http://dx.doi.org/10.1007/s12369-014-0254-y

[23] J. M. Angel-Fernandez and A. Bonarini, "Showing emotions: Emotion representation with no bio-inspired body," 2016, manuscript accepted.

[24] ——, "Towards enriching robot's actions with affective movements," in *The Twelfth ACM/IEEE International Conference on Human Robot Interaction*, ser. HRI '17, 2017.

[25] ——, "Identifying values to express emotions with a non-anthropomorphic platform," 2017, manuscript submitted.

[26] S. Niekum, "ar_track_alvar," http://wiki.ros.org/ar_track_alvar.

[27] E. Wilson and A. Goldfarb, *Theatre: The Lively Art*. McGraw-Hill Education, 2009.

[28] M. T. Kids, "Stage directions for actors."

[29] A. Drama, "Learning about the stage."

[30] R. Plutchik, "The Nature of Emotions," *American Scientist*, vol. 89, no. 4, pp. 344+, 2001. [Online]. Available: http://dx.doi.org/10.1511/2001.4.344

[31] J. Cacioppo, L. Tassinary, and G. Berntson, *Handbook of Psychophysiology*. University Press, 2000.

[32] G. Venture, H. Kadone, T. Zhang, J. Grzes, A. Berthoz, and H. Hicheur, "Recognizing emotions conveyed by human gait," *International Journal of Social Robotics*, vol. 6, no. 4, pp. 621–632, 2014. [Online]. Available: http://dx.doi.org/10.1007/s12369-014-0243-1