Using Perlin Noise to Generate Emotional Expressions in a Robot

Aryel Beck (aryelbeck@gmail.com)
Antoine Hiolle (a.hiolle@herts.ac.uk)
Lola Cañamero (l.canamero@herts.ac.uk)
Embodied Emotion, Cognition and (Inter-)Action Lab, School of Computer Science & STRI
University of Hertfordshire, College Lane, Hatfield, Herts AL10 9AB, UK

Abstract

The development of social robots that convey emotion with their bodies—instead of or in conjunction with their faces—is an increasingly active research topic in the field of human-robot interaction (HRI). Rather than focusing either on postural or on dynamics aspects of bodily expression in isolation, we present a model and an empirical study where we combine both elements and produce expressive behaviors by adding dynamic elements (in the form of Perlin noise) to a subset of static postures prototypical of basic emotions, with the aim of creating expressions easily understandable by children and at the same time lively and flexible enough to be believable and engaging. Results show that the noise increases the recognition rate of the emotions portrayed by the robot.

Keywords: Bodily emotional expression; human-robot interaction; affective robotics; Perlin noise.

Introduction

Echoing the importance of emotional expression in social interaction and communication among humans, the development of expressive robots that can interact with us in a human-oriented way is nowadays a very active research topic in the field of human-robot interaction (HRI). Interest in using robot's bodies for emotional expression is rapidly increasing. This is partly due to two main factors. On the one hand, an increasing corpus of research in psychology and neuroscience (e.g., (Wallbott, 1998; De Gelder, 2006; Avizer, Trope, & Todorov, 2012)) is emphasizing the role of the body in conveying emotion-specific information rather than merely non-specific information related to intensity as it was previously thought. On the other hand, the fact that a number of robotic platforms currently available have complex bodies with a high number of degrees of freedom and/or good motion capabilities, but do not necessarily have articulated faces—that is the case in Nao[1], the robot that we have used in this study.

While researchers typically focus either on the use of expressive postural elements or on expressive aspects of movement (Coulson, 2008)—see (Kleinsmith & Bianchi-Berthouze, 2012) for a survey—the combination of both aspects has not received as much attention in robotics. In the study resented here, we combine both elements and produce expressive behaviors by adding dynamic elements to a subset of static postures prototypical of basic emotions. Our underlying motivation from the point of view of HRI[2], as part of the European project ALIZ-E (www.aliz-e.org), was to create a set of expressions easily understandable by children and at the same time lively and flexible enough to be believable and engaging.

[1] `www.aldebaran-robotics.com`.

[2] See (Cañamero, 2002, 2008) for discussions of design issues regarding expressive robots for HRI.

Affect Space

This study is part of our research investigating the elaboration of an Affect Space for the generation of emotional body language to be displayed by robots. It builds on an Affect Space that was generated using key poses (Beck, Cañamero, & Bard, 2010; Beck, Hiolle, Mazel, & Cañamero, 2010). In the context of this paper, a key pose is a posture modeled after an actor performance so that it clearly describes the emotion displayed.

Static features

In animation, one of the standard methods for creating convincing and believable displays relies on expressive key poses rather than body language in motion (Thomas & Johnston, 1995; Vala, Paiva, & Rui Gomes, 2008). Taking inspiration from this method, in previous work (Beck, Cañamero, & Bard, 2010; Beck, Hiolle, et al., 2010) we used static key poses as a basis to produce expressive animated behaviors in a humanoid robot. This method presents the advantage of permitting to investigate and model independently postural and motion-related expressive elements. This approach is also consistent with research on affective body expression suggesting that form and movement information are processed by separate pathways in the brain (Kleinsmith & Bianchi-Berthouze, 2012). The key poses that we used are consistent with the static features[3] in (Kleinsmith, Bianchi-Berthouze, & Steed, 2011).

Our initial experiments (Beck, Cañamero, & Bard, 2010) showed that it is possible to successfully convey emotions using static key poses displayed by a Nao humanoid robot. Based on these results, we started to develop a continuous Affect Space for our robot by "blending" key poses to generate new expressions (Beck, Hiolle, et al., 2010). The resulting system maps static key poses into a continuous dimensional model of emotion. Empirical results regarding the interpretation of the static key poses generated by this Affect Space can be found in (Beck, Hiolle, et al., 2010). While some of the expressions were clearly recognized, our results also show that some of the generated key poses are ambiguous and do not convey a clear emotion. In addition, feedback from people interacting with the robot indicated that they found it too static, which might have a negative impact on the perception on the

[3] In particular, the collar joint angle was also found to be salient to the expression of emotion through body posture.

robot and hence on the interaction. This led us to hypothesize that the addition of dynamic aspects to the key poses could greatly improve the understanding and believability of the expressions.

Animating Emotional Key Poses Using Perlin Noise

To endow the key poses with a dynamic dimension, we added Perlin noise[4] (Perlin, 1990) to them. In animation, Perlin noise—a coherent noise that is highly controllable—is a well-known tool used to procedurally generate movements and increase the lifelikeness of animations. It presents the advantages of being simple and computationally cheap, which are important factors for implementation on a robotic platform. Moreover, the parameters used to generate it can be modulated, resulting in different types of animations. Perlin noise can be used to modify movement but also to create different types of non-repetitive and "idle" behaviors, as well as to generate textures. In robotics, Perlin noise and similar methods have also been used, applied to joint angles, to increase the lifelikeness of robot movements and to generate idle behaviors (Snibbe, Scheeff, & Rahardja, 1999; Ishiguro, 2005).

Going beyond standard practice, in the work reported in this paper we have used Perlin noise to generate all the movements of the robot, rather to simply modify existing trajectories. The addition of Perlin noise values to the current joint angles produces a Perlin noise-based animation for the current pose of the robot. Although this step has not been validated with formal perceptual studies, the movements generated have been successfully used as idle behavior in empirical interaction studies with children carried as part of the ALIZ-E project (Nalin et al., 2012).

Using Perlin Noise to Express Emotions

Following a "deep" approach to emotion modeling (Cañamero, 2008), affective expression in our robot is driven by the dynamics of the internal "affective state" of the robot in its interaction with the world. Consequently, movements produced by Perlin noise can be modulated by the internal state of the robot and used as a tool to express emotions. This novel use of Perlin noise can potentially be a powerful tool to create more subtle expressions in robots, since it permits to procedurally create non-repetitive body movements that convey different emotions or nuances of the same emotion. Another advantage of our approach is that such expression would not be limited to a single platform and could be reused across different robots—both humanoid and non-humanoid.

One of the main challenges posed by the use of Perlin noise to express emotions is to find a mapping between the parameters used to generate the noise and the emotion to be conveyed. In our model, we used the following mappings:

- *Velocity* was mapped to the time taken by the robot to move, i.e., the shorter the time the higher the velocity. This mapping was chosen, rather than directly using the speed of the motors, due to constraints imposed by our robot. However, it should be noted that the actual velocity of the movement also depends on the amplitude of the noise, since the time is kept constant but the amplitude varies. Based on the existing literature, we expected that this parameter would have a significant effect on the perception of the emotion as it is related to *Quantity of Motion* (Camurri, Mazzarino, & Volpe, 2003), *Speed* (Roether, Omlor, Christensen, & Giese, 2009; Bernhardt, 2010) and *Activation* (Wallbott, 1998; Hartmann, Mancini, Buisine, & Pelachaud, 2005).
- *Jerkiness* was introduced by applying random variations to the duration parameter, slightly modifying the interval of update of the joint angle. The literature suggests that jerkiness has a strong effect on the expression of emotion (Hartmann et al., 2005; Lee, Park, & Nam, 2007; Bernhardt, 2010).

[4] See `http://freespace.virgin.net/hugo.elias/models/m_perlin.htm` for a description of the method used.

The Experiment

To assess the potential of using Perlin noise to express emotions in robots, we designed a study to investigate the relation between characteristics of the movements generated using Perlin noise and the perceived emotion.

Independent Variables: Three independent variables were manipulated: *Emotional Key Pose*, *Velocity* and *Jerkiness*.

- *Key Pose* had five different values that corresponded to the different emotions tested.
- *Velocity* had three levels and described how fast the robot moved.
- *Jerkiness* had two levels. In the Jerky condition, the velocity of each movement (generated using Perlin noise) was multiplied by a random value between 0.5 and 1.5 ensuring that the mean of the velocity remained the same but introducing variation of speed during the animation. In the Regular (non-Jerky) condition, the speed (given by the Velocity condition) remained constant throughout the whole animation.

This resulted in $35(5\,KeyPoses * 3\,Velocity * 2\,Jerk + 5\,static)$ animations tested.

Dependent Variables: Perception of emotion was defined in terms of *Emotional Label*, *Valence* and *Arousal*.

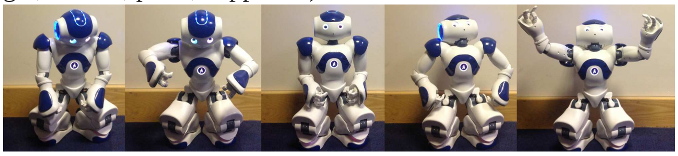
Participants

20 Participants were recruited, mostly members of staff of the University of Hertfordshire (9 females and 11 males) ranging in age from 18 to 55 (M=29.31, SD=11.93).

Apparatus

Five key poses were selected from previous studies (Figure 1): two positive, two negative and one neutral that had been

Figure 1: The five key poses (from left to right: sadness, anger, neutral, pride, happiness)



recognized well above chance level in previous studies (Beck, Cañamero, & Bard, 2010; Beck, Hiolle, et al., 2010). To ensure stability, the robot was sitting and only the joint angles of the upper body were modified while changing key pose. The animations were generated by adding Perlin noise to the joints of the upper body (as described above).

Procedure

The same experimenter tested all participants individually. Once each participant had given consent at the beginning of their session, they were given standardised explanation regarding the questionnaire that they were expected to answer and were instructed to imagine that the robot was reacting to something. In this context, *Valence* was defined as the extent to which this "something" was positive or negative, and *Arousal* was defined as the level of energy (low to high energy).

After confirming that they understood all the questions, participants watched and assessed the 35 animations. Each animation was displayed only once in a randomized order different for each participant. A distance was introduced to avoid having the same pose coming twice in a row. Each time, the robot took a pose and displayed an animation during 15 seconds and returned to a non-expressive key pose (a second neutral pose) until the participant answered. For each animation, participants were asked to describe the animation using their own terms and eventually choose an emotion label from a list of six emotions. The list was comprised of Anger, Sadness, Fear, Neutral, Pride, Happiness and Excitement. Participants completed ratings of *Valence* and *Arousal* on a 10-point Lickert scale. After all the poses had been assessed, participants were fully debriefed. Each session lasted approximately 30 minutes.

Results

Since this experiment uses a modified set of key poses (unlike in the test of the static key poses, here the robot is sitting), it was necessary to validate the material created for this study.

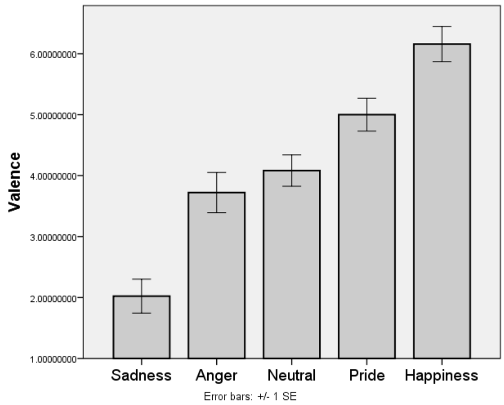
Validation of the Sitting Key Poses

Recognition rates showed that it was possible for participants to correctly identify the different static key poses far above chance level (Chance level would be 17%). Thus, it was possible for participants to identify the static key poses displayed (Table 1).

Table 1: Recognition rate of the Key Poses with and without added movements

Emotion	Recognition Rate Static	Recog. Rate with Movement	Best Condition
Sadness	84%	100%	Slow Regular
Anger	42%	68%	Fast Regular
Pride	63%	74%	Medium Regular
Happiness	79%	95%	Fast Jerky
Neutral	84%	74%	Medium Regular

Figure 2: Effect of Changing the *Key Pose* on *Valence*



As part of the validation of the material, a two-ways (static vs. highest recognition rate) Repeated Measures ANOVA was conducted on the total *Number of Correct Interpretations* comparing the static display and the highest recognition rate with movement for each emotion. This was done to check that it was possible to increase the recognition rate by adding movements generated with Perlin noise in at least one condition for the different key poses. The results show that this was the case ($F(1,18) = 9.08, p < 0.01, \eta^2 = 0.33$). Table IV also highlights the recognition rates as well as the conditions in which the highest recognition rates were obtained.

In the following sections, the data was analysed using 5(*Key Pose*)*3(*Velocity*)*2(*Jerkiness*) Repeated Measures Anovas on the dependent variables. It should be noted that since they do not have a *Jerkiness* condition, the static poses were not included in these tests.

Effect of Changing the Key Pose Displayed

Effect on the *Number of Correct Interpretations* As expected, *Key Pose* had a significant effect on the *Number of Correct Interpretations* ($F(4,72) = 6.89, p < 0.01, partial\, \eta^2 = 0.99$). This indicates that overall, when displayed with movements, the key poses were not all equally well recognized. Post-Hoc tests (Least Significant Difference) showed that the poses for Sadness and Pride were recognized better than the others ($p < 0.01$).

Effect on *Valence* *Key Pose* had a significant effect on *Valence* ($F(4,72) = 33.26, p < 0.01, partial\, \eta^2 = 0.65$). Post-hoc tests (Least significant Difference) showed that the pose for Sadness was perceived as more negative than the rest of the poses ($p < 0.01$ for all of them). The key pose for Anger was perceived as more negative than Happiness

Figure 3: Effect of Changing the Key Pose on Arousal

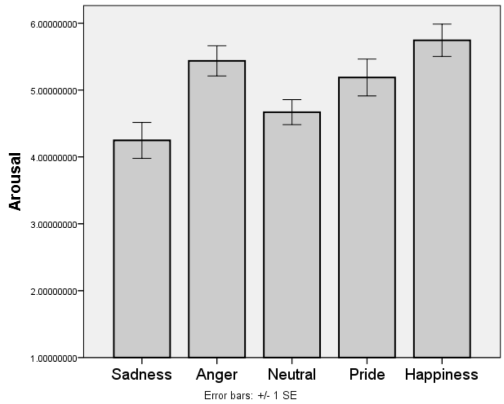


Table 2: Effect of Velocity and Jerkiness on Interpretation per Key Pose

Key Pose	Effect of Velocity	Effect of Jerkiness
Sadness	$F(2,34) = 5.34, p < 0.05, \eta^2 = 0.24$ $Slow > Medium(p < 0.05)$ $Slow > Fast(p < 0.01)$ $Medium = Fast(p = 0.31)$	$F(1,17) = 11.73, p < 0.01, \eta^2 = 0.41$ $Regular > Jerki(p < 0.01)$
Anger	$F(2,34) = 6.21, p < 0.01, \eta^2 = 12.43$ $Fast > Medium(p < 0.05)$ $Fast > Slow(p < 0.01)$ $Medium = Slow(p = 0.45)$	$F(1,18) = 0.79, p = 0.39, \eta^2 = 0.04$
Neutral	$F(2,36) = 48.69, p < 0.01, \eta^2 = 0.73)$ $Slow > Fast(p < 0.01)$ $Medium > Fast(p < 0.01)$ $Slow = Medium(p = 0.1)$	$F(1,18) = 0.00, p = 1, \eta^2 = 0.00$
Pride	$F(2,36) = 17.95, p < 0.01\eta^2 = 0.50$ $Slow > Fast(p < 0.01)$ $Medium > Fast(p < 0.01)$ $Slow = Fast(p = 0.19)$	$F(1,18) = 1.09, p = 0.31, \eta^2 = 0.06$
Happiness	$F(2,36) = 5.36, p < 0.01, \eta^2 = 0.23)$ $Fast > Slow(p < 0.01)$ $Fast = Medium(p = 0.09)$ $Medium = Slow(p = 0.17)$	$F(1,18) = 1.20, p = 0.29, \eta^2 = 0.06$

$(p < 0.01)$ and Pride $(p < 0.01)$. There was however no significant difference between Anger and Neutral $(p = 0.29)$. Pride was perceived as significantly more positive than the rest of the key pose ($p < 0.05$ for all of them). Happiness was perceived as significantly more positive than Sadness $(p < 0.01)$, Anger $(p < 0.01)$ and Neutral $(p < 0.05)$ (Figure 2)

These results indicate that participants' perception of *Valence* was affected by the *Key Pose* being displayed. Overall, negative key poses were interpreted as such and positive key poses were interpreted as positive (Figure 2).

Effect on *Arousal* Key Pose had a significant effect on *Arousal* $(F(4,72) = 13.29, p < 0.01, partial\,\eta^2 = 0.42)$. Post-Hoc tests(Least Significant Difference) showed that Sadness was perceived as less aroused than Anger $(p < 0.01)$, Pride $(p < 0.01)$, and Happiness $(p < 0.05)$. There was no significant difference between Sadness and Neutral $(p = 0.21)$. Anger was perceived as more aroused than Neutral $(p < 0.01)$. However, there was no significant difference with Happiness $(p = 0.26)$ and Pride $(p = 0.37)$. Pride was perceived as less aroused than neutral $(p < 0.01)$. There was a trend toward Pride being perceived as less aroused than Happiness $(p = 0.06)$.

These results indicate that perception of *Arousal* was affected by the key pose being displayed (Figure 3).

Effect of Velocity

Effect on Interpretation Velocity had a significant effect on the number of correct interpretation $(F(2,36) = 11.02, p < 0.01, Partial\,\eta^2 = 0.98)$. This effect was further investigated while looking at the interactions between the dependent variables.

Effect on Valence Although it did not reach significance, there was a trend of *Velocity* affecting *Valence* $(F(2,36) = 3.14, p = 0.06, partial\,\eta^2 = 0.15)$. Post-Hoc tests (Least Significant Difference) showed that there was a trend of Slow movement perceived as less positive than Fast $(p = 0.07)$. There was no difference between the Slow and Medium conditions $(p = 0.34)$. The Medium condition was perceived as significantly less positive than the Fast condition $(p < 0.05)$.

These results indicate that the fast movement condition was perceived as more positive than the other two.

Effect on Arousal *Velocity* had a significant effect on *Arousal* $(F(2,36) = 93.60, p < 0.01, partial\,\eta^2 = 0.84)$. Post-Hoc tests (Least Significant Difference) showed that the Slow condition was perceived as less aroused than the Medium condition $(p < 0.01)$ which in turn was perceived as less aroused than the Fast condition $(p < 0.01)$.

These results indicate that overall the faster the movement is, the more aroused the expression is perceived.

Effect of Jerkiness

Effect on Interpretation There was a trend of Jerky being more correctly interpreted than the same display in the Regular condition $(F(1,18) = 4.21, p = 0.55, partial\,\eta^2 = 0.49)$. This was further explored while considering the interactions between the dependent variables.

Effect on Valence Jerkiness had no significant effect on *Valence* $(F(1,18) = 0.26, p = 0.62, partial\,\eta^2 = 0.01)$. These results indicate that overall, participants' perception of *Valence* was not affected by the *Jerkiness* of the movements.

Effect on Arousal Jerkiness had a significant effect on *Arousal* $(F(1,18) = 27.51, p < 0.01, partial\,\eta^2 = 0.60)$.

Post-Hoc tests showed that the "Jerky" condition was perceived as more aroused than the Regular one $(p < 0.01)$.

Interaction between the independent variables

Interpretation There was an interaction between *Key Pose* and *Velocity* of movements over the Number of Correct Interpretation $(F(8,144) = 13.15, p < 0.01, partial\,\eta^2 = 1)$. Similarly, there was an interaction between Key Pose and Jerkiness $(F(4,72) = 2.54, p < 0.05, partial\,\eta^2 = 0.69)$. This indicates that the interpretation of emotion depended both on the *Key Pose* being displayed, on the *Velocity* of movement and on the *Jerkiness*. This was further investigated using repeated measures ANOVAs on the different *Key Pose* and *Ve-*

Table 3: Effect of Velocity on Valence per Key Pose Displayed

Key Pose	Repeated Anovas
Sadness	$F(2,36) = 0.43, p = 0.65, partial\, \eta^2 = 0.02$
Anger	$F(2,36) = 1.46, p = 0.25, partial\, \eta^2 = 0.08$
Neutral	$F(2,36) = 0.86, p = 0.43, partial\, \eta^2 = 0.05$
Pride	$F(2,36) = 1.57, p = 0.22, partial\, \eta^2 = 0.08$
Happiness	$F(2,36) = 10.24, p < 0.01, partial\, \eta^2 = 0.36$ $Fast > Slow(p < 0.01)$ $Fast > Medium(p < 0.01)$ $Medium = Slow(p = 0.33)$

locity conditions (Table 2). Table 2 shows that the highest recognition rate for Sadness was with Slow and Regular movements, for Anger, it was with Fast movements (no effect of jerkiness), neutral was better interpreted with Slow and Medium speed. Pride was better interpreted at Slow and medium speed. For Happiness, it was with Fast and Medium speed.

Valence There was a significant interaction between *Velocity* and *Key Pose* on *Valence* $(F(8,144) = 5.85, p < 0.05, partial\, \eta^2 = 0.11)$. This indicates that the effect of *Velocity* depends on the *Key Pose*. This was therefore investigated in details using 3(Velocity) Repeated Measure Anovas on the different Key Pose individually (Table 3).

Arousal There was a significant interaction between *Key Pose* and *Velocity* on *Arousal* $(F(8,144) = 5.81, p < 0.01, partial\, \eta^2 = 0.24)$. Repeated Measures Anovas were therefore conducted on the different *Key Pose* conditions separately. The results of these showed that the pattern were constant for all of them and that the Fast condition was perceived as more aroused than the Medium condition ($p < 0.01$ for all the *Key Poses*) which in turn was perceived as more *Aroused* than the Slow condition ($p < 0.01$ for all the Key Pose).

Discussion

Valence and Arousal As expected, *Key Pose* had a strong effect on *Valence* and *Arousal*. More precisely, the perceived *Valence* and *Arousal* were consistent with the respective positions of each *Key Pose* within the Affect Space (Figures 2 and 3). Moreover, *Velocity* had a marginal effect on *Valence*. However, the interactions between *Velocity* and *Key Pose* suggest that the difference in *Valence* was due to the key pose for happiness (Table 3) as it was found that for all the other key poses, *Velocity* had no effect on *Valence*. Similarly, *Jerkiness* did not affect the perceived *Valence* of the display. This is consistent with existing results in psychology which suggest that *Arousal* is a formless cue that relates directly to the movement kinematics while *Valence* seems to be related to the relations between the different limb segments (Pollick, Paterson, Bruderlin, & Sanford, 2001).

However, both *Velocity* and *Jerkiness* were found to increase the perception of *Arousal*. Taken together, the results suggest that the perceived *Valence* depended on the *Key Pose* displayed without taking into account the different dynamic conditions. In contrast, the perceived *Arousal* depended on all three dependent variables. Hence, participants relied only on the body posture to assess *Valence*. However, all the information available (*Key Pose*, *Velocity* and *Jerkiness*) was used to rate *Arousal*.

Interpretation Participants were able to correctly identify the different static key poses. Whilst the recognition rate for Anger was lower than for the other key poses, it was still above chance level. This low recognition rate could be due to the modification done to the material as the robot was sitting down. The key pose was better recognised in previous experiment with the robot standing up (Beck, Stevens, Bard, & Cañamero, 2012) and the lack of significant difference between the key poses for anger and neutral on *Valence* that was found in this study could be due to the key pose for anger being misinterpreted in most of the conditions. This will have to be investigated in future work.

Moreover, when compared with static poses, the recognition rates for the display with movements clearly show that adding appropriate dynamic elements improves significantly the expressivity of the key pose (Table 1). Although it was not possible to capture this statistically, *Velocity* seems to have a consistent effect on interpretation. For instance, the key pose for sadness was interpreted as sad in slow motion (resulting in the very high recognition rate in this condition); however, as the *Velocity* increased, it shifted toward anger and frustration. This is consistent with the results found with regards to the effect of *Velocity* on *Valence* (Table 3) which show that, with the exception of happiness, *Velocity* had not effect on *Valence*. Thus, these shifts in interpretation can be explained by the effect of *Velocity* on *Arousal*. In other words, a negative expression, remains negative, but its level of *Arousal* increases along with *Velocity* shifting from sadness to anger and frustration. The interpretations of the key poses were affected by the *Velocity* and the *Jerkiness* of the movements. More precisely, the dependence between *Key Pose* and *Velocity* with regards to the interpretation shows the importance of matching the *Velocity* and the *Jerkiness* of movements to the *Key Pose* in order to express specific areas of the Affect Space. The drop in recognition for Sadness in the Jerky condition suggests the importance of regular movement for this expression.

Even though pride was correctly labeled, the rating of *Arousal* was higher than what could have been expected. This was also the case in (Beck, Cañamero, & Bard, 2010) and could be due to this specific posture. It could also be related to the physical aspect of the Nao robot, as the arm joints are very salient in this key pose.

Limitations and Future Work It is important to highlight that the key poses used for this study are prototypical and were intentionally selected to be expressive. This is appropriate and beneficial for the development of an expressive system. However, it is likely that the use of prototypical expressions had an effect on the results found in this study. Moreover, the *Jerkiness* condition could have been implemented by manipulating the number of Harmonics and the Frequency of the noise. This could result in different visual results with different effects on the perception of emotion. It should also be noted that Perlin noise does not capture the relationship that exists between the rotation of one joint and another. This may result in unrealistic animations (Egges & Magnenat-Thalmann, 2005). Although this did not seem to be the case in this study as the material was carefully checked, it could still have affected the results.

This study did not consider the effect of context on the perception of the body language displayed. However, it can be argued that interpretation of emotion is context dependent and that changing the context could change the perception of the expressions generated by this Affect Space. On the other hand, work on facial expressions of emotion has shown that at least for a few basic emotions, context is not necessary to identify the expressed emotion. In other words, the expression of an emotion is to a certain extent independent from the context, as evidenced by the widespread use of FACS. Similarly, the high recognition rates obtained in this study suggest that these expressions could convey the intended emotion in different contexts. However, people's reaction to the emotional expression are likely to differ. This will be investigated as part of the ALIZ-E project.

Acknowledgments

This work was funded by the ALIZ-E FP7 European Project (Grant 248116). The opinions expressed are solely the authors' and not necessarily those of the consortium.

References

Avizer, H., Trope, Y., & Todorov, A. (2012). Body cues, not facial expressions, discriminate between intense positive and negative emotions. *Science*, *338*, 1225-1229.

Beck, A., Cañamero, L., & Bard, K. (2010, sept.). Towards an affect space for robots to display emotional body language. In *Ro-man, 2010 ieee* (p. 464 -469).

Beck, A., Hiolle, A., Mazel, A., & Cañamero, L. (2010). Interpretation of emotional body language displayed by robots. In *Proc. of the 3rd int. workshop on affective interaction in natural environments* (pp. 37–42). Firenze, Italy.

Beck, A., Stevens, B., Bard, K. A., & Cañamero, L. (2012, March). Emotional body language displayed by artificial agents. *ACM Trans.. Interact. Intell. Syst.*, *2*(1), 2:1–2:29.

Bernhardt, D. (2010). *Emotion inference from human body*. Unpublished doctoral dissertation, University of Cambridge, Computer Laboratory.

Camurri, A., Mazzarino, B., & Volpe, G. (2003). Analysis of expressive gesture: The eyesweb expressive gesture processing library. *Gesture-Based Communication in Human-Computer Interaction*, 460-467. (LNAI)

Cañamero, L. (2002). Playing the emotion game with feelix. In K. Dautenhahn, A. Bond, L. Cañamero, & B. Edmonds (Eds.), *Socially intelligent agents* (Vol. 3, p. 69-76). Springer US.

Cañamero, L. (2008). Animating affective robots for social interaction. In L. Cañamero & R. Aylett (Eds.), *Animating expressive characters for social interaction* (p. 103-121).

Coulson, M. (2008). Expressing emotion through body movement: A component process approach. In L. Cañamero & R. Aylett (Eds.), *Animating expressive characters for social interaction* (p. 7186). John Benjamins Publishing Company.

De Gelder, B. (2006). Toward the neurobiology of emotional body language. *Nature Reviews, Neuroscience*, *7*, 242-249.

Egges, A., & Magnenat-Thalmann, N. (2005). Emotional communicative body animation for multiple characters. In *Proc. of the first int. workshop on crowd simulation* (pp. 31–40). Lausanne, Switzerland.

Hartmann, B., Mancini, M., Buisine, S., & Pelachaud, C. (2005). Design and evaluation of expressive gesture synthesis for embodied conversational agents. In *Proc. 4th int. joint conf. on autonomous agents and multiagent systems* (pp. 1095–1096). The Netherlands.

Ishiguro, H. (2005). Android science: Toward a new cross-disciplinary framework. In *Cogsci-2005 worskshop: Toward social mechanisms of android science* (p. 1-6).

Kleinsmith, A., & Bianchi-Berthouze, N. (2012). Affective body expression perception and recognition: A survey. *IEEE Trans. on Affective Computing*, *99*(PrePrints).

Kleinsmith, A., Bianchi-Berthouze, N., & Steed, A. (2011, August). Automatic recognition of non-acted affective postures. *Trans.. Sys. Man Cyber. Part B*, *41*(4), 1027–1038.

Lee, J.-H., Park, J.-Y., & Nam, T.-J. (2007). Emotional interaction through physical movement. In *Proc. of the 12th int. conf. on human-computer interaction* (pp. 401–410). Berlin, Heidelberg: Springer-Verlag.

Nalin, M., Baroni, I., Kruijff-Korbayov, I., Cañamero, L., Lewis, M., Beck, A., et al. (2012). Childrens adaptation in long-term interactions with a humanoid robot. In *Proc. of ro-man12*.

Perlin, K. (1990). *Noise and turbulence*. Available from `http://www.mrl.nyu.edu/~perlin/doc/oscar.html`

Pollick, F., Paterson, H., Bruderlin, A., & Sanford, A. (2001). Perceiving affect from arm movement. *Cognition*, *82*(2), B51–B61.

Roether, C. L., Omlor, L., Christensen, A., & Giese, M. A. (2009). Critical features for the perception of emotion from gait. *Vision*, *9*(6).

Snibbe, S., Scheeff, M., & Rahardja, K. (1999). A layered architecture for lifelike robotic motion. In *Proc. of the 9th int. conference on advanced robotics.*

Thomas, F., & Johnston, O. (1995). *The illusion of life*. New-York: Abbeville Press.

Vala, M., Paiva, A., & Rui Gomes, M. (2008). Effective bodies for affective interaction. In L. Cañamero & R. Aylett (Eds.), *Animating expressive characters for social interaction* (p. 87-101).

Wallbott, H. G. (1998). Bodily expression of emotion. *European J. of Social Psychology*, *28*(6), 879–896.