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# Interpretation of Emotional Body Language Displayed by a Humanoid Robot: A Case Study with Children

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**Abstract** The work reported in this paper focuses on giving humanoid robots the capacity to express emotions with their body. Previous results show that adults are able to interpret different key poses displayed by a humanoid robot and also that changing the head position affects the expressiveness of the key poses in a consistent way. Moving the head down leads to decreased arousal (the level of energy) and valence (positive or negative emotion) whereas moving the head up produces an increase along these dimensions. Hence, changing the head position during an interaction should send intuitive signals. The study reported in this paper tested children's ability to recognize the emotional body language displayed by a humanoid robot. The results suggest that body postures and head position can be used to convey emotions during child-robot interaction.

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## 1 Introduction

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). Echoing the importance of emotional expression in social interaction and communication among humans, and in parallel with an older tradition of research regarding the use of facial expressions of emotions in HRI, research into bodily emotional expression and their modeling in robots has more recently begun to flourish. This is partly due to two main factors. On the one hand, an increasing corpus of research in psychology and neuroscience, such as [3, 15, 35], is emphasizing the role of the body in conveying emotion-specific information, rather than information only related to intensity as it was previously thought. On the other hand, is the fact that there are now a number of robotic platforms currently available that have complex bodies with a high number of degrees of freedom and/or good motion capabilities, but which do not necessarily have articulated faces.

The work reported in this paper is concerned with developing methods that will enable a robot to display emotions in a way that can be readily interpreted by children during an interaction. To this end, we are working towards an Affect Space for body expressions of humanoid robots [4, 5]. Our Affect Space draws from two main sources, as we will see in the next section (Sect. 2). On the one hand, dimensional models of emotions, according to which expressions can be analyzed (and in the case of robot, generated) in terms of a small number of continuous dimension, typically including at least Valence and Arousal. On the other hand, methods widely used in traditional animation, based on postural elements to define expressive postures of "key poses". Once the key poses are realized in robotic platforms, they can be used to drive the expressive animated behaviours. We opted for this design method for the study reported here, and more generally as a starting point to develop our Affect Space, because it permits to independently manipulate the position of the joints and test the effects of different body parts on the expressiveness of the robot's key poses. If expressive key poses can be automatically generated by changing the position of a subset of joints of the robot, they can then be used to drive the expressive behaviours of the robot. Building on previous work, where we assessed the recognition of a set of robot key poses by human adults, and tested the effect that moving the head up or down would have on the perceived emotion for a range of different key poses, in this study, described in Sect. 3, we investigate whether comparable results could obtained with children (cf. Sect. 4), and hence whether this type of bodily expression could have potential uses in child-robot interaction, as discussed in Sects. 5 and 6. The paper concludes (Sect. 7) with a summary of our findings and their relevance towards creating an Affect Space for affective bodily expression in robots.

## 2 Related Work

It has been shown that human body language can be interpreted accurately without facial or vocal cues [6, 15, 20]. This is further suggested by traditional animation, which focuses on the display of emotion through the body in order to increase believability. This has been codified as a rule in classical animations: "the expression must be captured throughout the whole body as well as in the face" [32]. Theatre follows a similar principle, by asking actors to become, in Artaud's words, "athletes of the emotions". Moreover, a large part of an actor's training addresses the non-verbal expression of emotions. All the above suggests that a humanoid robot, such as Aldebaran's Nao,[1] should be able to display emotions using its body, and that emotions such as fear, anger, happiness, stress, etc., could be readable when expressed through Nao's body.

### 2.1 Body Language as a Modality for a Robot to Display Emotions

Existing results show that humanoid robots can display emotions using body language. For instance, the robot WE-4RII can express discrete emotional states using a combination of body posture and facial expressions. The expressions have been tested in a perceptual study [17]. Another example is provided by Haring and colleagues [16], who have created a set of emotional expressions for the humanoid robot Nao. They used a combination of sound, body movement and eye colours to convey emotion. Although eye colour was found to be unreliable, sound and body movements conveyed the targeted emotions without the need of facial expression. However, such an approach may be problematic for long term interactions. Indeed, using such methods, the robot would be limited to a non-adaptive discrete set of predefined expressions which would be repeated over and over again. As a result, behaviour may be perceived as inappropriate, which in itself could be detrimental to the interaction. Another weakness of this approach is that the expressions do not necessarily generalize to different robots or situations. A set of emotional expression is developed for a specific platform and situation and validated in this context. However, the expressive features of the emotional display are not properly defined or investigated, and it is thus not possible to apply these results in different contexts. With the goal of exploring the expressive potential of body language for social robots, the work presented here focuses on methods inspired from continuous (dimensional) models of emotion stemming from psychology [29] and used previously in social robotics principally to generate facial expressions of emotion. Probably the best known example of a robot using such type of model—in this case for facial expressions—is Kismet [11]. Kismet's facial expressions are based on nine prototypical facial expressions that "blend" (interpolate) together along three axes: Arousal, Valence and Stance. Arousal is defined as the level of energy. Valence specifies the positive or negative quality of a stimulus. Stance reflects how approachable the stimulus is. This method defines an *Affect Space*, in which expressive behaviours span continuously across these three dimensions, allowing a wide range of expressions. The method is interesting for its simplicity. However, the stance dimension may be problematic as it is not related to any accepted model of emotions, which may cause problems for long term interaction outside the laboratory. Consequently, we focus on a two-dimensional (Valence, Arousal) Affect Space in our exploration of the potential that the body offers for a humanoid robot to express emotions.

### 2.2 Types of Body Language

Emotions, and more generally affect, can be expressed through different types of body language. Researchers have categorized the different types of body language in various ways. The categorization presented below, created from [12, 34], classifies body language into three different areas broadly used in the literature.

#### *2.2.1 Postures*

Postures are specific positionings that the body takes at a point in time (e.g. during a time frame in animation). It has

[1] http://www.aldebaran-robotics.com/en.

been established that postures are an effective medium to express emotion. For instance, De Silva et al. (2004) investigated cross-cultural recognition of four emotions (anger, fear, happiness, sadness) through interpretations of body postures. They built a set using actors to perform emotional postures and showed that it was possible for participants to correctly identify the different emotions [13]. Moreover, recent neuroscience findings suggest that there is a separate pathway in the brain for recognizing biological information dedicated to body form, postures [18].

These results suggest that humans are particularly sensitive to posture. Although a humanoid robot is not a biological entity, we could therefore expect that a humanoid robot interacting with humans could meaningfully use body postures to express emotions. This study focuses on the postural element of bodily expression and, in addition to the above research, draws from principles used in animation regarding body posture.

In animation, one of the established methods for creating convincing and believable displays consists in starting from the creation of expressive static postures, called *key poses*, rather than from body language in motion [32]. In the context of emotional body language, a key pose is a static posture modelled so that it clearly describes the emotion displayed. It captures a specific moment of the animation. Once the key poses are realized in robotic platforms, they can be used to drive the expressive animated behaviours. This method of creation was selected for this study and more generally as a starting point to develop our Affect Space because it permits to independently manipulate the position of the joints and test the effects on the expressiveness of the key poses. If expressive key poses can be automatically generated by changing the position of a subset of joints of the robot, they can then be used to drive the expressive behaviours of the robot.

#### *2.2.2 Movement*

It has been shown that many emotions are differentiated by characteristic body movements, and that these are effective cues for judging the emotional state of other people even in the absence of facial and vocal cues [2]. Indeed, as for postures, recent neuroscience findings suggest that there is also a separate pathway in the brain for recognizing motion [18]. Thus, a Nao robot displaying emotion should also do so during, and via, motion. Body movements include the movements themselves as well as the manner in which they are performed (i.e. movement speed, dynamics, curvature, etc.). The movements' dynamics have been shown to contribute to the emotional expression. For instance, Wallbott (1998) compared body language displayed by actors portraying different emotional states and found significant differences in the movement dynamics as well as in the type of movements performed across emotions [35]. Pollick and colleagues [27] investigated affect from point-light display of arm movements, and found that activation is a formless cue that relates directly to the kinematics of the movement. In robotics, existing work suggests that arousal is partly encoded by acceleration and that valence can be partly encoded by acceleration and curvature [30]. These studies are interesting because they show that dynamics is an essential component of emotional expression.

#### *2.2.3 Proxemics*

Proxemics relates to the distance between individuals during social interaction. Walters and colleagues [36] propose a framework for Human-Robot proxemics that takes into account a wide range of factors including the physical appearance of the robot, and some of its functionality [36]. Although this framework did not take it into account, proxemics is also indicative of emotional state [21]. However, Proxemics cannot be considered as an emotional expression in itself, but is required to complete a representation of realistic emotional behaviour. The reader can refer to [1] for a psychological overview of proxemics, and to [8] for examples of its use in robotics.

### 2.3 Our Previous Results

In previous work we conducted a perceptual study to assess the recognition of a set of robot key poses by human adults, and tested the effect that moving the head up or down would have on the perceived emotion for a range of different key poses [5, 6]. The position of the head was chosen because of its importance with regard to the expression of emotions [31]. Pioneering work by Wallbott (1998) shows that arm, shoulder and head position can be used to distinguish between fourteen emotions [35]. Moreover, head position has been found to be expressive for automatic recognition of emotion. For instance, Kleinsmith and colleagues [19] built models for the automatic recognition of affective postures. Among other features, their models use the neck and head positions to recognize emotions. The importance of the head position has also been highlighted for the automatic generation of expressive behaviours. Indeed, head position is one of the features used by Roether and colleagues [28] for the generation of affective gait. Furthermore, animation emphasizes the importance of creating a strong silhouette [23, 31] and manipulating the head position will considerably change a robot's silhouette. For these reasons, the head position was expected to have a strong effect on the key poses displayed.

This experiment showed that it was possible for adults to interpret the different key poses displayed by the robot. Consistent with the literature, it was also found that changing the head position affects the expressiveness of the key poses in a consistent way. It was found that moving the head down leads to decreased arousal, valence and stance whereas moving the head up increases these three dimensions [5]. This suggests that changing the head position during an interaction should send intuitive signals which will be used, for example, to indicate whether an interaction is successful. These results were established with adults and they could be sensitive to cultural and age differences.

### 2.4 Children's Perception of Emotion

According to Boone and Cunningham's research on developmental acquisition of emotion decoding from expressive body movement [9, 10], as children begin to produce certain actions, they have access to the perceptual expressive cues associated with these actions. In turn, this can lead to effective cue utilisation. Boone and Cunningham's experiment shows that, with respect to adults, it is possible to associate cues in naturally generated dance expression to specific emotions, and that children, from 8 years of age, can recognise them for the target emotions of happiness, sadness, anger, and fear. However, existing studies have also shown that emotional recognition continues to develop during adolescence [33]. Additionally, research in the perception of robots suggests that there may be differences in the way children and adults perceive them [37]. It is therefore not evident that children and adults would interpret the body language displayed by a robot similarly. Thus, the purpose of the study reported in this paper was to test the results of [5] with children and to investigate whether the head position could be used to convey different emotions to such a specific population.

## 3 The Study

The study setting was defined to be as similar as possible to the one used with adult participants [5]. It used a within-subjects design with two independent variables: Emotion Displayed, and Head Position respectively. The effect of changing the head position may vary depending on the position of other joints. In other words, the effect of moving the head up or down may differ depending on the emotion being displayed. Therefore, it was tested with six emotions (Emotion Displayed): Anger, Sadness, Fear, Pride, Happiness and Excitement (Table 1). Head position had three levels (Up, Down, and Straight), defined as the head position relative to the chest. One dependent variable was defined to explore the Affect Space: Correct Identification. It was used to test whether or not it was possible for participants to interpret the emotion of the key poses. Although the study conducted with adults was investigating Arousal, Valence and Stance as well, it was decided to remove them from this study because of the age difference.

### 3.1 Research Questions

To explore the issue presented in Sect. 2.4, four questions were tested in this study:

– (Q1) Are children as accurate as adults in identifying the key poses displayed by Nao?
  This question was introduced to test whether children would also be able to accurately interpret key poses displayed by the Nao robot.
– (Q2) What is the effect of changing the head position on the interpretation and perceived place of a key pose in the Affect Space?
  This question was introduced to test whether the head position of a robot interacting with children can be used to express different states in a continuous space.
– (Q3) Is the effect of moving the head similar across all the key poses? In other words, is the contribution of head position independent from the rest of the expression?
  Previous results suggest that the effect of changing the Head Position does not depend on the rest of the body. However, these results were obtained with adults and it is not evident that this will still be the case with children.
– (Q4) Is the effect of changing the head position similar for adults and children?
  Previous results obtained with adults have shown that manipulating head position is a very effective way of expressing different Valence and Arousal. Hence, this question was introduced to test whether the same method can be used for both populations or if a different approach should be developed.

### 3.2 Participants

24 Children (13 females, 11 males) were recruited from the school "scuola media Dante Alighieri" (Italy) ranging in age from 11 to 13 ($M = 12$, $SD = 0.3$).

### 3.3 Material

The same material as in the study conducted with adults was used. The six key poses (Fig. 1) were constructed by using performances from a professional actor and a professional director that was motion-captured and video-recorded from a previous study [4]. The actor performances were validated in a perceptual experiment [4, 6] conducted before building the material for this study. The recognition rates were 97.5 % for Anger, 85 % for Fear, 85 % for Sadness, 95 % for Happiness and 100 % for Pride (Chance level in this study was 12 %) [4, 6]. For each emotion, an expressive key pose was selected based on its expressivity, and on the likelihood of displaying it in the robot. Each joint of the robot was carefully positioned to match the original pose using the motion capture data. Each panel of Fig. 1 shows the key poses in the

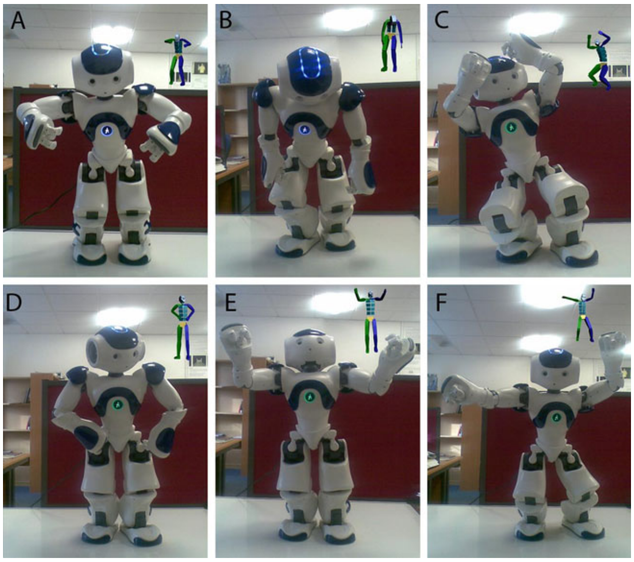



**Fig. 1** The six key poses (*A*: Anger, *B*: Sadness, *C*: Fear, *D*: Pride, *E*: Happiness, *F*: Excitement)

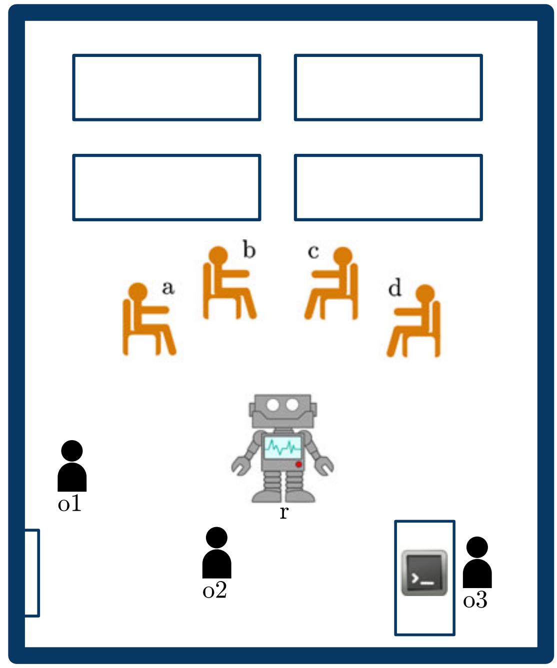



**Fig. 2** The setting of the study. *o1*, *o2*, *o3* are the experimenters; *r* is the robot; *a* , *b* , *c* , *d* are the four children

Nao and the original key pose used as a model (top right of the image). The platform chosen for this study was Nao, a humanoid robot with 25 degrees of freedom. The poses used in this study were generated by systematically altering the head positions of 6 emotional key poses. For Head Position-Down, the head was rotated vertically all the way down. For Head Position-Up, the head was moved vertically completely up. For Head Position-straight, the head was aligned with the chest. This resulted in 18 poses (6 Emotion Displayed by 3 Head Positions).

### 3.4 Procedure

The same experimenters tested all participants in groups of four. Participants were given full explanation regarding the questionnaire that they were expected to answer, and were instructed to "imagine that the robot is reacting to something". The setting of the study is shown in Fig. 2. Three experimenters were present: the first one took care of the children (*o1* in Fig. 2). The second one watched over the robot, making sure not to obstruct the children's view (*o2* in Fig. 2). The last one was operating the laptop, remotely controlling the robot through a wireless connection (*o3* in Fig. 2). The four children were sitting on a chair (*a*, *b*, *c* and *d* in Fig. 2), facing the robot and writing the answer on a paper questionnaire. The robot was placed on a table approximately 2 meters away from each child.

To make sure that the answers were as unbiased as possible, the children were advised that the study was not intended to judge their skills, but for helping the experimenters to "teach Nao how to behave like a human". After confirming that they understood all the questions, participants watched and assessed the 18 poses. Each pose was displayed only once, in a randomized order, which was different for each group of participants. For each pose, participants were asked to assign an emotion label chosen from a list of six emotions. The pose was changed (by touching the head of the robot) only after the four children confirmed they had made their choice. The list was comprised of Anger, Sadness, Fear, Pride, Happiness and Excitement. When all the poses were assessed, participants were fully debriefed. The sessions lasted approximately 30 minutes.

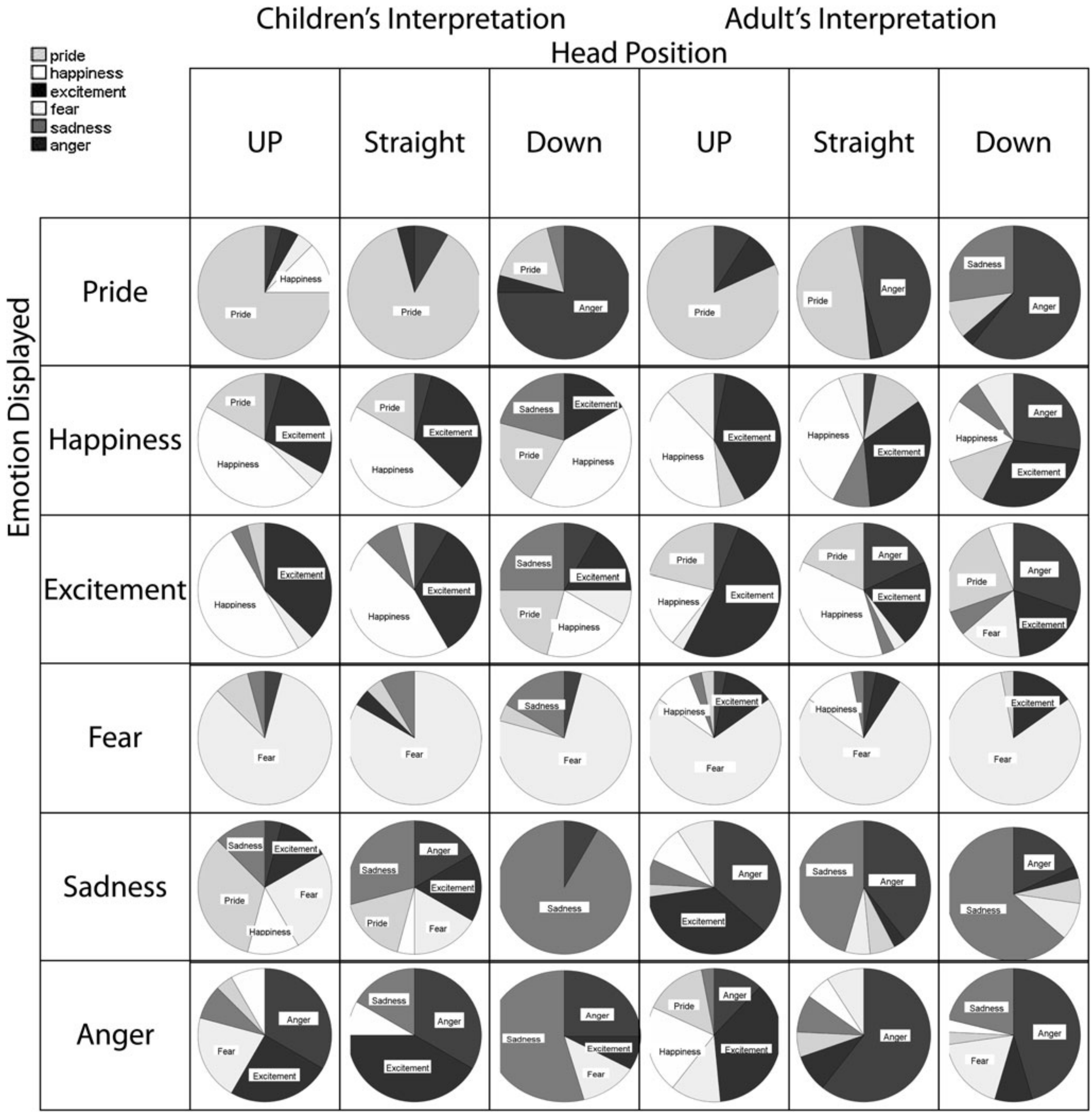
## 4 Results

Repeated Measures ANOVA (6 Emotion Displayed × 3 Head Positions) was conducted on Correct Identification. Emotion Displayed had a significant effect on Correct Identification ($F(5,115) = 12.03$, $p < 0.01$, Partial $\eta^2 = 0.34$). Head Position had no significant main effect on Correct Identification ($F(2,46) = 1.45$, $p = 0.25$, Partial $\eta^2 = 0.06$). These results indicate that the participants' performance was different across emotions. Nevertheless, Table 1 shows that the recognition rates were above chance level for all the key poses (Chance level would be $(1-(5/6)^3) \times 100 = 42$ %). It should also be noted that they varied from 58 % for anger, to 100 % for pride. Moreover, for most of the key poses, the recognition rates obtained with children are comparable to the ones obtained with adults (Table 1). However, the recognition rate for anger was higher for adults than for children (88 % vs. 58 %) and the recog-

**Table 1** Percentage of participants who correctly identified the emotional key pose at least once (Chance level would be 42 %)

| | Pride | Happiness | Excitement | Fear | Sadness | Anger |
|---|---|---|---|---|---|---|
| Children | 100 % | 83 % | 63 % | 92 % | 92 % | 58 % |
| Adults | 88 % | 73 % | 73 % | 92 % | 85 % | 88 % |

**Table 2** Interpretation of the Key Poses by children and adults




nition rate for pride was lower for adults than for children (88 % vs. 100 %).

There was a significant interaction between Emotion Displayed and Head Position ($F(10, 230) = 9.32$, $p < 0.01$, Partial $\eta^2 = 0.29$). This indicates that the effect of Head Position on Correct Identification depended on the individual emotion being displayed. Therefore, the effect of Head Position were considered separately for each emotion and are reported in Table 2. The table shows how the emotional interpretations of the displays shifted as a function of both the

Emotion Displayed and the Head Position. Participants were better at interpreting the negative emotions when the Head Position was Straight or Down. Participants were better at interpreting the positive emotions when the Head Position was Up.

## 5 Discussion

Let us examine how the study answered our different research questions.

### 5.1 (Q1) Are Children as Accurate as Adults in Identifying the Key Poses Displayed by the Nao?

The first goal of the study was to test the expressivity of the key poses displayed by the robot with children. As with adults, the results show that the children who participated in the study were better than the chance level at interpreting the different key poses taken by the robot (Table 1). However, the results also show that children were not as good as adults in interpreting the anger key pose. This difference is further discussed in Sect. 5.4. These recognition rates were obtained using static key poses only. Moreover, as with adults, the relatively low recognition rates for Happiness and Excitement were mainly due to these two emotions being mistaken for one another (Table 2).

These results clearly show that it is possible for children within this age group to interpret emotions displayed by a humanoid robot and that the lack of facial expression is not a barrier to expressing emotions. This suggests that they could be used to improve robots' social skills. This is important as social robots need to be able to express their internal states in order to interact with humans in a natural and intuitive way.

### 5.2 (Q2) What Is the Effect of Changing the Head Position?

As in [5], Head Position had a strong effect on the interpretation of the key poses being displayed (Table 2). For instance, children's interpretations of the Pride display were very similar to those of the adults. More precisely, it was interpreted as Pride when the head was up or straight. However, with the head down, a majority of children interpreted it as anger (Table 2). Fear was not affected by the change in Head Position and was correctly interpreted in all conditions by both the adults and the children. This further suggests that the interpretations of the key poses were similar in the adults and children's testing conditions. Moreover, with the exception of fear, moving the head up leads to the key poses being interpreted as positive, while moving the head down leads to negative labels being used (Table 2). Thus, the effect is consistent with [5], moving the head down leads to decreased valence whereas moving the head up produces an increase along this dimension.

### 5.3 (Q3) Is the Effect of Moving the Head Similar Across All the Key Poses?

With the exception of Fear, which was not affected by the change in Head Position, the other key poses follow a similar pattern. Key poses with the Head Up, were given more positive labels, whereas the Head Down was interpreted as negative more often (Table 2). It should be noted that this was also the case for the Anger display for which the recognition rate was lower (Table 1).

### 5.4 (Q4) Is the Effect of Changing the Head Position Similar for Adults and Children?

Although the overall results are similar between adults and children, there are however some interesting differences. The interpretation of the Anger Key Pose differed between the two populations. The adults shifted from Excitement/Happiness when the head was up to Anger when the Head was down. However, most the children interpreted the Key Pose as Fear-Excitement-Anger when the head was up. It shifted to Excitement-Anger when the head was straight and to Sadness when the Head was down (Table 2). Interestingly, children were less accurate than adults at interpreting the Anger key pose (58 % vs. 89 %). Three possible causes for these differences can be identified:

(1) Cultural differences: Psychology research on perception of emotion has shown that humans are better at interpreting other emotions within their social group [14]. The performance after which the key poses were constructed was acted by a British performer. This could explain why children were less accurate than adults in interpreting the anger display. Adults may have benefited from a cultural in group advantage [26]. However, this would raise questions for the other key poses as the recognition rate of Anger was the only one to be affected. Nevertheless, it could still explain the differences that were found with regards to the effect of the Head Position (Table 2).
(2) Age Differences: Another possible explanation with regards to the lower recognition of Anger as well as the differences in interpretations (Table 2) could be the age differences between the two populations. However, existing results suggest that children within this age group should be as accurate as adults whilst interpreting emotional key poses [22].
(3) A third possibility is the different settings between the two studies. Whilst the setting was kept as similar as possible between the two studies, it was necessary to

get the children participants in group of four. This induced some variations in view points and two out of four children observed the key poses slightly from the side (Fig. 2). Interestingly, this difference is consistent with the literature that suggests that a frontal view-point increase the recognition rate of postures displaying Anger [24]. This possibility is interesting as the aim is to use these emotional displays during child-robot interaction. It may be difficult to always ensure that the expressions will always be seen from a frontal point of view so the fact that Anger may be more difficult to interpret from the side should be investigated. It would suggest that a different method for expressing Anger may be more appropriate when a frontal view point cannot be ensured.

This is an interesting issue and should be explored in future research as it is not possible to draw definitive conclusions from this study. Moreover, it is important to highlight that the material used for this study is prototypical and was intentionally selected to be expressive. This is appropriate for the type of child-robot interaction that we investigate in the ALIZ-E project; however, it is likely that the use of prototypical expressions had an effect on the results and on the similarities of the interpretations that were found in this study.

## 6 Use of Our Key Poses for Child-Robot Interaction in the ALIZ-E Project

The ALIZ-E project focuses on the design of long-term, adaptive social interaction between robots and child users in real-world settings [7]. The project works together with a hospital in Italy, where children come for five days in order to get taught how to live with diabetes. During this stay, the children learn general facts about a healthier lifestyle, as well as how to measure their own glucose level, dose and self-administrate insulin injections. By developing robotic companions for diabetic children, we aim to support the following goals: reducing children's stress and anxiety level; improving their response to treatments; improving their self-efficacy; motivating children to do physical activities [25].

Within this context, the poses assessed in this study have been used during some experimental interactions between children and Nao carried out in the hospital [38]. The robot had to express emotions in order to give feedback to the child's performance in some particular tasks—namely playing Quiz and Imitation games. In ongoing work, we are developing another experimental activity where a child and a robot interact whilst playing a game inspired by the popular board game of Snakes and Ladders. The results and key poses presented in this paper are part of the expressive elements that we are using to improve the robot pro-social behaviour. This should improve the naturalness and spontaneity of the interactions.

## 7 Conclusion

As with adults, we found that moving the head up increased the identification of some emotions (pride, happiness, and excitement), whereas moving the head down increased correct identification for other displays (anger, sadness). Fear, however, was well identified regardless of Head Position. Our results have design implications for improving emotional body language displayed by robots. The results of this study suggests that the expressivity of the negative emotions (anger and sadness) can be improved by moving the head down, while the expressivity of the positive emotion (happiness, excitement and pride) can be improved by moving the head up. These results have already been successfully integrated in an automated expressive system [7]. The robot can automatically change its head position to express changes in its internal state. Future work will explore the effect of moving the different parts of the body on the interpretation of the body language displayed, as well as adding dynamic elements to the expressions that have been identified in Sect. 2.1. If similar results can be established for the other parts of the body, it will be possible to create a rich Affect Space for humanoid robots.

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