Evaluation of the Facial Expressions of a Humanoid Robot

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Abstract. Facial expressions are salient social features that crucial in communication, and humans are capable of reading the messages faces convey and the emotions they display. Robots that interact with humans will need to employ similar communication channels for successful interactions. Here, we focus on the readability of the facial expressions of a humanoid robot. We conducted an online survey where participants evaluated emotional stimuli and assessed the robot's expressions. Results suggest that the robot's facial expressions are correctly recognised and the appraisal of the robots expressive elements are consistent with the literature.

Keywords: Facial expressions · Human-robot interaction · Emotion recognition

1 Introduction

The face and more specifically facial cues play an important role in social perception [1], as they allow to infer the emotional and mental states of others. It seems that social features (such as human faces or bodies) are more salient compared to neutral scenes (like plants or scenery) [2]. Such findings led to a plethora of studies concerning to how we perceive and process faces. More specifically, facial expressions are crucial in communication, and humans are very apt in reading the messages facial expressions convey and the emotions they display [3].

As robots gain popularity, it is important to design them in way that allows humans to understand and intuitively interpret communication channels (such as facial expressions) in a transparent way [4]. Here, we concentrate on the expression and readability of the facial expressions of the humanoid robot iCub. Key regions of the face, such as the eyes or mouth have been identified as salient cues for emotion recognition [5] and different combinations produce a variety of expressions. Usually, a robot's capability for expression is limited, and the purpose of this study is to establish a valid scale of facial expressions that are correctly recognised by humans.

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2 Methods

For this study, we used the iCub humanoid robot. Its face consists of eyes, ears, eyebrows and mouth. The eyebrows and mouth are displayed via strips of LEDs while the eyes include eyelids whose openness or closeness can be controlled by a motor. In total, their combination provides us with approximately 480 different facial expressions.

To evaluate the readability of the iCub's facial expressions, we conducted an online survey in which users evaluated a stimulus using the Self Assessment Manikin (SAM) [6] and the Affective Slider (AS) [7]. The SAM is a non-verbal pictorial assessment technique to measure self-reported valence and arousal associated with a person's affective state. Each scale consists of nine items. We also used the Affective Slider for higher precision. The Affective Slider is a digital self-reporting tool composed of two slider controls for the quick assessment of a stimulus in terms of valence (positive or negative) and arousal (intensity). A depiction of the SAM scale and the AS can be seen in Fig. 1A.

The presented stimuli consisted of pictures of the iCub with various configurations of its mouth, eyebrows and eye-opening. We assessed the affective response of the robot's expression as opposed to an avatar and created three alternative versions of the head (tin, random shape and no head) to examine whether the anthropomorphic shape of the head would play a role in appraisal (Fig. 1B). Additionally, we showed images of the KDEF [8] and the IAPS (International Affective Picture System) database [9] (Fig. 1C). The last two categories served to ensure that participants could correctly recognise a facial expression and appraise an affective stimulus.

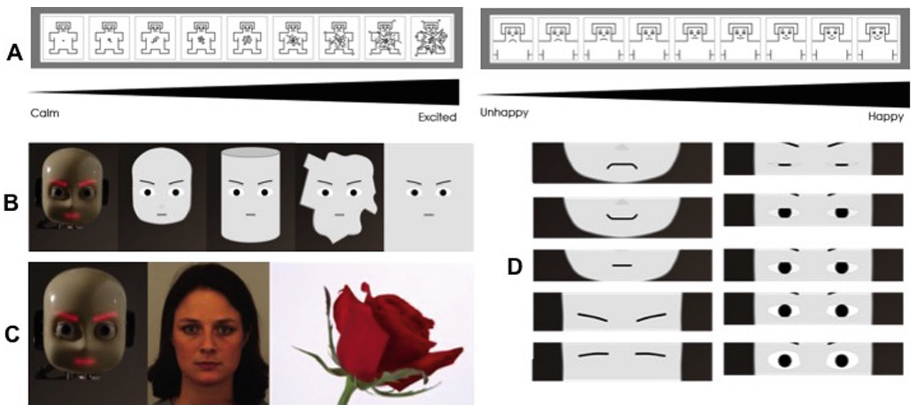

Fig. 1. Examples of the experimental setup. (A) the SAM (top) and AS (bottom) scale for arousal (left) and valence (right) (B) images of the variation of the iCub's face stimuli with the same facial expression (C) images of affective stimuli: the iCub, a photo of the KDEF database and an illustration of the IAPS database (the real image is not represented here to ensure the validity of the database) (D) variations of the expressive elements of the iCub.

To avoid any biases, we randomised the position of the stimuli (right/left) and the position of the SAM and AS. Additionally, to avoid any possible effects of the previous image, upon the evaluation of each stimulus, a black screen appeared for 3 s. All images were aligned to the same eye position. Before the survey, participants signed a consent form, were introduced to the scope of the study and provided us with demographic data (like gender and age).

As the test space was quite large and to eliminate certain stimuli, we performed a pilot (pretest) study with only the cartoon versions of the iCub to determine if the shape of the head affected the recognition of emotion and if the scale of the eye-opening was essential or not. The level of the eye-opening ranged from 0.0 to 1 with intervals of 0.1. The results of the pretest suggested no perceptual differences in several of the ranges of eye-opening and hence, we chose the following values of eye aperture: 0, 0.4, 0.6, 0.8 and 1 where 0 is shut and 1 completely open. The selected combinations of facial features can be found in Fig. 1D.

In total, 33 participants (19 females, between 19 and 52 years old) took part in the study and each stimulus was evaluated on average eight times.

3 Results

First, we examined the correlation between the two affective scales (SAM and AS). We found a strong significant positive correlation (Spearman's rank order) between the two affective scales for both arousal ($r_s = 0.874$, $p < 0.001$) and valence ($r_s = 0.961$, $p < 0.001$). Thus, we used the Affective Slider's results for the evaluation of the proposed stimuli. Then we assessed the participants' evaluation of the affective images. Our results suggest that the participants were able to recognise a facial expression correctly and found no significant differences between their evaluation of the affective images and the IAPS scores. We, therefore, did not exclude any participant.

Due to the small sample on our data, we could not evaluate whether the recognition of the facial expression between the robot image and avatar was different. We then examined the correlation between the mouth configurations and valence or arousal of the data acquired from the Affective Slider. We found a significant positive correlation between the mouth and valence ($r_s = 0.926$, $p < 0.001$), but not arousal ($r_s = 0.074$, $p = 0.424$). Results suggested that the happier the mouth, the more positive it is perceived. Results were consistent with the literature on how the mouth contributes to the facial expression in terms of valence.

We found a medium significant positive correlation between the eye opening and arousal ($r_s = 0.458$, $p < 0.001$) but not valence ($r_s = 0.074$, $p > 0.5$). Results suggested that the wider the eyes open, the more "intense" the expression was perceived. Our results were consistent with the literature regarding the eye-opening and the perceived arousal of the emotion. Finally, we examined the correlation between the position of the eyebrow and valence or arousal. We found a significant positive correlation between the position of the eyebrows and arousal ($r_s = 0.657$, $p < 0.001$) but not valence ($r_s = 0.08$, $p > 0.05$). Consequently, the more close the eyebrows were to the eyes, the more "intense" the facial expression was perceived. Results were consistent with the literature regarding the intensity of expression and the position of the eyebrow (for example in the case of anger).

4 Conclusion

This study aimed to evaluate the readability of the facial expressions of the iCub. Our results suggested that the robot's facial expressions were correctly recognised. Additionally, the results were consistent with the literature, as we found a positive correlation between the robot's mouth configuration (ranging from happy, to neutral to sad in a variety of intensities) and valence and eye aperture and arousal. The contribution of this work is twofold. On the one hand, we evaluated the readability of the iCub's facial expressions, and on the other, the results of this study will inform the expression system of the robot for future interactions.

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