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Non-verbal behavior of the robot companion: a contribution to the likeability

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Abstract

Modern emotional robots can support multimodal communicative interaction with humans through speech, hand gestures, head movements, eye and mouth animations. In the framework of this work, the contribution of individual active organs of the robot to the overall positive impression created by the robot in the user is investigated. The F-2 robot was used as an experimental platform. The experimental study revealed that users are significantly more likely to prefer a robot that uses gestures, head movements, eyes and mouth animation in its behavior compared to a robot in which the corresponding part of the body is stationary. The impact of robot's eye movements on the user is not so clear: subjects significantly more often prefer a robot that uses eye movements in behavior, but they relatively rarely notice the difference between the two patterns of robot behavior – the behavior of the robot with fixed eyes and behavior of one with moving eyes.

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Keywords: Emotional robot; human-machine interaction; behavior modeling.

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1. Introduction

Elements of non-verbal behavior, such as changing the direction of gaze, facial expressions and gestures, carry important information about the interlocutor, about his character, emotions, involvement, attention focus, and others. This “natural” interface of communication between people is opposite to the interfaces that are implemented in electronic devices with a graphic screen and icons. Modern research in the field of emotional robotics is largely aimed at transferring the features of human communicative behavior to the robot: to implement a natural human interface when communicating with a robot – communication with the help of speech, facial expressions, and gestures. This behavior enables the robot to interact naturally and intuitively with humans and determines how attractive to humans the robot [1].

Particularly important is the ability of the robot to demonstrate emotions that are considered important for human communication. Therefore, emotions can play an important role in human-machine interaction: on the one hand, these are the emotions that the robot evokes in humans during direct interaction, on the other hand, the emotions that the robot expresses in order to increase user satisfaction from such interaction.

In our work, we aim to achieve the maximum degree of anthropomorphism for a robot. Anthropomorphism is the human tendency to assign human abilities to inanimate objects such as robots [2, 3]. Robots with a sufficient degree of anthropomorphization cause a range of emotional manifestations in humans: from sympathy to compassion (for example, in [4] it was revealed that people have empathy for the robot dinosaur, which was turned over and pulled by the tail).

Attributing human abilities to a robot – its anthropomorphization – can be achieved in two different ways [5]. On the one hand, there is an opinion that robots possessing external human features are easily anthropomorphized. However, with excessive external similarity of the robot with a person, the opposite effect occurs, as described in [6], where it is argued that the appeal of the robot to the user grows with its anthropomorphism only to a certain limit, after which there is a sharp decline and robots begin to cause people mixed or even repulsive feelings. On the other hand, the anthropomorphization of the robot can be due to the peculiarities of its behavior: associated with the ability to demonstrate non-verbal behavior characteristic of human communication. Therefore, robots that can mimic the social behavior of people do not necessarily have to fully match the human appearance.

In our work, we adhere to the second approach and strive for maximum naturalness of the communicative behavior of the robot. To do this we investigate the communicative behavior of real people in different emotional situations – we develop a multimodal PEC corpus. In addition, in our laboratory we are developing a companion robot F-2 [7, 8], capable of implementing the identified patterns of human communication in its behavior.

We conducted a study that provides further insights into the question of human-robot interaction. We investigated the influence of different robot’s parts on the common robot’s attractiveness for the user and turned off robot’s parts during short stories. The contribution of robot’s parts to the attractiveness for the user such as hands, head, eyes, and mouth has been investigated.

2. Modeling of multimodal robot behavior

Non-verbal human behavior in dialogue is the subject of research in a number of major scientific fields. In the study of attention and oculomotor behavior, a fairly detailed review is given in [9, 10]. The interaction between gaze and head movements is discussed in detail in [11, 12]. In a number of works attempts are made to provoke in humans a sense of eye contact with the robot [13, 14]. The simulation of eye contact with the user by the robot is essential to enhance its attractiveness [15]. In previous experiments with the F-2 robot it was also shown that the direction of the robot's gaze is significant for increasing its attractiveness. The robot told the same story twice: in one of the stories, the robot tracked the location of the interlocutor in space, and periodically turned his head and looked at the user [16].

The analysis of human gestures is a fundamental scientific topic represented in [17, 18] and [19]. A number of studies have evaluated the contribution of gestures to increasing the attractiveness of the robot [20]. Thus, in [21] the authors showed that a robot accompanying a statement with gestures looks more attractive even if these gestures do not directly correspond to the statement.

This range of research poses an interesting challenge: to evaluate the contribution of each active part of the robot to the overall level of attractiveness of the robot to a human.

2.1. The Russian Emotional Corpus – REC

The Russian Emotional Corpus (REC) includes annotated video recordings of natural communication in tense emotional situations. (a) 295 recordings of oral university exams and tests (length from 26 sec to 60 min, average 6 min, total length 29,5 hours; 5 humanitarian university courses, 2 universities). (b) “One window” municipal service interactions with clients on the questions regarding community facilities (water, central heating), issued bills, rental, discounts etc. (15 days, 2,5 weeks at 6 working days, 146 hours, including idle time, divided into 510 recordings, length from 5 sec to 30 min, average 3,8 min, total length 32 hours). (c) Emotional interviews (10 recordings, 10 hours). Annotation of the corpus describes speech (text, syntagmatic structure, speech acts, face threatening acts and the cases of irony), facial expression, head and posture movements, gaze direction and hand gestures. In the recorded emotional situations informants show diverse emotional cues and numerous rational and emotional communicative strategies. The annotation allows us: (a) to search for a specific cue (like smiles or squints) and describe its usage and functions in natural communication, or (b) to search for specific patterns – like behavior markers of hesitation or facial cues at the end of utterances with face threatening acts. These observations help us to animate emotional computer agents which receive semantic trees at their input, simulate rich emotional dynamics and produce semantic trees, ready-made phrases, and gestures for the output.

2.2. F-2 Robot

F-2 emotional robot is a model and an experimental base for studying human communication and cognition. The goal of the project was to design a computer implementation of a cognitive architecture, able to receive incoming phrases, process them via linguistic and cognitive procedures, select a corresponding output reaction (possibly – emotion) and animate a robot. In an isolated running mode the architecture reads diverse texts (prose, blogs or news) and saves the extracted semantics with the suggested reaction for the robot – to a database.

The F-2 robot was designed with the resemblance to cartoon characters or toys. While advanced robots may encounter the problem of “uncanny valley” (a very human-like robot loses human confidence due to minor divergences with natural human behavior), F-2 is initially considered as a non-anthropomorphic cartoon-like or toy-like device. F-2 should maintain the emotional contact with the user through speech, facial expressions and gestures – like cartoon characters – thus bypassing the “uncanny valley” pitfall. It was designed to be easily assembled from standard electronic components by other research groups. Therefore, as a physical robot, it may serve as an experimental base for human-robot interaction. F-2 has 6 degrees of freedom (2 in the neck, 2 in each hand) and projects its face to a 5” monitor. It has soft hands, so it can touch itself or automanipulate. It can also receive the coordinates of surrounding human faces via an external face-detection system (e. g. MS Kinect) and simulate gazes towards the eyes of the addressee.

3. Experimental research

The research is devoted to the study of the influence of different active organs of the robot on its attractiveness to the user. As part of the study, the behavior of a robot accompanying the story with gestures, eye movements, head and mouth movements was compared with the behavior of a robot that did not use one of these active organs.

3.1. Subjects

The study was conducted in the summer of 2019. The subjects were participants of the educational program in the children’s camp, as well as teachers and counselors (N = 29, male 12, female 17, mean age 19).

3.2. Method

As part of the experiment, subjects were asked to listen to five short stories told by the robot. The subject sat down in front of the robot, which was located at a table. The subjects had to listen to each story twice: with the robot using all active organs - full-motion - and without a specific active organ (no eyes, head or hand movements, or no mouth animation) - deficit. The fifth story was a control one – the behavior of the robot did not differ in the first and second presentation. The order in which the stories were presented was randomized for each subject. The order of presentation of the two experimental conditions (full-motion, deficit) also varied for different stories. After presenting two experimental conditions for each story, the subject chose the most favourite type of robot behavior and evaluated the behavior of the robot on a five-point Likert scale. The subjects were asked to describe in a free form what they thought was the difference between the two modes of storytelling by the robot.

3.3. Results

As expected, in each case, the subjects in all cases chose the robot that uses full-motion behavior. The distribution of each active part is shown in Fig. 1. An interesting result of the experiment was that the contribution of the active organs in the attractiveness of the robot is distributed in following sequence: the robot with hand movements is preferred by 72% of the subjects, the mouth movements make the robot preferred in 69% of cases, head movements affect the preference in 59% of cases, eye movements are important for 45% of the subjects.

As the control condition, the subjects were offered two performances of the same story with the same non-verbal behavior of the robot in the two cases. In the control condition, the preferences of the subjects were distributed randomly.

A relatively large percentage of people (17%) who chose a robot without hand movements, as can be seen from the questionnaires, is due to the fact that the subjects negatively perceived the sound of electric drives. The subjects at the same time unambiguously recorded the differences between the experimental conditions: they paid attention to the fact that the robot's arms move in the full-body condition, but not in the deficit condition. When moving the head there was another situation: the subjects did not clearly paid attention to the sound of electric drives and hardly distinguished experimental conditions.

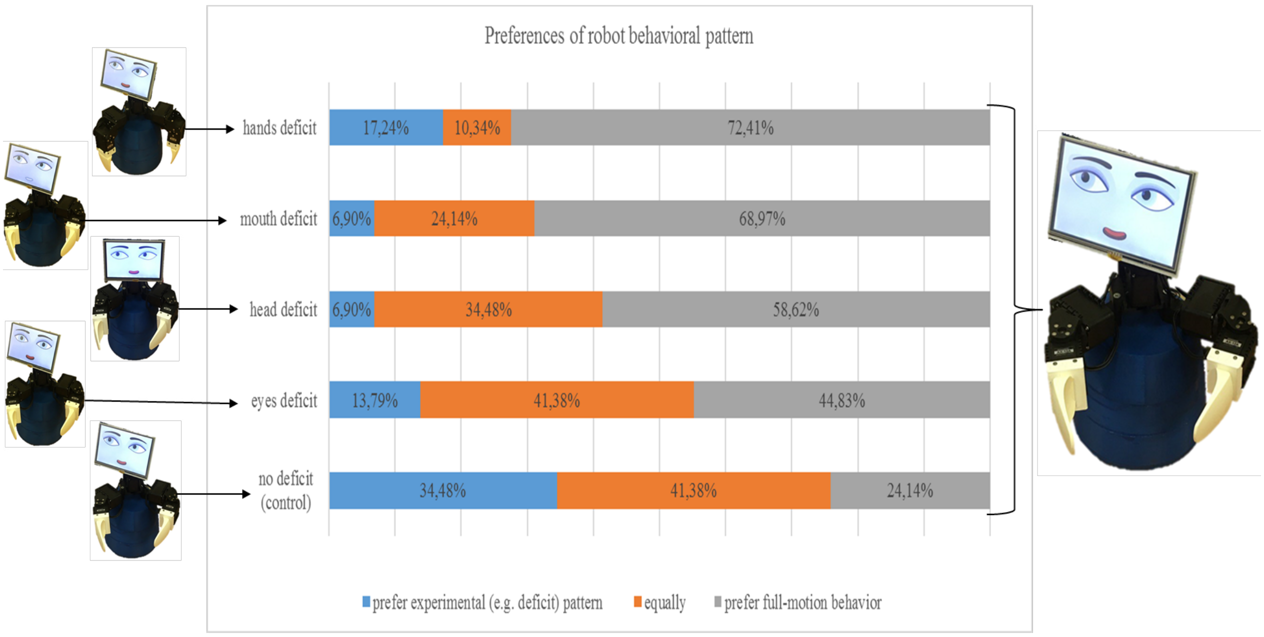

Fig. 1. Preferences of participants.

When processing the results of the scale questionnaire, it can be concluded that the subjects significantly more likely to evaluate the robot that uses all the active organs as more attractive than the robot that does not use the movements of the hands, head or mouth. This is represented on Fig. 2 (a, b, c). However, in the case of eye movements (Fig. 2 (d)) the subjects could not give a clear assessment of the two conditions (the difference is not significant).

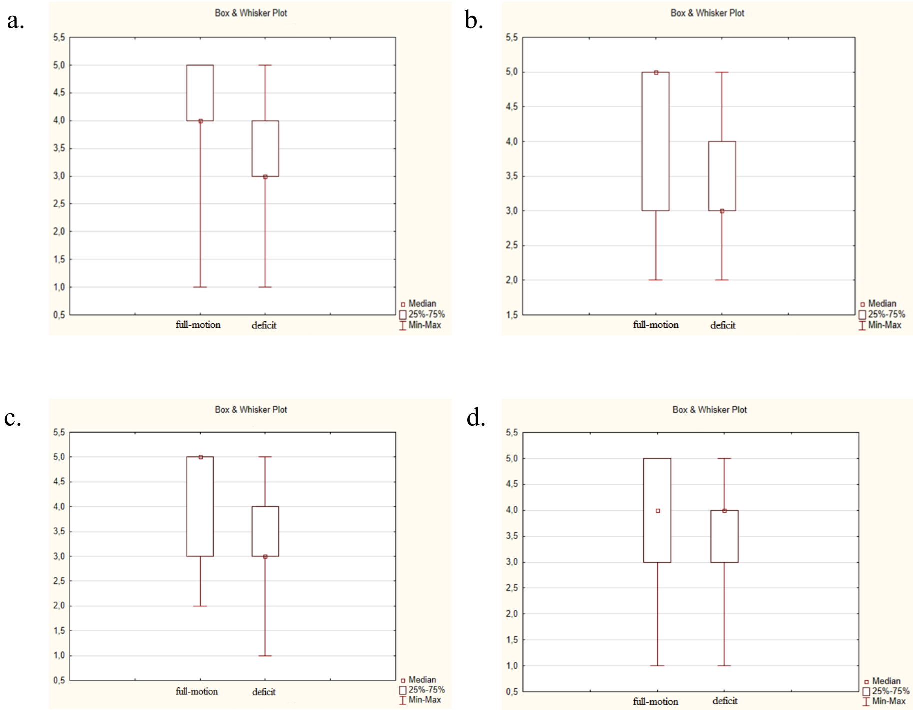

Fig. 2 Differences between experimental conditions: a. Evaluation of hands deficit (p<0,05); b. Evaluation of mouth deficit (p<0,05); c. Evaluation of head deficit (p<0,05); d. Evaluation of eyes deficit (p=0,06).

Since subjects are significantly more likely to prefer this behavior of the robot in which the eyes are involved, we can expect some implicit evaluation. It is supported by the fact that, according to the qualitative analysis questionnaire, in the case of eye-movement deficit subject suggests unreal interpretations of the difference. For example, subjects suggest that the robot spoke faster or that it said something new. Moreover, participants can subjectively interpret these differences, for example, to suggest that the robot was kinder, more interested. The same interpretations were found in the control condition when subjects were asked to evaluate two identical robot behaviors.

However, the study participants noted that not all hand movements are suitable for the robot. Consequently, further experiments should be done to study the effect of different types of gestures on the overall attractiveness of the robot to humans. It is also important to better assess the psychological characteristics of respondents, such as extroversion / introversion or emotional intelligence.

4. Conclusion

The results show that for the attractiveness of the robot active organs are important in the following order (in descending importance): hands, mouth, head, eyes. This particularly means that the robot that uses hand movements will be preferable to the robot that uses head movements (robots like Kismet, Philips iCat, Furhat Robotics).

The study revealed a number of features of communication between a robot and a human. Importantly, the effect of the eyes on the robot's attractiveness is implicit, highlighting once again the need for further investigation of the robot's eye-movement behavior.

The results of the study were introduced into the system of F-2 robot non-verbal behavior, as follows: the probability of expressive movements on the robot actuators is proportional to their importance estimated during the experiment. We expect to test the effectiveness of this approach in further research.

As for a further perspective of the project, first, it is necessary to separate robot gestures more differentially, for example, to use open, closed gestures, and their combination. Second, special attention should be paid to the appearance of the robot: the influence of detailed animation of mouth, pupils, eyelids, and eyebrows. Additionally, it is necessary to investigate the perception of the face of the robot with and without a nose, with different types of eyes and eyebrows. Execute experiments using different robot voice parameters (female/male or gender neutral).

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