# Using Eye Shape to Improve Affect Recognition on a Humanoid Robot with Limited Expression

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#### Abstract

Appropriate affect expression on robots is important in using robots to interact with humans. A pilot study was conducted to examine the recognition of emotive eye shape on the Nao as well as whether the addition of eye shape to emotive gestures would improve recognition of emotion. A comparison was made between the recognition and classification of emotive eye shapes, gestures, and the combination of both into a multimodal display. The combined display of both gesture and eye shape to convey emotion was more consistently recognized than either modality alone. The information gathered from the pilot study will be used to inform future interactive work with the Nao.

# Introduction

Humanoid robots tend to have several modes of expression, but this doesn't mean that they are all always necessary, nor does it mean that they must always be used the same way. It is important to explore different means of expression available to different robots to evaluate their desirability for use in human-robot interactions.

This work focuses on the evaluation of emotion synthesis and sought to incorporate emotive eye shapes into emotional displays on the Aldebaran Nao to improve the recognition of affect in those displays. The Nao is a well-established platform in the field of robotics and human-robot interaction. It is used for its relatively low cost, portability, and expressive capabilities. The six emotive gestures and six corresponding eye shapes implemented here display the six basic emotions defined by Ekman and Friesen: happiness, sadness, anger, fear, surprise, and disgust (Ekman and Friesen, 1971). These displays were evaluated based on recognition in a pilot study.

# Related Work

Emotive gestures have been implemented on several different robots (Li et al., 2009; Manohar et al., 2011) that often have no or limited facial expression. Many robots that use emotive facial expressions alone have more detailed faces or are simply faces without bodies (Arai et al., 2003; Sosnowski et al., 2006; Ribiero et al., 2011).

Much previous work has been done using the Nao to convey emotion. Most of this work has involved developing emotional displays for the Nao using only gesture (Beck et al., 2010a; Beck et al., 2010b; Cohen and Neerincx, 2011), but some have gone further and incorporated other modalities available to the Nao, such as light (Haring et al., 2011; Monceau et al., 2009) and sound (Haring et al., 2011). Published emotional displays have mostly been found to be recognizable by subjects, and in fact, the recognition of emotive gestures used by the Nao was

found to be just as good as the recognition of emotive facial expressions by the iCat, a robot that is limited to only facial movement (Cohen and Neerincx, 2011).

Previous works that used the Nao's eye LEDs to convey emotion along with gesture have only manipulated the color of the LEDs (Haring et al., 2011; Monceau et al., 2009). In both cases, the purpose of changing the color of the Nao's eyes during emotive gestures was to emphasize the emotion being displayed by using a color that is normally associated with that emotion, such as red for anger. However, the emotional interpretation of color is a complicated subject and actually presents a large area of research. According to Manav's work in color-emotion associations, people have drastically different reaction to color depending on chroma, saturation, and brightness (2007). For example, the color blue is traditionally associated with sadness, but shades of green were found to be more depressive than blue in this study (Manav, 2007). Because of the amount of previous work that has explored coloring the Nao's eyes and the vagueness of published work on color-emotion associations, a new direction was used in this study instead.

There are more functions of the Nao's eye LEDs than just changing color. This work instead explores the use of *eye shape* in emphasizing emotive gestures displayed by the Nao. Unlike color, eye shape has emotion associations well-documented by Ekman (1972) as well as others discussed below (Lundqvist et al., 1999; Baron-Cohen and Wheelwright, 1997). The following sections discuss the derivation of the eye shapes and emotive gestures displayed by the Nao.

# **Implementation**

For this study, eye shapes and gestures were created for the each of the six basic emotions, happiness, sadness, anger, fear, disgust, and surprise, described by Ekman and Friesen (1971). These emotions were chosen because they have been well studied and there is much literature available about how they are displayed. The main theoretical perspective discussed in class that this project builds upon is work by Ekman, which was used in determining some of the eye shapes (1972).

# **Neutral Pose/Eye shape**

In addition to the six emotional eye shapes and poses, a neutral pose and eye shape was needed as an intermediary between each emotional display. The neutral pose was set to be the Nao in a standing position with its legs straight and arms down at its sides as seen in Figure 1. The neutral eye shape was created to be similar to shape of human eyes in a neutral position. In this position the top eyelids are slightly lower than the fully open position (Tian, Kanade, and Cohn, 2001). The neutral eye shape on the Nao mimics this by turning off the three upper LEDs in the Nao's eyes as seen in Figure 2. Another reason for partially closing the upper lids of the eye for neutral rather than mimicking the eye being completely open and turning on all the LEDs is that it allows for a distinction between the surprise eye shape, where all the LEDs are on, and neutral. It is important for these eye shapes to be different because if they were not, then this would introduce confounds when comparing the emotional displays created with the gestures to those created with both the gestures and the eye shapes.

#### Gestures

The gesture poses created in this study were based off of three studies. One was a study by Coulson where static images of mannequins in many different postures were rated by participants

as conveying different emotions (2004). The poses with the highest concordance rating for each of the six emotions were used as a basis for the gestures here (Coulson, 2004). A study by Kleinsmith and Silva where two dimensional rendered avatars in different poses were rated by participants was also used as a basis for the gestures here (2006). Written descriptions of different postures that correspond to emotions were also used (Wallbott, 1998).

#### **Happiness**

This gesture was created by keeping the arms straight and raising them slightly in front of the head in a V shape as seen in Figure 1. This arm position was based off the arm position of the pose with the highest concordance for happiness in Coulson's study (2004). The mannequin in this pose was also leaning back slightly with the head tilted backwards (Coulson, 2004). These aspects of the pose, however, were not included due to the physical limitations of the Nao robot. The two dimensional rendered avatar in the study by Kleinsmith and Silva expressing joy also had a similar arm movement (2006). Raising the arms is also described for "elated joy" (Wallbott, 1998).

#### Sadness

This gesture was created by bending the knees, slightly opening the hands, and bending the torso forward as seen in Figure 1. Bent knees and bending the torso forward were based off the poses of sadness for both the mannequins and avatars (Coulson, 2004; Kleinsmith and Silva, 2006). Wallbott describes the upper body as being "collapsed" for the sadness gesture, which also supports leaning the torso forward (1998).

#### Anger

This gesture was created by bending the arms and putting the closed hands on the hips as seen in Figure 1. This gesture was based on Kleinsmith and Silva's avatar for anger which has one arm in this position (2006). Instead of following the pose of this avatar completely with the other arm in a raised position, both arms were put into the bent with hand on hip position in order to make the gesture symmetrical.

#### Fear

This gesture was created by bending the knees, moving the right foot backwards slightly, and putting the hands slightly in front of the face with the arms bent as seen in Figure 1. The step back and bent knees are based off the mannequin with highest concordance for fear in Coulson's study (2004). The positions of the arms and hands are similar to the positions of the arms and hands of the avatar for fear (Kleinsmith and Silva, 2006). This avatar also has one foot behind the other with the knees bent (Kleinsmith and Silva, 2006).

#### Disaust

This gesture was created by moving the right foot backwards, raising the arms in a straight and parallel position to the front, opening the hands slightly, and turning the head to the right as seen in Figure 1. The arms in front and foot backwards are based off the mannequin pose for disgust (Coulson, 2004). The position of this mannequin also involves leaning the head and torso backwards (Coulson, 2004). Because leaning the head backwards a noticeable amount and leaning the torso backwards without causing the robot to fall backwards is not physically possible an alternative head position was used. Instead, the head was turned to the right because this is similar to a head shake, which has been used to express negative emotions (Lee and Marsella, 2006).

# **Surprise**

This gesture was created by moving the arms up above the head, slightly bending the elbows, and slightly bending the knees as seen in Figure 1. The position of the arms slightly bent and above the head was based off the mannequin with the most concordance for surprise in Coulson's study (2004). The avatar in Kleinsmith and Silva's study was also in a position with the arms raised (2006). The mannequin is also shown with one leg behind the other (Coulson, 2004). Because of stability problems involved with moving the arms upwards and one foot backwards simultaneously, the foot could not be moved backwards for this gesture. Instead, both knees were bent in order to increase the stability of the robot.

Emotion	Gesture	Emotion	Gesture	Emotion	Gesture
Neutral		Anger	3: 3: 3: 3: 3: 3: 3: 3: 3: 3: 3: 3: 3: 3	Surprise	1: (a) (b) (b) (c) (c) (c) (c) (c) (c) (c) (c) (c) (c
Happiness		Fear			
Sadness		Disgust	E S		

Figure 1: Emotional gesture displays on Nao for the neutral pose and the six basic emotions.

# **Eye Shapes**

The Nao has two eyes each with eight LEDs laid out in a circular pattern. In this study, the LEDs were turned on and off in order to create different eye shapes on the Nao as seen in Figure 2. This was done by using the lit LEDs to represent the sclera of the eyes for some of the

eye shapes, and the unlit LEDs as the eye lids. Because directly mimicking the eyelids in this way only creates a small set of possible eye shapes (open, closed, squinting, top lid lowered, and bottom lid raised), the LEDs around the eyes were also used in as a way of mimicking eyebrows for some of the eye shapes.

#### **Happiness**

For happiness, the lower three LEDs are turned off while the rest are turned on. This mimics the lower eyelids being raised while the upper eyelids are also raised opening the upper part of the eye. This shape was chosen to mimic how the lower eye lid is raised when a person is expressing happiness (Ekman, 1972). Another reason for raising the lower eye lid is that the eye movements associated with a real smile involve movement around the eye and raising the lower eye lid (Ekman and Friesen, 1982). In a study by Lundqvist et al. representations of eye shapes formed by the upper half of a circle were found to have the least negative valance when compared to full circle and lower half circle eye shapes with pupils (1999). The upper half circle shape is similar to the shape created by raising the lower eyelid.

#### **Sadness**

The eye shape for sadness was chosen to reflect the shape of the eyebrows instead of the eyelids. This was done for both sadness and anger because it has been found that eyebrows are more important for expressing emotion than the eye shapes, and for these two emotions there are eyebrow shapes that can be strongly related to each of them (Lundqvist et al., 1999). When a person expresses sadness, the eyebrows are typically raised and brought together in the center and lowered on the outer part of the face (Ekman, 1972). This forms an upside down V shape with the eyebrows. Another reason for using this upside down V shape is that representations of eyebrows in that shape were found to show less negative valance than representations of eyebrows in a V shape (Lundqvist et al., 1999).

## Anger

The eye shape for anger was chosen to mimic a V shape of the eyebrows. This shape was chosen because it relates to negative valance (Lundqvist et al., 1999). Also, humans display anger by lowering the center of their eyebrows to create a short of V shape (Ekman, 1972). Another reason for only mimicking the eyebrows for anger is that humans display anger by lowering their upper eyelids and raising their lower eyelids to the point of squinting and showing little to no sclera (Ekman, 1972).

#### Fear

The display for fear is a mimicking a combination of the eyebrows and eyelids with the bottom four LEDs off and upper four LEDs on in a slight upside down V shape. One example of an actor's portrayal of fear involves completely opening the eyes (Baron-Cohen and Wheelwright, 1997). This display of fear with the eyes completely open and all the LEDs on was not used because it would have been the same as the expression for surprise. People often confuse the expression of fear and surprise and will associate expressions of fear as expressions of surprise (Ekman and Friesen, 1982). In order to avoid this confusion the fear expression was created to be very different than the surprise expression. Humans display fear by raising the lower eyelids slightly more than would be done for surprise (Ekman, 1972). This raising of the lower eyelids along with the upside down V shape of the eyebrows was combined in the fear eye shape.

Emotion	Eyebrows	Eyelids	Derived Eye Shape	Implemented Eye Shape
Neutral	None	Top and bottom eye lids lowered		
Happiness	None	Bottom and top eye lids raised 1,2,3		
Sadness	Eyebrows slanted in upside down V shape <sup>2,3</sup>	None		
Anger	Eyebrows slanted in V shape <sup>2,3</sup>	None		
Fear	Eyebrows slanted in upside down V shape	Top and bottom eyelids raised 1,3,4		
Disgust	None	Upper eyelids lowered, lower eyelids raised <sup>3,4</sup>		
Surprise	None	Upper eyelids raised, lower eyelids lowered <sup>1,3</sup>		

Figure 2: Eye shapes described by eyebrow shape and eyelid shape and displayed diagrammatically and on the Nao for neutral and each of the six emotions. ¹(Ekman and Friesen, 1982), ²(Lundqvist et al., 1999), ³(Ekman, 1972), ¹(Baron-Cohen and Wheelwright, 1997)

# Disgust

Squinting of the eyes is mimicked for the disgust eye shape by turning off the upper and lower LEDs and turning on the two horizontal center LEDs. This shape was chosen because in humans the shape of the eyes when displaying disgust involves narrowing of the eyes (Baron-Cohen and Wheelwright, 1997). It can also involve raising the lower eyelids, lowering the center of the eyebrows and scrunching up the nose (Ekman, 1972). These three facial features also create a sense of squinting.

# **Surprise**

The surprise eye shape was created by turning on all the LEDs to mimic a completely open eye. This shape was chosen because humans display surprise by widely opening the eyes (Ekman, 1972).

## Methods

A small pilot study of 11 participants was conducted to test the emotional displays. Three experimental conditions were tested:

- *Condition 1*: The participant was shown the six basic emotions as only eye shape displays.
- *Condition 2:* The participant was shown the six basic emotions as only gesture displays.
- *Condition 3:* The participant was shown the six basic emotions as displays with both eye shape and gesture.

## **Experimental Procedure**

The participants did not know the hypothesis of the experiment. Participants were seated in front of the Nao robot, which was standing on a table. The Nao's eye level was slightly above the eye level of the participant.

Participants viewing the set of eye shapes only and the set of gestures only were randomly shown either eye shapes first or gestures first. The displays were shown to the participants in a randomized order. In all cases, the participants began by seeing the Nao in the neutral pose with the neutral eye shape. The Nao moved from the neutral pose to the emotional gesture display in around 0.4 seconds for each gesture. All of the emotional displays, both eyes and gestures, were held for at least 2 seconds before the Nao returned to the neutral position. The Nao would then remain in the neutral position until the participant was done selecting an emotion on their questionnaire.

Participants were given a forced-choice questionnaire and told to circle which one of the six basic emotions they felt the Nao was displaying. Because of the small sample size, only one response was allowed per display, but responses could be repeated for more than one display.

# Results

Although none of the results of the pilot study are significant due to the small sample size, some interesting trends were observed. For Condition 1, sadness and surprise were the most well-recognized eye shapes, followed by happiness. Disgust was the least recognized eye shape. For Condition 2, sadness was the most well-recognized gesture, followed by happiness, then anger and fear. Disgust was, again, the least recognized gesture. In Condition 3, anger and sadness were always recognized, and fear was recognized the second most. Disgust, happiness and surprise tied for the least recognized display.

	Participant Identification						
ion	Eyes Only	Anger	Disgust	Fear	Happiness	Sadness	Surprise
Displayed Emoti	Anger	3	1	1	0	1	0
	Disgust	3	0	1	0	2	0
	Fear	1	0	2	2	0	1
	Happiness	0	1	0	4	0	2
Ω	Sadness	0	1	0	0	3	0

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Participant Identification

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	Participant identification						
Displayed Emotion	Gesture Only	Anger	Disgust	Fear	Happiness	Sadness	Surprise
	Anger	4	1	0	1	0	0
	Disgust	0	1	4	0	0	1
	Fear	0	0	4	0	0	2
	Happiness	0	0	0	5	0	1
	Sadness	0	0	0	0	6	0
	Surprise	0	0	3	1	0	2

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motion	Eyes and						
ρt	Gesture	Anger	Disgust	Fear	Happiness	Sadness	Surprise
Displayed En	Anger	5	0	0	0	0	0
	Disgust	0	2	1	2	0	0
	Fear	0	0	4	0	0	1
	Happiness	0	1	0	2	0	2
	Sadness	0	0	0	0	5	0
	Surprise	0	0	1	2	0	2

Figure 3: The consensus for the identification of each emotive display. The left axis shows the name of the emotive gesture, while the top axis shows what that display was identified as by participants.

## Discussion

Surprise

Because this work was only a pilot study, the next logical step in exploring the usefulness of eye shape is to conduct a full study. The results from this small number of initial participants are not statistically significant. For assured statistical significance, a full study would need to have around 50 participants. This pilot study has shown some interesting trends that could be used to inform future work. The inclusion of eye shape in other applications using the Nao could allow the subtle expression of encouragement (happiness) when its body must be also used to perform non-emotive gestures necessary to further the interaction.

# **Conclusion**

In this paper the expressive modality of eye shape was explored on the Aldebaran Nao robot. Although much previous work with the Nao has used its "eyes" (LEDs) to convey additional affective information along with gesture, most of this work has been done using the eye color. Eye shape presents a different approach with more thorough supporting background literature.

Six eye shapes were derived along with six gestures representing the six basic emotions: anger, fear, disgust, happiness, sadness, and surprise. The relation between eye shape and affect recognition was tested in a pilot study. The pilot study supported the original hypothesis, and the addition of eye shape to emotive gestures proved more consistently recognizable than gesture alone. Eye shape can then be incorporated into future work with the Nao as another form of expression that can add richness to an interaction.

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