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Virtual Actor with Social-Emotional Intelligence

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Abstract

This work continues the effort to design and test the cognitive architecture eBICA: a general model of emotionally biased behavior control and decision making, with the focus on social emotional relationships. The key building blocks of the model include dynamics of mutual appraisals of actors, bi-directionally linked to behavior, on the one hand, and on the other hand – to M-schemas, that establish normal behavior of two or more actors involved in a mutual relationship, such as partnership. To test the model, we implement a Virtual Actor embodied as an avatar in a specifically designed virtual environment, and use several paradigms of its social interaction with humans. We show that virtual environments and associated paradigms can be divided into a hierarchy, on top of which are paradigms with dynamically changing social relationships and roles. Using paradigms of this kind, we show that a virtual actor can be indistinguishable from a human participant in three dimensions: efficiency, believability and social acceptability. Some of the social measures demonstrate a higher-than-human performance, inspiring an idea of a new challenge for BICA and AI. The general model of a Virtual Actor presented here is anticipated to sparkle ideas of broad impacts on many practical areas.

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Keywords: cognitive modeling, virtual actor, emotional intelligence, virtual environment; Turing test

1 Introduction

Research in the field of cognitive architectures that capture the essence of the human mind [1] becomes increasingly popular today. Today intelligent virtual agents with elements of social-emotional intelligence are in the focus of attention [8,11]. This work is a continuation of our previous line of research [2-7,10,13].

Our previously used virtual environment [2] has been modified and further enhanced with new functionality in this study. The previously used experimental paradigms [2,3,4] are re-implemented in the new environment, and new paradigms are added here. The main objective of the study is to explore practically the following question: "Is it possible to create a Virtual Actor within the framework of the

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chosen environment and paradigms, such that its behavior is indistinguishable from the human behavior, on three groups of measures: efficiency, believability, and social acceptability?" Here we provide an answer.

2 Materials and methods

2.1 The Hierarchy of Virtual Environments

There are many kinds of virtual environments used today in cognitive modeling and research. Environments are divided into single-user multi-user, by type of control, by tasks facing the subject. An important aspect of a virtual environment in the context of the present study is an opportunity of social dynamics between actors in a virtual environment. Existing environments can be divided according to the type of social interaction: 1) no social interaction, 2) static social interaction, 3) dynamic, naturally emerging social interaction. The resultant taxonomy is shown in Figure 1.

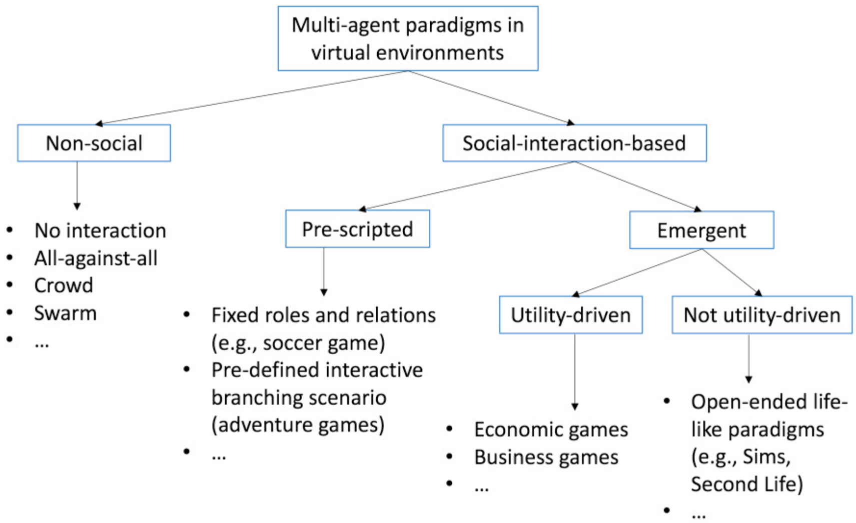

Figure 1: Taxonomy of multi-agent paradigms of social interactions in virtual environments, such as computer games. Utility-driven social interactions include rational behavior based on the maximization of a certain utility function. Not utility-driven social interactions may be driven by social emotions and individual feelings, among other factors.

Non-social, or independent, behavior occurs when social relationships among subjects are not impossible in the context of a given virtual environment. In this case, the overall effectiveness of the participant is independent of his or her ability to socialize and to emotionally interact with other participants, but is determined solely by factors like the reaction speed and previous experience with games in virtual environments.

Pre-scripted, or static social interactions occur in those virtual environments, in which social roles are set in advance and remain unchanged throughout the session. Thus, this environment allows participants to demonstrate the social and emotional aspect of their relationships, but at the same time, rapid changes in relations with each other are impossible.

In dynamic virtual environments, players have the ability to quickly change their roles within the paradigm. Thus, in this type of virtual environment, opportunities for social and emotional interaction are fully manifested. The state of leadership of one actor in relation to others is volatile and can be subject to a great variation over time in the course of players' interactions. Within such environments actors equivalent and reach their goals by a relationship with other actors.

2.2 Experimental Paradigms

In this study, the previously developed experimental paradigm "Teleport" was used, which is described in detail in our previous work [5], and a new implementation was created for the paradigm "Shooters" (Figure 2). Both paradigms were implemented on a specially designed platform on the basis of Unity. One feature of this platform is that humans and avatars are represented by avatars, that are indistinguishable from each other by their appearance and kinematics, and only differ by letter labels attached to them. Another feature is that the platform allows us to collect automatically large volumes of annotated data, containing detailed information about all events, including all behavioral actions of participants and Virtual Actors that happen during the experimental session.

Figure 2. A snapshot of the paradigm "Shooters" implemented in a virtual environment.

In the Shooters paradigm (Figure 2), three Actors (possibly of different nature) appear on the platform. Each of the actors has the opportunity to ask another for help or thank another actor. As in the previous paradigm, actors have the ability to cast off each other over long distances. A feature of this paradigm is the lack of a rescue zone. At given conditions, the actor has to survive on the platform to increase own score, indicated in the lower left corner. In addition, each player has an interface that allows him to answer as to who he believes is a virtual actor, and who is a human. Each of the actors has several options available to him. 1. Ask for help from another actor. A request for help from the actor is accompanied by the synthetic voice, speaking to that actor to which the action is applied, and also by making a rutn towards the target, followed by a special animation and a light effect. 2. Thank the other actor: express gratitude to the actor – implemented similarly. 3. Kick (push) the other actor. To kick another actor, it is necessary to approach this actor and click on it, then, under the condition that the KICK button is active, The actor, over whom the action was committed, flies a large distance is the direction opposite to the location of the actor, who gave him a kick. 4. Aim at the actor. To carry out the aiming action, it's enough to click on the actor - the target. After this, there will be a quick turn toward the target. The light indication will light up and then the actor will follow the direction toward the target, until another action will be performed. 5. Make a shot. To shoot, one needs to press the SHOOT button. After this there will be a release of the projectile in the direction straight ahead of the actor. The projectile can hit the target or miss. When a hit occurs, the affected actor is transferred to the state "wounded". In each round, one actor can shoot only once. 6. To cure one of the actors. This action only works for actors in the state "wounded". To activate it, one needs to press the HEAL button and the target, which must be healed. This action is also possible to perform only once per round. New actions in this experimental paradigm, with respect to the Teleport, are the actions of healing and shooting. The round in this paradigm ends after the actors present on the platform have ran out of charges. Also, a round may end given the condition that only one actor remains on the platform. A feature of this paradigm is the lack of a rescue zone. Under these conditions, the actor needs to stay alive on the platform until the round's end in order to win.

2.3 Model of a Virtual Actor

The basic idea of how to implement a model of a Virtual Actor is described in our previous work [4]. Constructs and equations used here originate from the eBICA* model introduced by Samsonovich [13] and give rise to the Virtual Actor model of this study. A new element is an M-schema (originally "moral schema"), also first introduced in [13], that is defined here in a particular case.

The model of a Virtual Actor used in this study is general, yet implemented in an adaptation for the selected paradigms. Each Actor has an embodiment in the environment and variables associated with it, that show its current state, including a positional state and f physical state. For example, a positional state in Teleport could be "on the tower of salvation" or "in the play zone", and the physical state could be "alive", "dead", "wounded," etc. In a more complex model, the actor will have an emotional component in its physical state [13], for example, "calm", "annoyed." For the present study, Actors use a data structure to store the ratings of other avatars. In this model, this structure is represented by a tuple:

$$\text{actor} = \langle B, S, D \rangle, \tag{1}$$

where B is the body (avatar) of the Virtual Actor, S is a state of the Virtual Actor, and D is the set of Dictionary entries. A dictionary entry is a pair of a key and a value, represented by a tuple:

$$D = \langle B, A \rangle, \tag{2}$$

where A is the rating – appraisal of the actor, who controls B. The appraisals A take values on the weak semantic map [12]. In our case, they are two-dimensional vectors with the components Valence and Dominance:

$$A = (\text{Valence, Dominance}). \tag{3}$$

Appraisals are values for action probability calculations. They need to be chosen in such a way that their values do not contradict position of their names on the semantic map [12], but at the same time they were adjusted in such a way that the actions having the greatest contribution to the game process were represented by the largest score for the absolute value (see also Section 2.5). Each action that is possible to perform in selected paradigms can be described by the following tuple:

$$\text{action} = \langle N, A, \text{S\_actor}, \text{S\_target} \rangle, \tag{4}$$

* Emotional Biologically Inspired Cognitive Architecture

where N - the name of the action, A - action evaluation, S_actor - state of the actor, S_target - state of the target. After the action is entered into the list of possible actions, new attributes are added to it, and the action is represented by a tuple of the following form:

$$\text{action} = \langle N, A, S\_\text{actor}, S\_\text{target}, B\_\text{calc}, B\_\text{exe}\rangle, \tag{5}$$

where the attributes N, A, S_actor, S_target remain unchanged, B_calc - the body against which to calculate the probability of action, B_exe - the body (avatar) with respect to which the action will be performed. These attributes can be explained as follows. The model is based on socially-emotional relationships, therefore, all actions have a recipient actor. Consider, for example, an action such as teleport activation, which is performed upon the teleport, an inanimate object. Nevertheless, since a certain actor is more likely than others to be able to use the teleport after its activation, the action of teleport activation has this actor as the recipient, as if the action was performed for him.

Action probabilities are given by the same equations as in previous works [2,13], when no M-schema is active. After activating an M-schema, the actor follows different rules. In this case, the likelihood of an action selection $L(a)$ is given by the equation

$$L(a) = \left[\mathrm{Re}\big((F - A)a\big)\right]_+ , \tag{6}$$

in which A is the target appraisal derived from behavior, F is the “feeling” about the target: the appraisal that is considered normal for the target, according to the M-schema; a is the appraisal of the action; Re is the real part, and [...]+ is the positive part.

2.4 Subjects and Procedures

For the experiments, a laboratory was equipped with computers of the same configuration connected to the network. It is worth noting that the location of computers was chosen in such a way that the subjects could not see each other. During the experiment, each of the subjects uses individual headphones, in which music is played from "Virtual environment". Thus, participants do not see or hear each other. At the avatars are created each time the random letters identifying them, which does not allow the subjects to remember who someone is playing, and above all remember the avatar controlled by a "virtual actor" under a letter.

On the first day of the final experiment, there were two groups of participants. In the first group, 8 people participated, who were Bachelor college students from NRNU MEPhI majoring in Program Engineering, in the 18-24 age group. All eight participants were male, for all participants the native language was Russian. In the second group, 8 people participated, who were Bachelor college students from NRNU MEPhI, in the 18-24 age group, 4 male participants, 4 female participants, for all these participants Russian was the native language.

On the second day of the final experiment, there was one group of participants. The group consisted of 12 people, including 11 Bachelor college students from MEPhI in the age group 18-24, among which were 8 male participants, 4 female participants, plus 1 male participant, age between 25 and 30, from University College London. For 11 participants, the native language was Russian, for one participant the native language was English.

In total, there were 28 participants in the final experiments. Each of the subjects voluntarily signed an informed consent form before participation in the experiment.

Detailed logs of all events in each round of each session were recorded and analyzed automatically by the implemented platform. In addition, participants completed survey forms.

2.5 Semantic Map of Elements of Behavior

In order for the Virtual Actor model to work, appraisals of particular actions (in Eq. 6) must be known. Therefore, we constructed a weak semantic map of actions in selected paradigms, by making an assignment of appraisal values to actions. Several sources were used for this purpose, including the semantic map coordinates of English words used to label the actions [4,13], estimates of the effect the action has on chances of winning or dominating in the game, and ranking by human subjects. In the latter part, 8 subjects from the above pool were used. Subjects were asked to rank 3 familiar to them game actions - Kick, Save, and Take Off - on the Likert scale from 1 to 10, along 3 dimensions, each perceived from 2 perspectives: the author and the target of the action. Dimensions of Valence (V), Arousal (A) and Dominance (D) were captured by the following questions: “How positive do you feel about the action?”; “How dominant you or somebody becomes due to performing / being a target of the action?”; and “To what extent performing / being a target of this action will excite or calm you?” The averaged outcomes are represented in Figure 3.

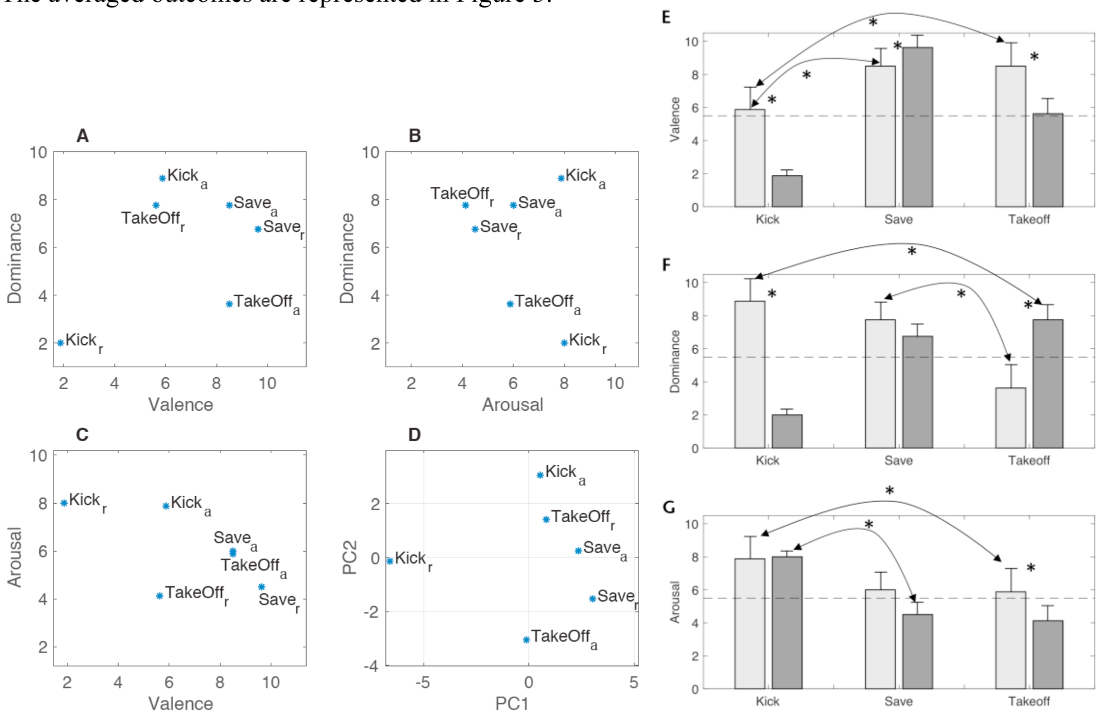

Figure 3. Semantic map of elements of behavior – available actions in selected paradigms, based on the ranking. A – C: the map in original coordinates ranked by the subjects. D: result of the principal component analysis. PC1, PC2 are the first and the second principal components. E-G: means and standard deviations on individual scales. Subs. “a”, light box – author perspective; subs. “r”, dark box – recipient perspective. Asterisks mark significance.

In addition, it was calculated based on the ranking data that the following is significant (Figure 3, panels E-G, asterisk marks): Va(Kick)>Vr(Kick), Vr(Save)>Va(Save), Va(TakeOff)>Vr(TakeOff), Va(Kick)<Va(Save), Va(Kick)<Va(TakeOff), Da(Kick)>Dr(Kick), Da(Kick)>Dr(TakeOff), Da(Save)>Da(TakeOff), Ar(Kick)>Ar(Save), Aa(Kick)>Aa(TakeOff)>Ar(TakeOff).

3 Main Results

Three main metrics were used in this study to evaluate the Virtual Actor social behavior: believability (how frequently the actor was identified as a himan), social acceptability (how frequently the actor was selected as a partner – or as a competitor), and efficiency (the survival rate). Results for each of them are described below.

3.1 Believability

Believability of the Virtual Actor has two components: one due to the implementation of the Virtual Environment, and another – to the model of the Virtual Actor.

Summarizing all the collected answers in survey forms, it is possible to conclude the following: some subjects say that the behavior of the Actor is too slow, while others, on the contrary, say that the "virtual actor" is too quick to respond. At the same time, statistically speaking, the participants have failed in determining who is the Virtual Actor, and who is the human – see Figure 4.

SessionID	Session Type	AI Type	ParticipantID	Avatar letter	Actor letter	Answer letter	Correct answer	Почему вы так считаете?
31510	1bot	moral	31	A	C	B	False	Потому что Автомат не ста
31510	1bot	moral	33	B	C	C	True	быстрее начал действоватt
31659	1bot	moral	29	C	B	B	True	Тактика игры
31659	1bot	moral	36	A	B	C	False	Методично убивал одного и
49156	1bot	moral	32	C	A	A	True	стрелял в меня, не шёл на к
49156	1bot	moral	38	B	A	C	False	быстрая реакция, постоянн
75444	1bot	moral	28	B	A	A	True	
75444	1bot	moral	37	C	A	B	False	A appeared annoyed by me c
88052	1bot	moral	30	A	B	C	False	тактика "против всех"
88052	1bot	moral	39	C	B	A	False	Использовал агрессивное п
99874	1bot	moral	34	C	A	C	False	Поведение слишком уверен
99874	1bot	moral	35	B	A	C	False	Дерганые движения

Figure 4. A fragment of the compiled summary of survey forms for the “Shooters” paradigm. Red color indicates wrong identification of the Virtual Actor. The right column contains answers, typed by the participants in Russian. “Avatar letter” is the label of the avatar, controlled by the participant. “Actor letter” is the label of the avatar, controlled by the Virtual Actor. “Answer letter” is the participant’s answer to the question, under what letter was the avatar controlled by the Virtual Actor. In 8 out of 12 cases the answer is wrong.

It is notable that a correct identification of the Virtual Actor, when it occurs, is not correlated with subject’s judgment of the avatar as moving unnaturally. Therefore, given the current implementation of the virtual environment, it is impossible to know who is the Virtual Actor and who is a human, based on how quickly or slowly the avatar responds to actions. It is also not possible to reliably give the correct answer to the same question, based on the Actor’s high-level behavior, as results indicate. Indeed, overall, based on the total set of 60 answers given by participants, the 95% confidence interval for the probability of correctly guessing who of the two opponents is the automaton is (0.34, 0.60), meaning that the null hypothesis of “guessing by chance” cannot be rejected (P-value = 0.69). The rate of mistakes over all sessions is actually higher than chance, although not significantly higher.

3.2 Efficiency

Summarizing results of all sessions, we found no statistically significant difference in efficiency (i.e., the survival frequency) between the Virtual Actor and human participants. This is true for each implemented paradigm separately and for all experimental sessions taken together.

3.3 Social Acceptability

Social acceptability was evaluated based on two criteria: Criterion 1, the frequency of selection of the virtual actor as a partner, and Criterion 2, the frequency of selection of the virtual actor as a competitor. Results are described below.

Criterion 1. One of the questions to participants was: "Did you select a partner?" In 63% of all cases, subjects answered that they did. Only in 30% of those cases their partner choice was the Virtual Actor. Statistical analysis shows that the selection was not random: the bias was toward another human participant (P-value < 0.007). At the same time, there was no significant correlation between the partner choice by a participant and their guess as to who was the human. Therefore, the higher-than-chance probability to choose a human partner characterizes decisions made intuitively, without awareness of who is the human and who is the automaton. Still, based on Criterion 1, we conclude that the implemented Virtual Actor has lower than human social acceptability.

Criterion 2. Participants also answered the question, whom did they consider as their competitor. In 63% of cases they answered that they did consider somebody as their competitor, and in 82% of those cases their choice of the competitor was another human participant, and not the Virtual Actor. The 95% confidence interval for the probability of this outcome is (0.68, 0.91), and the value of the estimated probability is therefore significantly higher than the chance level of 50% (P-value < 6.e-5). This is a remarkable outcome. It tells us that the created Virtual Actor is more socially acceptable than a typical human participant, based on Criterion 2.

4 Conclusions and Discussion

In conclusion, in this work we presented a new platform that can be used for social psychological experiments in virtual environments, with anonymous participation of humans and Virtual Actors. We also presented the study of an implemented Virtual Actor based on the eBICA model [13]. This model uses a semantic map of elements of behavior, together with M-schemas, to generate decision making and behavior of a Virtual Actor. Results of the study allow us to validate the model.

Two experimental paradigms were implemented and used for empirical testing of the model. The outcomes are the following.

1. Virtual Actor is indistinguishable from a typical human participant based on its efficiency.
2. Virtual Actor is indistinguishable from a typical human participant based on its believability.
3. Virtual Actor is slightly worse than a typical human participant in social acceptability, based on Criterion 1.
4. Virtual Actor is better than a typical human in social acceptability, based Criterion 2.

The overall conclusion is that the implemented Virtual Actor performs at a human level. This outcome constitutes a strong support for the designed model of a Virtual Actor, based on the further developed cognitive architecture eBICA.

The main volume of data collected in this study automatically in the form of logs of all events happening in the environment is not presented here, due to the limited volume of this publication. Its analysis will provide us with new insights into the model, as well as being able to serve as an alternative, behavior-based, objective basis for evaluations of the three characteristics presented here. For example, social acceptability can be measured by the frequency of obtaining help from others. Analysis of these details will be presented elsewhere.

The fact that on one scale (Criterion 2 of social acceptability) the Virtual Actor scored significantly better than an average human is totally remarkable. If this choice could be regarded as an answer to a modified Turing test [14] question, then we would claim a precedent of an “Overman”: a machine that looks more human than the humans themselves. In fact, the idea of the Overman challenge was inspired by the higher-than-chance (although not significantly higher) rate of participant's mistakes (Figure 4).

The idea is the following. Consider a study – this one or another one – in which humans and automata participate anonymously, and let one of the task for human participants be to identify the human among other entities in the environment. Let us say, the result is negative when the human is identified correctly, and the result is positive when the automaton is identified as a human by mistake. The goal in the Turing test challenge [14] is to make probabilities of the positive and negative answers statistically equal. In contrast, the goal in the *Overman Challenge* is to make the probability of the positive result significantly higher. The present study demonstrates that not only this is logically possible, but may be practically achievable, while at the same time nontrivial.

Therefore, this work needs a continuation. In future work, it is planned to make an extension to the existing set of paradigms for testing models of social emotional intelligence with Virtual Actors. New interaction paradigms will allow for achieving more ambitious goals with relatively simple means. Using the developed platform, it will be possible to make and test further modifications of the Virtual Actor, at the same time expanding the range of domains of the applicability of the model.

The last remark that should be made here is that the emergence of intelligent virtual actors possessing human-level social-emotional intelligence raises many ethical and philosophical questions [9]. Work in this area is therefore very important. Our platform will enable a comparison of different modeling approaches based on them artificial systems to each other and to the human brain and its internal dynamics, in terms of many behavioral characteristics in many virtual environments.

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