# The Expression of Mental States in a Humanoid Robot

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**Abstract.** We explore to what degree movement together with facial features in a humanoid robot, such as eyes and mouth, can be used to convey mental states. Several animation variants were iteratively tested in a series of experiments to reach a set of five expressive states that can be reliably expressed by the robot. These expressions combine biologically motivated cues such as eye movements and pupil dilation with elements that only have a conventional significance, such as changes in eye color.

**Keywords:** mental states, emotions, humanoid robot

## 1 Introduction

What features of a robot facilitate natural interaction with humans? It has been claimed that a human appearance is easier to interact with [3]. Features such as eyes and mouth convey much information, and these can be used by humans to infer different mental states and alter human perception [2]. For example. robots with big round irises are judged as more friendly by humans [4] and gaze has a strong influence on a human interacting with the robot [1]. In a series of experiments, we developed and evaluated a number of expressions of mental states in the humanoid robot Epi. This robot has been designed to give a childlike impression while still being decidedly robotic. The robot has two degrees of freedom in the neck and each eye can move laterally. In addition, the irises can change color and the pupils can dilate and contract. There is also a grid of LEDs that resembles a mouth that can be animated by changing their colour and intensity.

## 2 Methods

A set of candidate mental states were selected to be tested in the robot: The **neutral** state was designed to include a minimal amount of communicative features. The eyes used white for color at 50% intensity. No light or color was used in the mouth. Pupils were kept at an initial state, with no change in size. No movement


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was included in either neck or eyes. Blinking was included. (Fig. 1A). A throbber effect in the eyes of Epi was used to convey the mental state of **thinking**. Throbber was implemented by lighting blue LEDs with different intensity in a serial manner. The pupils were held at constant size and that blinking was not used. This mapping relates to computers rather than humans. This mental state also included an upwards movement of the entire head. **Anger**, was displayed by constricting the pupils. In addition, red eyes convey anger more effectively than white. Although this has no biological counterpart, angry robots are conventionally shown with red eyes. Intensity was kept at the baseline value at 50%. Color in the mouth was not used, but blinking was included. In addition, the head moved back and fourth sideways (Fig. 1D & 2A). The third mental state, **happy**, followed the same principles as the design of angry. Pupils were programmed to dilate. The color used was green, on the basis that it was opposite of red in the sense of traffic light coding. Mouth color was excluded again. No movement was used for the eyes but the neck moved upwards. Blinking was also included (Fig. 1C). For the fourth state, **confused**, the eye colors were changed to red, relying on the mapping that red means something has gone wrong. In combination with this, movement of the neck from left to right in a head-shaking manner were used to further display that a problem had taken place. Blinking and pupillary change was not included. The final mental state, **sad**, directed both eyes so they focused inwards to make the robot appear sad. Blue eyes with an with average intensity was used. A movement of the neck, directed right and down, was used. Blinking was also included (Fig. 1B).

To test the different behaviors, 20 participants were recruited, all of which were found on the university grounds at Lunds University. No reward was promised for participating. Participant were asked to sit in a chair facing Epi. Between Epi and the participant was a paper with different mental states written on it, and five pieces of paper with the numbers one to five written on them. The participant was asked to display a number, and then watch Epi as a behavioral pattern was presented. Following this, the participant was asked to place the piece of paper at the written mental state that they felt corresponded best with Epi's behavioral pattern. Participants were allowed to display the same number several time before making a decision, and could change their choices during the test. Once all five pieces of papers had been placed on the paper with mental

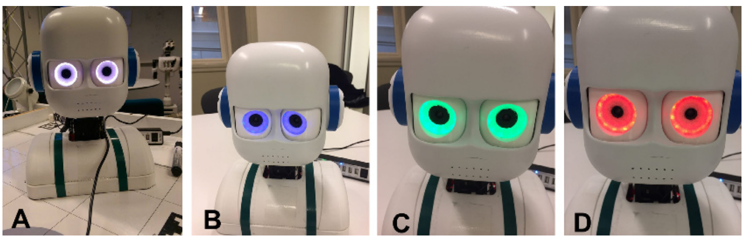


Fig. 1: The robot Epi. A: neutral. B: sad. C: happy. D: angry.

states, the second part of the experiment started where the participants were asked to judge to what degree they felt each behavior captured the mental state they had attributed to it. This judgment was made on a 1 to 5 scale.

## 3 Results and Discussion

The results showed that at least two of the five designed mental states can be easily identified and have a high degree of distinctness (Fig. 3). Both *angry* and *sad* were correctly identified by all 20 participants, and received values of distinctness close to 5. The variability regarding distinctness was also kept reasonably low for both states, indicating that close to all participants considered these states to be very distinct. The majority of participants were able to identify *thinking*, *happy* and *confused*, but judgment of distinctness was about average. The variability in participants judgment of distinctness is also very large, which shows that the mental states created likely won't be universally useful. Some participants, however, considered these states to be highly distinct, and further testing might reveal that some features included in these states can be used to infer the mental state. An example of this was observed when testing the mental state *happy*, which several people mentioned became much more distinct once they had come to realize that the mouth was indeed lit. The mouth used in this experiment was very limited in its design, and even when the robot was looking up it was often difficult to notice the light. For *thinking*, the computer metaphor used in the current design is limited. Adding another feature frequently associated with loading, in the form of a loading bar, did not increase its usefulness as a tool for conveying thinking in the robot. Unfortunately, *confused* is not efficient in conveying the mental state. After trying three significantly different designs and still not getting any improvements to the results, it seems reasonable to assume that this mental state is difficult to display with the tools available.

While the results are very positive, it is important to mention that the test allowed for different methods of exclusion. The participants knew beforehand which mental states were to appear, and they could only connect one behavioral pattern to one mental state. Even if a mental state was not very clear it would

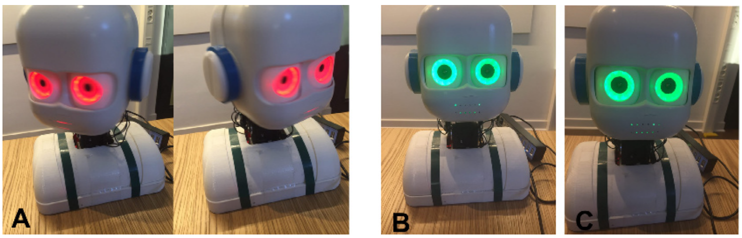


Fig. 2: A: The implementation of a shaking head movement in the mental state *angry*. B, C: Two different designs of smiling. The left one was superior and therefore used in later experiments.

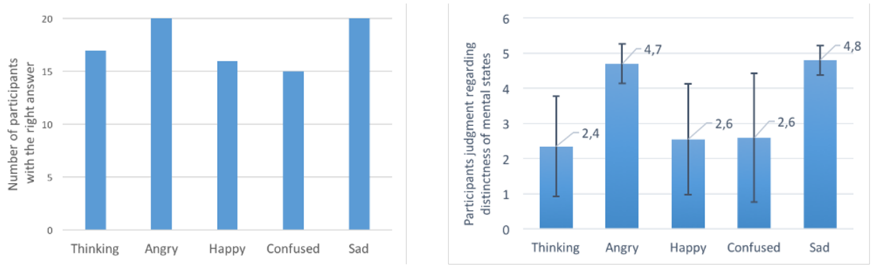


Fig. 3: Left: Results from the experiment. Each bar represents a correct mapping between designed mental state and interpreted mental state. Right: The mean value of the participants judgment regarding distinctness of the five mental states represented with a numeric rating scale, where 5 was very distinct and 1 was indistinct. Also including standard deviation.

still be possible for the participant to reach a correct conclusion by excluding behaviors that had already been mapped to another state. Considering that the participants were also allowed to change their decisions after having seen all mental states, and could see each mental state more than once, it seems likely that this method could be used. Not knowing if the mental states could be identified without methods of exclusion makes the gathered results less useful. It is possible that the mental state can not be properly distinguished on their own, and if this is the case they would be much less useful in a more natural situation. An attempt to reduce this problem was to include the scale of distinctness. If a mental state is rated as highly distinct by the participants, it seems more likely that it would be able to convey the correct mental state in a natural setting. These ratings might arguably also be affected by knowing which states exist beforehand, but it seems likely that state which received both high values for identification and distinctness should be employing a good design.

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