Proceedings of the 17th IEEE International Symposium on Robot and Human Interactive Communication, Technische Universität München, Munich, Germany, August 1-3, 2008

Are Emotional Robots More Fun to Play With?

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*Abstract***— In this paper we describe a robotic game buddy whose emotional behaviour is influenced by the state of the game. Using the iCat robot and chess as the game scenario, an architecture for incorporating emotions as a result of a heuristic evaluation of the state of the game was developed. The game buddy was evaluated in two ways. First, we investigated the effects of the character's emotional behaviour on the user's perception of the game state. And secondly we compared a robotic with a screen based version of the iCat in terms of their influence on user's enjoyment. The results suggested that user's perception of the game increases with the iCat's emotional behaviour, and that the enjoyment is higher when interacting with the robotic version.**

I. Introduction

ROBOTS are becoming part of our daily lives. In spite of the classical view that robots are more adequate for settings like mine fields or production lines, they are now becoming well accepted for household tasks (as vacuum cleaners or as entertainment robots). Indeed, in the last few years, the field of social robotics [1] has emerged as a strong field, where robots are especially designed to interact with people. Such interactions can vary from robots whose sole purpose is to entertain people, to robots that behave as assistants, helping humans to perform tasks in several domains. There are application areas where the presence of social skills in robots is indeed quite significant [2], such as entertainment, health care, tour guides and education.

Emotional information exchange plays an important role in human social interaction. When interacting with robotic characters or synthetic characters, such social interaction must be carefully drafted. Indeed, current research in synthetic characters, considers that one of the principal ways to achieve believability is through emotional interaction, as it helps to know that characters are aware and "care" about what happens in the world [3]. If tomorrow's robots are going to be part of our world, they should have some emotional behaviour that allows them to communicate and respond in ways people can understand. Endowing robots with emotions can be very useful for a variety of reasons: (1) it facilitates human-robot interaction; (2) can provide feedback to the user, such as indicating the robot's internal state, goals and intentions; (3) can act as a control mechanism, driving behaviour and reflecting how the robot is affected by different factors over time [4].

Humans usually express emotions through speech, facial expression and/or body gestures [5]. Human expressivity has been inspirational in the area of synthetic characters (both with robotic or screen based embodiments [6][7]). However, little is known about the effects that the physical embodiments have on the user's perception and relation with these characters. Furthermore, there are few studies comparing robotic characters to virtual synthetic characters, determining the impact that different embodiments has on factors such as engagement, attachment and so on.

In this paper, we investigate the effects of emotions and embodiment in social robots that act as game companions. Regarding emotions, we analyse how the robot's emotional behaviour can help users to better understand the game they are playing. Regarding embodiment, we wanted to test if the user's enjoyment is different when we alter the embodiment between a robotic and a graphical synthetic character (although looking and acting exactly the same).

The paper is organised as follows. In the next section we provide a brief literature review on social robots, with special emphasis on robots that have some emotional behaviour. Then, we describe the architecture behind our game buddy. Finally, we describe two preliminary experiments carried on to evaluate the effects of the proposed emotion model in the user's perception of the game, and the effects of the embodiment in the user's enjoyment. We finish the paper with some conclusions and future work.

II. Related Work

For many years emotions applied to machines were viewed as of secondary importance, yet that changed when the field of Affective Computing came along. Actually, emotions are critical in social robots, as Breazeal demonstrates in her work with Kismet [8]. The behaviour of this robot is totally determined by its emotions and it engages people by communicating its affective state and other social cues through facial expressions, gaze and affective speech.

Another social robot capable of expressing emotions is eMuu, which was designed to be the interface between the environment of an intelligent home and its inhabitants. Studies involving eMuu [9] were performed to evaluate how convincing, trustworthy and intense its emotional expressions were viewed by the user, and if such expressions were appropriate in a certain situation. The results of the experiment showed that eMuu's emotions were perceived as convincing as emotional expressions of humans and also that

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The research leading to these results has received funding from European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement nº 215554.

the interaction with such a robot is more enjoyable than non-expressive characters. A screen based version of eMuu was created to evaluate the effects that embodiment had on user's enjoyment. The results suggested that the embodiment had no significant influence on the user's enjoyment. Still, the robotic version had more positive aspects in the evaluation, such as social facilitation effects and higher forgiveness to speech recognition errors. This study contradicts Wainer's *et al.* investigation [10], which argues that physical or material embodiment in a task-oriented setting can make a difference in the user's enjoyment of the task. Enjoyment is a difficult concept to measure, and one possible explanation for the conflicting results in these experiments is that two different definitions of enjoyment were employed.

Furthermore, the cost reduction in electronics led to the appearance of a miscellany of commercial robotic toys for children, from inexpensive dolls like Hasbro's Baby Alive or Furby, to more expensive pets such as Sony's AIBO or Pleo, the robot dinosaur. However, in terms of behaviour, these robots are much more basic than the research examples, especially regarding emotional behaviour. Even though, it is impressive the success they have achieved, particularly among children. Kahn *et al* [11] analyzed people's conceptions of AIBO to infer about how humans conceptualize their relationship with a robotic pet. One of the categories in analysis was social standing, referring to ways in which AIBO does or does not engage in social interactions such as emotional connection and companionship. More than half of the participants made affirmative references to this category, suggesting that interactions with robotic pets are similar to interactions with real pets. Results like these are harder to find in screen based characters. Robotic characters usually enhance the feeling of social presence, resulting in more positive evaluations [12].

Although much work remains undone, there is already a common understanding that social robots endowed with some kind of emotional behaviour can successfully engage people. Yet, we believe that emotions can provide much more than that, as we will discuss in this paper.

III. ARCHITECTURE

To investigate the effects of emotions and embodiment on social robots, we developed a scenario where the Philips iCat [13] acts as the opponent of a user in a chess game, and its emotional behaviour is influenced by the game state. Users may then interpret the iCat's emotional expressions and by doing so acquire additional information to better understand the game.

The architecture was primarily conceived for characters embedded in turn based games, which are games where each player has a period of analysis and thinking before committing to an action (*e.g.* chess). The interaction cycle is depicted in Fig. 1. In the first stage of the interaction, the character introduces itself and invites the user to play. The user can take the time she wants to think before actually playing her turn. After the user's turn, it is the character's turn. Here, there is a preliminary phase to appraise the changes in the game, followed by the adjustment of the emotional state as a consequence of those changes. Finally, the character expresses its emotional state and plays its turn. The cycle continues until one of the players wins the match.

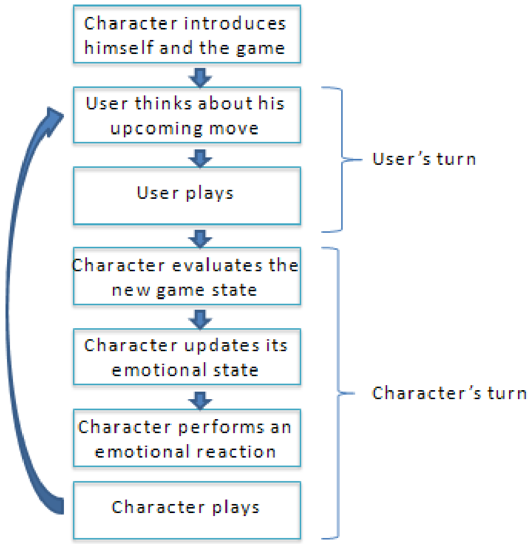

Fig. 1.Interaction cycle between the user and the character.

The architecture is divided in three different modules: game, emotion and animation. This division allows for the model to be employed in other games (*e.g.* checkers) and different character embodiments (physical or screen based). In the remaining of this section, the three modules of the architecture and some technical issues of our implementation scenario will be described.

A. Game Module

The game module represents the interactive game played by both the user and the character. It contains the core dynamics of the game, such as the rules and the algorithms that evaluate the game state. Broadly speaking, this module perceives the game events and selects the actions taken by the character during the game. After each opponent's move, the game evaluates the advantage/disadvantage of the character's position in the game. This value is the main input for the emotion module, as the character's affective state is determined by the dynamics of the game score.

In our chess game implementation, the game module is divided in two different components: a chess engine and a user interface. Regarding the chess engine, we used the Tom Kerrigan's Simple Chess Program [14] to compute the character's move and return the evaluation value to the emotion module. Regarding the interface, we wanted to make the experience as close as possible to traditional chess. Therefore, we used the DGT Electronic Chess Board [15], a tangible user interface that has the appearance of a regular wooden chess board and connects to the computer through USB interface.

B. Emotion Module

The emotion module manages the character's affective state. It receives the evaluation values from the game module, processes those values and updates the two different modalities of the character's affective state: emotional reactions and mood. Our approach is inspired by Scherer' work [16], which separates the affective states in five categories: emotion, mood, interpersonal stances, attitudes, and personality traits. Our character only has the first two categories, emotion (that we called emotional reactions) and mood. We decided not to include the remaining three categories because, at this time, we did not have enough information from the outside world of the agent to allow a good representation of those states.

Emotional reactions are the immediate emotions experienced after the user's turn in the game. According to Scherer [16], emotions are relatively brief episodes of response to the evaluation of an external or internal event as being of major significance. Although they have a short duration, they are quite explicit. Emotional reactions can be associated with previous expectations, particularly in turn-based games, where we unintentionally and inevitably build an idea of our opponent's performance. For instance, the more we think we "know" our opponent, the more we get surprised with her failure if we consider she is a great player. In other words, we tend to *anticipate* our opponent's performance during the game. To endow our agent with this kind of behaviour, we employed an anticipatory system named *emotivector*. An *anticipatory system* is a system containing a predictive model of itself and/or of its environment that allows it to change state at an instant in accord with the model's predictions pertaining to a later instant [17]. The *emotivector* is an anticipatory system that generates an affective signal resulting from the mismatch between the expected and the sensed values of the sensor to which it is coupled to [18].

	more R	as expected	more P
expected R	stronger R (S+)	expected R	weaker R ($+)
negligible	unexpected R	negligible	unexpected P
expected P	weaker P ($-)	expected P	stronger P (S-)

Fig. 2. Emotivector model. "R" means reward and "P" stands for punishment. If the current expected value is higher than the previous one, the generated affective signal will belong to the first row of the table; if there are no changes, it belongs to the second row and if the value is lower it belongs to the third row. Depending if the sensed value is higher, within a threshold value or lower than the expected value, three different sensations can be elicited (stronger, expected and weaker). The threshold is computed based on the history of mismatches between the expected and the sensed values. Computing the threshold value has the advantage of not requiring fine-tuning, which is fundamental to our model, since the signals picked up by the emotivector can vary depending on the game that is being used.

The emotivector is coupled to the evaluation values received from the game module. When a new value is received, the emotivector system catches this value and by using the history of evaluation values, an expected value is computed (applying the moving averages prediction algorithm [19]). By confronting the expectation with the actual sensed value, the emotivector generates one of the nine different affective signals for that percept (see Fig. 2). For instance, after three moves in the chess game, if the iCat has already captured an opponent's piece, it might be expecting a reward for the user's next move. So, if the user actually plays a bad move (*e.g.*, by putting her queen in a very dangerous position), the elicited sensation will be a "stronger reward", which means "this evaluation is better than I was expecting". On the other hand, if iCat is expecting a reward, and the opponent captures an iCat's piece, the elicited sensation will be a "weaker reward", which means "this sensation was worse than I was expecting".

Mood is a less intense affective state and thus less likely to be triggered by a particular stimulus or event. Moods generally have either a positive or a negative valence effect and are longer lasting [16]. Valence refers to the affective value associated with a stimulus. We consider that, in addition to the polarity (positive or negative), valence can also have a certain intensity. Thus, we represent mood as a valence variable V that ranges between a minimum (negative) and a maximum (positive) value. The magnitude of V stands for the intensity. Positive values are associated to good scores in the game, whereas negative are related to bad scores. In our approach, mood is a background affective state that is explicit when emotional reactions are not occurring.

The evaluation of the game state is also used to compute the valence of the mood. However, to do so, some pre-processing is required. It may not be desirable a linear correspondence between the evaluation and the valence value, because in evaluation functions many times the boundary values only happen at the end of the game. Thus, we introduce an intermediate filter function F(x), which filters the values received from the game module before they "become" a valence value. For instance, in the chess game scenario we employed a logarithmic function, since the chess heuristic returns values close to zero almost the entire game. This way, valence reflects even the slight changes in the game score.

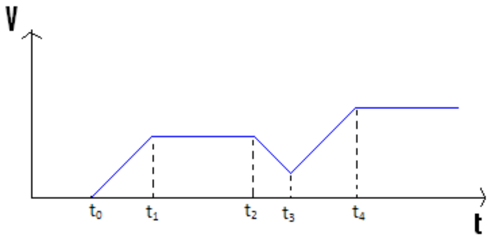

Fig. 3. Valence evolution in the chess game. One of the axes of the graphic represents time (t) and the other comprises the valence values (V).

Mood tends to come back to zero in the absence of new stimuli. As such, we associated a decay rate to the valence value. Fig. 3 contains an example of the evolution of the valence value in a chess game. When a new stimulus is received (*i.e.*, when the user makes a move), the valence gradually increases until it reaches the new value (according to the affective model, mood should not change abruptly). When the game begins the valence is neutral, which means that none of the players has any advantage or disadvantage.

At instant t_0 the user plays her first move, and the iCat acquired a little advantage in the game, which gradually raises its valence to a positive value, reaching such value at instant t_1. Notice that at t_0 an emotional reaction was also triggered by the emotivector system, which means that the mood was overridden by the reaction for a brief period. Then, for a certain period of time, the valence remains in the same value, since no other moves are played by the user. At the instant t_2, the valence starts decaying at the predefined decay rate, due to the absence of new stimuli. But at the instant t_3 the user plays a new move, which again brings more advantage to the iCat. Thus, instead of keeping on with the decay, the valence increases towards the new value.

C. Animation Module

The module responsible for conveying the emotions computed in the emotion module, as well as the game actions taken by the character during the game, is the animation module. This module manipulates the characters' body parts by setting the value of a single body part in real time or through predefined animations (*i.e.*, scripts containing a temporal sequence of some body parts and their values). Each one of the nine affective signals generated by emotivector system is mapped into a different animation (*e.g.* sad, happy…), using the predefined animations method. On the other hand, mood uses direct manipulation. Two different poses, each one corresponding to the limits of the valence space, must be defined. The mood is an interpolation of those two body parameterizations. The animation module also performs other predefined animations that we named idle animations, such as blinking or looking to sides randomly, to increase the character's overall believability. Idle animations can only occur when no emotional reactions are being played, but mood coexists with them. We established a priority policy for body part manipulation since it may happen that some of the parts are used concurrently [20]. In the presence of overlapping values, the most priority values are the ones played by emotional reactions' animations, followed by the mood and finally the idle animations.

The animation module communicates with the iCat's control software, which manages the character's facial expressions[1]. We used animations from the library of the OPPR software for the emotional reactions, since these animations were previously submitted to tests ensuring that users perceive those emotional expressions on the iCat's embodiment [21]. We made a correspondence between these animations and each one of the nine emotivector sensations. For example, the "stronger reward" sensation means that we experienced a reward much better than we were expecting and therefore the correspondent emotion is "excitement". The OPPR platform also contains a screen based version of the iCat, which looks exactly like the robotic one. This feature is very important for the evaluation that we will perform regarding the embodiment.

[1] The iCat Research Platform from Philips comprises both the iCat robot and a software application called Open Platform for Personal Robotics (OPPR) that allows the development of new applications for the iCat.

IV. Evaluation

This section describes two preliminary experiments that we conducted. Both the experiments were performed by having the iCat as the opponent of a human player in a chess match (see Fig. 4). We attempted to validate the two following hypothesis:

HI: If the iCat's emotional behaviour reflects what happens in the game, users will have a better perception about the game.

H2: The enjoyment of the experiment is higher when users are playing with the robotic version of the iCat than when they are playing with the screen based version.

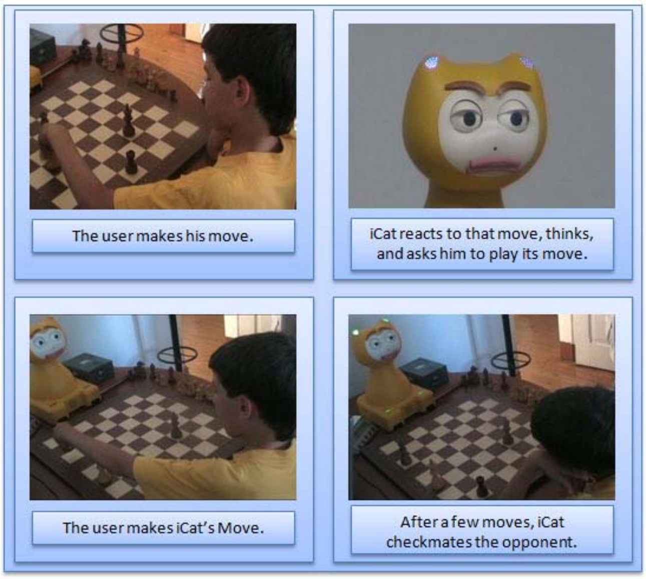

Fig. 4. User playing with the iCat at a local chess club.

A. Experiment 1: Impact of the iCat's emotional behaviour on the user's perception of the game

Experimental Design: A total of 9 participants between 7 and 31 years old took part in the experiment. None of the participants had prior experience interacting with the iCat and all of them already had some prior experience playing chess. The experiment was performed in two different sessions, the first one in the facilities of a local chess club and the second one at Instituto Superior Técnico – Technical University of Lisbon.

Procedure: Users played three chess problems against the robotic iCat, with different levels of difficulty (easy, medium and hard). The exercises were proposed by the chess club instructor.

Manipulation: Three different treatments regarding the iCat's emotional behaviour were used: (1) in agreement with the developed emotion model (*emotional*); (2) incoherent random emotional behaviour, where reactions to the user's move are randomly chosen between eight possible animations (only the right one cannot be selected), and valence is also a random value (*random*); (3) without expressing any emotional state, that is, a neutral/idle behaviour (*neutral*). Participants interacted with the three versions of the iCat's emotional behaviour in a balanced order, each one in one of the exercises. Apart from the control condition, the idle animations were performed by the robot in the three games.

Measure: We measured the perception of the game by comparing what the user thinks about the game with the value obtained from the chess engine's evaluation function.

During the experiment, we asked the users to complete the following assertions: (1) *By your analysis of the game, the iCat is...* a) *winning*; b) *loosing*; c) *neither winning nor loosing*. (2) *According to the iCat's expression, it is…* a) *winning*; b) *loosing*; c) *neither winning nor loosing*. The answers to the first question were compared with the result of the chess evaluation function at that moment. If the two variables match (*e.g.*, if the user thinks that iCat is losing and the chess evaluation function also indicates that), we consider that the user could successfully perceive the game state. The answers to the second question were used to evaluate if users were able to correctly interpret the iCat's facial expressions (in the *emotional* condition, if the answer matched the evaluation function).

Results: In each exercise, we asked the users the perception of the game questions three times, which means that we have a sample of 27 values for each control condition. The number of successful perceptions was higher in the *emotional* condition (23, whereas in the *neutral* condition was 20, and 16 in the *random* condition).

We performed a Spearman correlation test with a two-tailed test of significance for the data of each condition. We had three variables to correlate: the user's perception of the game based on the iCat's expression, the user's perception of the game based on her analysis and the actual game state (obtained from the chess evaluation function).

The correlation between the "user's own analysis of the game" and the "actual game state" variables was higher in the *emotional* condition. The value of this correlation is 0.930 ($p < 0.001$). With the *random* samples the correlation decreases to 0.485 ($p = 0.010$) and in the *neutral* the value is 0.680 ($p < 0.001$). These results indicate that the user's perception of the game increases when the iCat's emotional behaviour is animated with the previously described emotional system.

Regarding the correlation between the perception of the game based on the iCat's expression and the user's own analysis of the game, we found correlations between these variables in two of the conditions. In the correlation tests using the data from *emotional* condition, such correlation is really strong (0.958 for $p < 0.001$) and in the *neutral* condition the value is 0.580 ($p = 0.002$). The second result was quite unexpected. One possible explanation for such correlation is that users tend to interpret the iCat's neutral behaviour by taking into account their opinion in the game. Thus, we cannot guarantee a total independence between the variables "user's perception based on iCat's expression" and "user's perception based on own analysis".

Finally, concerning the relation between the game perception based on iCat's expression and the actual game state, it is significant to refer that there is a strong correlation between these variables when applying the test to the values retrieved from the *emotional* condition (0.980 for $p < 0.001$). This means that users were able to correctly interpret the iCat's emotional behaviour.

Discussion: Subjects succeeded more times in the perception of the game when the iCat's emotional behaviour was controlled by our emotional system. Further, the correlation between the user's analysis of the game and the actual game state variables was substantially higher in this case. These two results suggest that the emotional behaviour indeed helps the users to have a better perception of the game. One of the reasons why the emotional expressiveness may have influenced the users on their evaluations is that people typically assume that emotions are spontaneous and therefore they are an honest way of communication between them and the robot.

During the experiment, we could also retrieve some relevant qualitative data through observation. For instance, all participants were quite polite when interacting with the iCat. After playing the iCat's move, when iCat said "thank you", they usually replied with a "you're welcome" sentence. Another interesting (but not so surprising) result was that children paid more attention to the iCat than grownups did.

B. Experiment 2: Comparison of user's enjoyment in the robotic and screen based version of the iCat

Experimental Design: A nonparametric Mann-Whitney U test with 2 independent samples (robotic and screen based) was performed in order to evaluate the differences on the user's enjoyment. A total of 18 participants were involved in the experiment.

Procedure: All participants played a single chess exercise from a predetermined position against the iCat (an entire chess game without time restrictions would have taken up to 2 hours or more to play). After each game against the robotic or screen character, users filled up a questionnaire to measure their enjoyment.

Manipulation: This experiment was conducted using two different testing scenarios. One of the scenarios comprised the robotic version of the iCat, and the other one the screen based iCat. In each testing scenario we had 9 participants from the same locations and ages of the first experiment. The participants who played with the robotic iCat did not play with the virtual one and vice versa, because they would have played the same position twice and that could compromise the results. In the robotic setup, the participants sat in front of a table containing the DGT electronic chessboard and the iCat robot. In this scenario, the participants made their moves on the chessboard and watched over iCat's emotional behaviour. The screen based scenario was identical, but instead of having the iCat robot, a 17 inch TFT monitor displaying in full screen the 3D version of the iCat was used (approximately with the same size of the real robot).

Measure: To evaluate our dependent variable, user enjoyment, we chose a model designed to evaluate user enjoyment in games, the *game flow* [22]. Game flow is based in the flow theory analysed by Csikszentmihalyi [23], who conducted an extensive research on what makes experiences enjoyable. The game flow model states that for a game to have flow (*i.e.*, user enjoyment), the elements that must be present are: concentration, challenge, player skills, control, clear goals, feedback, immersion and social interaction. To evaluate each one of these elements we employed the criteria presented in the game flow model[2]. As in the original experiment of Sweetser and Wyeth, the value of each element is calculated by a simple mean of the assigned criteria. Each criterion is a series of five point evaluation Likert scale questions. User enjoyment is calculated by a simple mean of the seven elements of the game flow model. Each element is a dependent variable of our experiment.

Results: We ran the Mann-Whitney U test with the user's enjoyment variable, calculated using the participants' questionnaires. The test produced a score of -2,035 (p-value = 0,042) in the direction "robotic character > screen character". We performed another Mann Whitney U test with the different game elements of game flow as dependent variables. Here, the results showed that the game elements which are significantly influenced by the embodiment are Feedback, Immersion and Social interaction.

Discussion: The results were consistent with our second hypothesis. The robotic scenario had a more immersive user experience, an improved feedback and a more believable social interaction. In the related work, we referred that robotic characters usually enhance the feeling of social presence, resulting in more positive evaluations. By employing the game flow model to compare the user's enjoyment in the two scenarios, we concluded that the elements significantly higher in the robotic embodiment are also the ones related to the feeling of social presence, rather than the ones related to the game itself. This could be the reason why the eMuu's evaluation had different results, as they used a single question to evaluate enjoyment.

V. CONCLUSION AND FUTURE WORK

The field of social robots is yet in its early stage of development. Still, there are already some assumptions regarding the role that robots will play in our lives in a near future. Social robots can engage and entertain people, but they can also behave as assistants, helping people to accomplish different sorts of tasks. In this paper, we attempted to bring together these two directions, by creating the behaviour of a chess playing robot that can engage players and at the same time guides and helps them in the game, by the means of its emotional behaviour.

In summary, the findings of the first experiment indicate that a social robot with emotional behaviour can perform better the task of helping users to understand a gaming situation (than a robot without emotional behaviour). In the future, we want to investigate if such assumption can be extended to other domains beyond entertainment, for instance in the field of education. The second experiment clarified that user's enjoyment is higher when they are interacting with a robotic embodied character, when compared to the screen based version of the same character.

[2] Clear goals element was removed because the only existing goal in our game is very clear, to win the chess exercise.

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