Social Behavior Investigation of Intelligent Virtual Agents

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Key Words: *Intelligent virtual agents (IVA); architecture; social behavior; social scenario; moral emotions; social emotionw primary and secondary emotions; needs; rationalities; knowledge; ambivalence; choice; deception.*

Abstract: *This paper investigates the social behaviour of an intelligent virtual agent (IVA) with PRE-ThINK architecture with the help of typical working student's life scenario modeling. The program system and the PRE-ThINK architecture, adapted for this scenario, are proposed, and their components are considered. The dynamics of the decision making process in problem situations caused by the implementation of this architecture is shown, when mixed emotions arise and the realization of what happened reflects on the agent's temper. IVA's social behavior is shown, during which in the process of communicating with the user the agent expresses* learned *from experience secondary emotions, which can be either in harmony or in conflict with the* realized *secondary emotions, resulting both from the agent's generalized condition and the events. The investigated secondary emotions are: relief, confidence, prestige, uncertainty, confirmed fear, disappointment; and also the socially expressed secondary emotions such as refrained sadness, refrained anger, businesslike manners, politeness and authoritativeness. The results show that the users perceive the modeled IVAs as socially functioning persons, recognize their real emotional state and are interested in their problems.*

1. Introduction

In general, social norms are commonly believed rules in social interaction. These rules serve as a guide for human behavior, and as the basis for their beliefs and expectations about others. Without them, communication can break down easily [Si Mei, Stacy C. Marsella, and David V. Pynadath 2006].

Social interaction is accompanied by social emotions. Social emotions can be defined as one's emotions projecting on or affected by others. They are „valenced reactions", which can occur as a result of how people understand events. The first modification to the OCC model, (that define a cognitive approach for looking at emotions) is to allow for the definition of social emotions [Ortonty, A., Clore, G. L., Collins 1988].

[Damasio 1994] distinguishes at least two classes of emotions, namely, primary and secondary emotions, on the basis of his neurobiological findings. According to them secondary emotions are more dependent on the agent's cognitive reasoning abilities. The appraisal of secondary emotions depends much more on the situational context and an agent's memory than that of primary emotions. The releasers of secondary emotions might be learned based on the history of primary emotions in connection with memories of events, agents, and objects. The agent's facial expressions of primary emotions may accompany secondary emotions such that they do not necessarily need to be expressed by their own set of facial expressions. Secondary emotions also modulate the agent's simulated embodiment, such as its general level of arousal. The agent expresses its awareness of secondary emotions verbally. Secondary emotions are based on more complex data structures than primary ones. Accordingly, only some general aspects of secondary emotions (such as their respective valence components) are represented in three-dimensional emotion space PAD that determines values of the intensity of the pleasure, arousal and dominance.

Recently a number of investigators distinguish between primary and secondary emotions, underlining the importance of their modeling and studying [Andrй, E., Klesen, M., Gebhard, P., Allen, S. ,&Rist, T. (1999); Pelachaud, C., & Bilvi, M. (2003).; Becker-Asano, C., & Wachsmuth, I (2008)].

[Rehm Matthias and Elisabeth Andre 2005] focus on synthetic agents that may express emotions that are in conflict with their appraisal processes and they put a question: how to handle situations in which the agent decides to display an emotion which is in conflict with its internal appraisal processes in social settings.

Acording to [Benny Ping-Han Lee et.al. 2006] the emotion models and architectures for virtual agents are not yet advanced enough to be imbued with coexisting emotions but this is very important because mixed emotions, especially those in conflict, sway agent decisions and result in dramatic changes in social scenarios.

In order to contribute to further development of the described problems, this paper investigates the social behavior of an intelligent virtual agent (IVA) with PRE-ThINK architecture by means of typical working student's life scenario modeling. The program system and the PRE-ThINK architecture, adapted for this scenario, are proposed. The basic modules of the programming system and the implementation of this architecture are considered. The mechanism of arising of the agent's thoughts, as well as their assessment, is cleared out. The dynamics of the decision making process in problem situations is shown, when mixed emotions arise and the IVA's behavior changes in a way, allowing achieving all of the goals of the scenario,.

The social behavior, shown by the agent, as well as his/her generalized condition of awareness, which are not always in harmony, is explained and presented. The proposed scenario allows for modeling and expressing of both primary and secondary emotions. The social emotions, shown by the IVA, when giving answers to user's questions in the experimental on-line information site, are a mixture of primary (spontaneously caused by the current context emotions) and secondary emotions (*demonstrated* - learned from IVA's experience in a similar situation; *and realized* - caused by the IVA's self-esteem related to his/her generalized condition and by all the simultaneous events, hidden for the users).

The IVA aspires to hiding the secondary emotions, caused by the realization of his/her generalized condition when the condition is not quite good due to a failure, disappointment or

overtiredness. The IVA aspires to expressing the necessary social emotions, learned from experience, when communicating with the users of the site, regardless of his/her real temper or feelings at the moment. The current situations could cause spontaneous primary emotions, but even they are also influenced by the temper and by the learned reactions of the IVA.

The rest of this paper is organized as follows: Section 2 considers similar developments; the third section presents the scenario for the goals of the experiment; the fourth section comprises the description of the programming system and the model of IVA with PRE-ThINK architecture, adapted for typical working student's life scenario modeling. Section 5 gives description of the experiments and experimental results. The sixth section includes discussion and directions for further development of the programming system; a generalization of the present work is proposed at the end.

2. Background

There is a considerable body of work on social norms and norms in conversations in particular, including formalization of norms and obligations [Boella, G., Torre, L.v.d. 2003], how norms emerge, spread and get enforced in a society [Castelfranchi, C. 1995], levels of cooperation in social communications [Airenti, G., Bara, B.G., Colombetti, M. 1993], discourse obligations in dialogues [Traum, D.R., Allen, J.F. 1994] etc.

In Thespian's decision-theoretic framework [Si Mei, Stacy C. Marsella, and David V. Pynadath 2006], conversational norms enable the characters to behave human-like by making relevant responses, following natural turn-taking patterns, and having appropriate conversational flow.

[deRosis Fiorella, Catherine Pelachaud et. al. 2003] as well as Prendinger and colleagues [Prendinger Helmut and Mitsuru Ishizuka 2001] developed agents that are able to control their emotional displays if the social situation requires it. For instance, if the social distance between an agent and its conversational partner is high, Prendinger's agent would not show anger to the full extent.

The virtual tutor COSMO [Lester J. C. et. al. 2000] intentionally portrays emotions with the goal of motivating students and thus increasing the learning effect.

In the WASABI architecture [Becker-Asano, C., Wachsmuth, I.] use their agent's cognitive reasoning abilities to model the mood-congruent elicitation of secondary emotions as well. They explain how nine primary emotions together with three secondary emotions-namely the prospect-based emotions hope, fears-confirmed, and relief -were integrated in such a way that their mood congruent elicitation can be guaranteed. They discussing results of a study on the effect of secondary emotion simulation in a card game scenario.

In [Gebhard Patrick, 2005] layered model of affect, called ALMA are simulated three interacting kinds of affect as they occur in human beings: 1. Emotions reflect short-term affect, which is usually bound to a specific event, action or object, which is the cause of this emotion. After its elicitation emotions usually decay and disappear of the individual's focus. 2. Moods reflect medium-term affect, which is generally not related with a concrete event, action or object. Moods are longer lasting stable affective states, which have a great influence on human's cognitive functions.[Morris W. N. 1989] 3. Personality reflects long-term affect. Personality reflects individual differences in mental characteristics. A common personality schema is the Big Five model of personality [McCrae R. R. and John O. P. 1992]. It specifies the general (affective) behavior by the traits openness, conscientiousness, extraversion, agreeableness and neuroticism.

In [Benny Ping-Han Lee et. al. 2006] an improved emotion model integrated with decision making algorithms is proposed to deal with two topics: the generation of coexisting emotions, and the resolution to ambivalence, in which two emotions conflict.

[Rehm Matthias and Elisabeth Andre 2005] model situations in games and monologues in which the agent fails to entirely conceal its „felt" emotions and they investigate the influence of such a behavior on the relationship between agent and user.

Many researchers model IVA behaviour aiming at establishing a trust-based relationship between the user and the IVA [Celso M. de Melo et. al. 2009, Jonathan Gratch et. al 2007, Timothy W. Bickmore et. al.2007, Radoslaw Niewiadomski et. al. 2008]. Thus IVA-s are modelled, having capabilities to express the so called moral emotions (pity, gladness, sympathy, remorse) [Celso M. de Melo 2009], and the way in which the frequency and the moment of sending a positive feedback from the user to the IVA [Jonathan Gratch et. al. 2007], influence the trust between them, is investigated. Agent's behaviour is modelled so that it follows the user's behaviour [Jonathan Gratch et. al. 2007].

A hypothesis has been derived [D.Budakova et. al., 2010] that agents with subjective behaviour could be well accepted among users, if this behaviour is a well grounded and fair subjective behaviour. Only in this case it will lead to users' reactions like sharpening their attention, increasing their trust in the agent and more natural perception of the IVA. An option for the user to try to meet the requirements of the IVA and gain its approval exists as well. [D. Budakova et. al., 2010].

It is assumed that an intelligent virtual agent (IVA), capable of detecting a critical situation, of analyzing it and choosing the best possible option to take care of all individuals concerned, would easily gain trust. Such a behavioural model is presented with the help of the PRE-ThINK architecture. [Budakova D., 2011].

The PRE-ThINK architecture, proposed in [Budakova D. 2011] (abbreviation from the initial letters of the basic components making it up - Principles, Rationalities, Emotions, Thoughts, Investigations, Needs, and Knowledge) also allows for modelling an IVA, having capabilities to detect and analyze conflicts. Problem situations evoke conflicting thoughts, accompanied by mixed emotions and they are related to a number of different ways of action. The agent considers in advance (Pre-Think) in what way each possible action in a critical situation would reflect over all individuals concerned by it. The originated social thoughts are assessed from emotional, rational and needs-related points of view in accordance with the knowledge, priorities and principles of the agent. Agent's behaviour motivators are its needs according to Maslow's theory [Maslow A.H. 1970].

In the present paper the agent with PRE-ThINK architecture

is used to investigate social behavior in typical working student's life scenario.

3. The Scenario

For the purposes of the experiment the behavior of the typical working student is modeled, that have to follow the polite form of social communication at work; fulfill diligently its duties at work; manages to pass all its exams; and manage to attend all meetings and parties, organized by its friends. According to this particular scenario the IVA is modeled to be an attractive 20-year-old blond student, giving information to the users of an experimental, especially developed for the experiment site, in the role of an on-line receptionist.

The users can only observe the IVA's behavior in its role of an on-line receptionist. The other events, related to its modeled personal identity in accordance with the modeled scenario (student's life, sleeping time, party time) as well as the course of time, remain hidden for the users of the site and are only simulated in a programming way.

The new aspect in the proposed paper is that a situation is modeled, in which the hidden/refrained emotions are caused by events that are outside the current context and not related to the current events, while the shown emotions are related to the current context but they are well considered and result from personal experience as well as from studying of social standards.

The real (realized and refrained) secondary emotions of the agent, on one hand, could be: confidence, satisfaction with the achievements and self-belief. They result from well fulfilled tasks, passed exams, well spent time at parties with friends, high ranking by the users of the site, and they evoke at first happiness, relief and pleasure and after their rationalization they turn in the course of time into self-confidence, certainty and authoritativeness.

This can be expressed by politeness, energy, friendliness, readiness to help and understand the others, willingness to communicate and join both the others and various good causes.

On the other hand, these emotions could also be: inferiority complex, disappointment and depression, lack of self-belief, what is caused by failures at the exams, unfulfilled tasks at work, lowered ranking by the users, and they evoke at first fear and anticipation of failures, as well as confirmed fear and after their rationalization in the course of time they turn into disappointment and inferiority complex. They could be expressed by irritability, aggression, dictatorial behavior or shyness, sadness, depression and self-isolation from the others.

The model allows for realization of other scenarios for social behavior investigation as well as for observation of the process of decision taking.

In order to reach all her goals, the IVA plans her time for studying, working, sleeping and meetings with friends, so that their optimal apportionment is achieved. The scenario allows observing how in the course of time, day by day, each deadline is met and the IVA achieves this perfect time apportionment.

The IVA makes her plans in accordance with her principles to neglect (only within the thresholds of dissatisfaction) the basic needs in order to achieve the higher goals. Consequently, new situations and new choices could be realized in case of changing the relation between the needs and the corresponding IVA's actions and goals, as well as by setting new actions, different from the already predefined ones.

Studying the way in which an IVA gains experience from the communication with the users of the site or the way the IVA learns to be businesslike and polite regardless of her problems, failures or successes will be a subject of another investigation.

It is presumed that with the further development of the system it could be possible to realize a backward investigation, i.e., having given the taken decisions in a problematic situation, to build the model of the investigated person.

The simulated course of time could be quickened or slowed down.

4. The Program System Description

The basic modules of the program system are:

1) **interface module**; 2) **module for simulating the course of time** - days and hours; 3) **module for decision making and defining the agent's actions by means of the PRE-ThINK architecture** according to her goals, principles, priorities and the assessment of the generated thoughts; 4) **module for initialization of the scenario**, comprising the relation need - action, deadlines for achieving goals, related to the different needs and emotions, the necessary number of working hours for successful fulfilling of a task, the hours for passing an exam and for normal attendance of parties, as well as the agent's luck and abilities (*figure 1*).

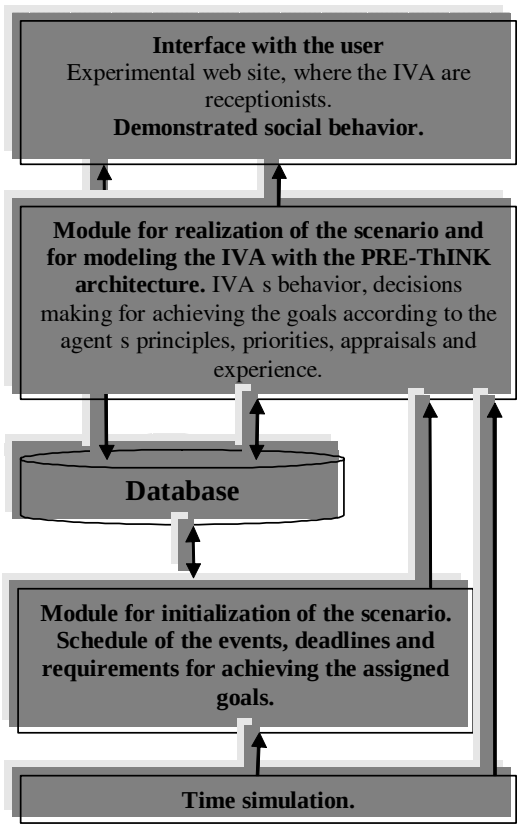

Figure 1. Structural scheme of the program systems

The Interface Module

The interface module includes the experimental web site, working for the purposes of the experiment, with an IVA - receptionist, modeled according to the scenario of personal identity and with the PRE-ThINK architecture. The IVA gives the web site's visitors information in correspondence with the topics offered like forthcoming events at the university and in the investigation groups at the university; explains the location of the laboratories in the building of the university; tells when and where the various classes happen. The IVA has social conversational capabilities. She always greets the web site users, asks them how she could help them, how they feel, what is new etc. When in good temper, she speaks a bit highly, uses jokes in her answers; when sad, she tries to hide her sadness, speaks slower and more quietly, gives shorter answers and apologizes.

The experimental site is divided into three frames. The first one is for choosing the topic in which the user is interested; the second - for modeling the IVA's behavior, for initialization of the scenario, as well as for simulating the course of time; and the third is for visualization of the agent's head and realization of the agent's multimodal social behavior.

The following relation is realized: a chosen question and a corresponding answer, generalized condition of the agent, temper, temperament, self-confidence, emotional but socially appropriate pronunciation of the answer by the IVA.

The user can see and ask the IVA questions by means of the site only. The rest of events and experiences from the predefined scenario remain hidden from him/her.

The Module for Initialization of the Scenario

The relation need - action is preset as it follows: physiological need - need of sleeping; need of safety - working position as an on-line receptionist; need of love and belonging - attendance at parties with friends; need of self-actualization - university course (*figure 2)*.

According to Maslow's theory the needs in normal human development are arranged as follows: physiological (ph), safety (s), love and belonging (lb), esteem and self-assessment (es), self-actualization (sa), aesthetics (a). In the architecture considered here the needs are associated with weights Wneed corresponding to their priority. Wph, Ws, Wlb, Wes, Wsa, Wa.

When, because of the occurrence of an event, one or more needs prove to be unfulfilled, i.e., there is a crisis situation, then

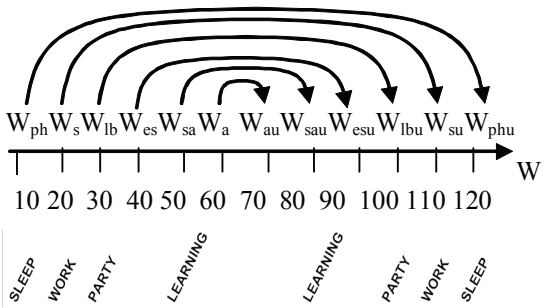

Figure 2. Arrangement of the fulfilled and unfulfilled needs in a crisis situation and their weight together with the correspondence of the relation need-action according to the considered scenario

the needs rearrange so that the unfulfilled ones receive first priority. The unfulfilled needs arrange in an order, opposite to the order of needs weights in a normal state of the agent. The unfulfilled needs are denoted by W_{phu}, W_{su}, W_{lbu}, W_{esu}, W_{sau}, W_{au}. This concept is illustrated in *figure 2* where the predetermined (according to the scenario) simplified relations of the type need - action are denominated both for a normal and for a crisis situation. This is the sequence of the IVA's priorities when there are no problems and the activities are arranged according to their correspondence from the most basic physiological need towards the higher ones - confidence, love and belonging, self-actualization, on the one hand, and according to their rearrangement when a need has remained dissatisfied because of the circumstances.

The system in the next version is envisaged to be able to process the cases in which an activity could be related to a different degree with more than one need and just the opposite case when each need is related to a different degree with more than one activity.

The **dates** of the exams, the dates of fulfilling the working tasks and the dates of the parties are predetermined. The hours necessary for the agent to get ready for the exams, the **hours** for a task to be fulfilled successfully, the sleeping hours and the hours to enjoy a party are also predefined.

The IVA's **luck** and **abilities** are predetermined as well and they can facilitate or slow down the fulfillment of a task, they can lead to a failure at an exam, they can ruin one's sleeping or his/her time at a party. The **thresholds of dissatisfaction** for each task, related to a particular agent's activity are also predefined.

An **initial schedule** for realization of the IVA's goals is predetermined. It defines the initial apportionment of the hours in the agent's day and night and it is as it follows: working time from 8.00 to 17.00 - during this time the IVA fulfills the tasks related to her job position as an on-line receptionist; after that 3 hours are envisaged for meetings with friends; 3 more hours are distributed for exam preparation and the rest of the hours from 23.00 until 8.00 are for sleeping till morning when she has to go to work again.

This is the exact initial apportionment of the time which changes in the course of the events in the agent's life and their optimum arrangement is a goal of the algorithm for decisions making by the IVA.

The variables, in which every success or failure, related to a particular event, will be memorized, are set to zero. They are, for instance: success_studying; success_work; success_party; failure_studying; failure_work; failure_party; sufficient_sleeping; insufficient_ sleeping; general condition_good, general condition_bad, general condition_worsening, general condition_bettering. All of these assessments are related to the emotions, which are formed, realized and expressed in the course of time in result from the IVA's successes and failures. They are, respectively: happiness, anticipation of a success, confirmation of a success, satisfaction, self-confidence, and prestige, on one hand, and, on the other hand - sadness, anticipation of a failure, confirmed failure, disappointment, depression or anger.

The IVA's aspiration/goal is to succeed in each of the

directions, to be in good spirits and have self-confidence.

Simulating the Course of Time

The course of time is simulated by means of the component Timer. Every hour is counted out and the sequence of the morning, the noon, the evening and the night is controlled; it is also controlled what the IVA is supposed to do according to the initial schedule in each particular moment; the real agent's behavior and actions in a moment are also controlled and the activities from the schedule and the real behavior according to the decision made are compared. All the agent's activities are saved in the database. The IVA knows how many tasks remain to be fulfilled, how many successes and failures are, to which activities they are related.

Modelling of the IVA with the PRE-ThINK architecture and the process of decision making for defining the IVA's behavior

IVA's principles. Anticipated IVA's behavior in accordance with these principles

The IVA takes its decisions based on its principles. The following IVA principles have been modelled: „Choose the better possible action"; „Neglect the basic needs until reaching a definite threshold of dissatisfaction, giving priority to the highest-order needs", „Follow a polite form of social behavior regardless of your personal successes or problems".

The IVA starts following her initial schedule and realizes whether she manages to cope with the assigned tasks or not. She also realizes how many tasks from each activity remain to be fulfilled, e.g., how many exams to pass, how many working tasks etc. According to the principles if the IVA does not pass her exams, for example, she will try to reallocate more hours for studying at the expense of the sleeping hours at first; if this does not help, then the new arrangement of hours is done at the expense of the working hours; and, last, at the expense of the time spent with friends. If all of these measures do not help and her physiological need - her needs of safety and friendship are seriously threatened, then, according to her principles, realizing Maslow's theory and according to the predetermined at the initialization very simple relation need-action, the IVA will stop her studies in order to redress the balance of the more basic needs, sacrificed in the name of her assigned highest need/goal in this scenario.

IVA's thoughts. Process of decision making

Each thought of the agent is related to an emotional (positive (+) or negative (-) sign), rational and need value and receive the weight of this need.

Each thought is addressed to the situation s be denoted by Th_s. If the importance of the thought Th_s is denoted by I_{Th_s}, the weight of the need, related to this thought is expressed by W_{needTh_s}, , the emotion implied by this thought is marked by $E_{emot.Th\_s}$, then, following the formulae for calculating the assessment value of the thought O_{Th_s} corresponding to the situation s will be [Budakova D., 2011]:

$$O_{Th\_s} = E_{emot.Th\_s} * W_{needTh\_s} * I_{Th\_s}.$$

If a thought is partially related to more than one need then the sum of the weight percentages of the needs to which it is related is taken into account in the formulae.

Each thought is related to an action.

The assessment values of the thoughts related to one and the same action in one and the same situation are put on the one basin of the „thoughts balance". The assessment values of the thoughts for the same situation, but related to another action, are put on another basin etc. Our „thoughts balance" will have as many basins as the alternative actions considered by the agent in the particular situation are. The module of the assessment values is summed and the action from the basin having the highest assessment value is undertaken. The emotion, experienced by the IVA in a particular situation is determined by the prevalent emotion. After an action has been undertaken, the agent keeps track of the effect from it. The IVA's state and priorities are changed anew and they depend on whether the problem has been solved or there is a new conflict situation to be solved [Budakova D., 2011].

The described mechanism for decision making is adapted for the purposes of the considered scenario. Instead of choosing the action from the basin having the highest assessment value, the action with the lowest ranking is sought for here, i.e., the less important for the moment. The hours used for it will be reduced in order to spare *time for other more important activities and, respectively, for achieving other dissatisfied goals*.

Mechanism of origination and assessment of the IVA's thoughts

The IVA's thoughts are generated in 24 hour each clock round and they are related to the events from the agent's schedule, to her generalized condition, to the successful or unsuccessful fulfillment of the goals, as well as to the possibilities for action. Each thought, related to achieving a goal/action, is assessed from emotional, rational and need-related point of view. For example, if the IVA has failed at her exam today, her thoughts are of the type:

I am sad because I did not manage to prepare myself well enough for the exam. I am a very capable person and I believe in myself. (Emotion: uncertainty and anticipation of failure). I have to increase my time for studying and I will cope with my task as always. (Emotion: hope and anxiety). The sleeping hours are enough and I feel good. (+) The working hours are enough and I cope with my tasks perfectly well (+). The time for meetings with friends is enough and I feel well (+).

Thoughts related to possible actions:

I can increase my hours for studying at the expense of reducing the sleeping time. Emotion (+); weight of the need for sleeping 10; rational assessment - easy and safe 1; general assessment of the thought related to this action (+10).

I can increase my hours for studying at the expense of reducing the working hours. Emotion (+); weight of the need for work 20; rational assessment - easy and safe 2; general assessment of the thought related to this action (+40).

I can increase my hours for studying at the expense of reducing the hours for meeting friends. Emotion (+); weight of the need for meeting friends 30; rational assessment - easy and safe 2; general assessment of the thought related to this action (+60).

The initial choice of action in this situation is to reduce the time for sleeping and increase the time for studying as this is the easiest and the safest action related to the need with the lowest weight. All the other possible actions are much harder and they are related to higher needs, which are difficult to neglect.

If the spared hours turn out to be insufficient for the successful passing the exam and it is impossible to reduce further the sleeping time because of reaching the threshold of tiredness, then the next appropriate action would be to reduce the time for fulfilling the working tasks and duties in order to increase the time for studying a bit more etc.

In addition to choosing an action for improving her generalized condition, the agent also generates thoughts about her social behavior at her working place. For example:

Today I am sad because of the failure at my exam but I have to be polite with the users of the site and give them exhaustive information.

Today I am in perfect temper and in addition to the information I will give the users I could also be witty, etc.

5. Experimental Setting and the Experiment

I. Investigation of the IVA's Behavior

According to the described scenario the following elements are predetermined:

1. Schedule of the sequence of events/IVA's goals;
2. Schedule for realization of the goals.

The schedule of the sequence of events/goals comprises the events from the first until the last day of the experiment and the number of hours needed for meetings with friends, sleeping, passing the exams and successful fulfillment of the working tasks. The days are numbered from first to thirty fifth. In order to further simplify the scenario it is assumed that the IVA studies for every exam until the day of the exam and works over a task until its deadline. Regardless of whether an exam is passed or a task is completed, after their deadlines the IVA starts studying for the next exam and working over the next task. Only the success or the failure influence the agent's generalized condition and they initialize the process of rearranging the hours in the schedule for realization of the goals.

The days of the parties, predetermined for the time of the experiment are accordingly on the 2nd, 5th, 12th, 18th and 26th day of the experiment and the duration of the parties is from 6 to 8 hours.

The IVA's schedule for realization of the goals is also determined initially and it is the schedule which the IVA is supposed to optimize in the course of the experiment depending on the successes and failures.

The initially determined schedule for the particular experiment is the following:

8:00 - 17:00 working time;
17:00 - 20:00 time for friends;
20:00 - 23:00 time for studying;
23:00 - 8:00 time for sleeping.

The idea is to give the IVA the possibility to redistribute these hours, for example, in case there is a party, i.e., instead of sleeping to go with her friends to the organized party; if she has failed at an exam, she can increase the hours for studying at the expense of the sleeping hours etc.

The first experiment illustrates the consequences for the IVA if she follows the schedule without changes. The IVA studies less than needed and correspondingly she fails at the exams. The working time turns out to be sufficient for fulfilling the tasks and duties perfectly.

The sleeping hours are also sufficient and the IVA does not miss a party.

The second experience shows how the agent tries to cope with her problems at the university by increasing at first the hours for studying at the expense of the sleeping hours and then, at the expense of the working hours.

After she fails at her first exam, the IVA increases the time for studying at the expense of the sleeping time. After the second failure she reduces the sleeping time even more in order to study harder. After the third failure she reduces the working time, too, and this is how she manages to pass the fourth and the fifth exams. The success turns out to be sufficient for bringing back her happiness and self-confidence.

II. Investigation of Intelligent Virtual Agents' Social Behavior

For the purposes of the second experiment two IVAs are modeled with visualized speaking heads. They are called Lilly (*figure 3a*) and Mira (*figure 3b*).

The two modeled virtual agents have the same problems but show different social behavior. Both virtual agents always give the users complete, precise and clear information.

The IVA Mira is modeled to be extremely friendly, to express her happiness or sadness in a very open way, to be inclined to sharing her problems comparatively easily. She continuously tries to make friends with the users by asking questions, expressing suggestions, sharing information about the root of the events they are interested in. When sad, she speaks slower than usual and in a lower voice. Her answers, however, are still complete and exhaustive.

The IVA Lilly is modeled to behave in a more reserved way. Her answers are always complete and concrete but short and quick. She does not want to share her problems and always evades personal questions. She never tries to make friends with the users and talk to them. She is just polite and always wishes them success. When sad, she speaks even faster than usual and in a loud voice. Her face expression shows either severity or some boredom and nervousness.

Masking some of the feelings (their restraining) is achieved by introducing mimics, not corresponding to the emotional state, which the IVA tries to express, as well as by changing the loudness and the speed of speaking. The users are expected to catch and discuss exactly these discrepancies.

The visualization of the IVAs is realized by means of the program product Crazy Talk 6.

For the purposes of the experiment the program was offered to 30 students at the TU-Sofia, Plovdiv Branch. They had the opportunity to get information about forthcoming events at the university from the virtual agents Mira and Lilly. They were

Fig. 3a The IVA Lilly

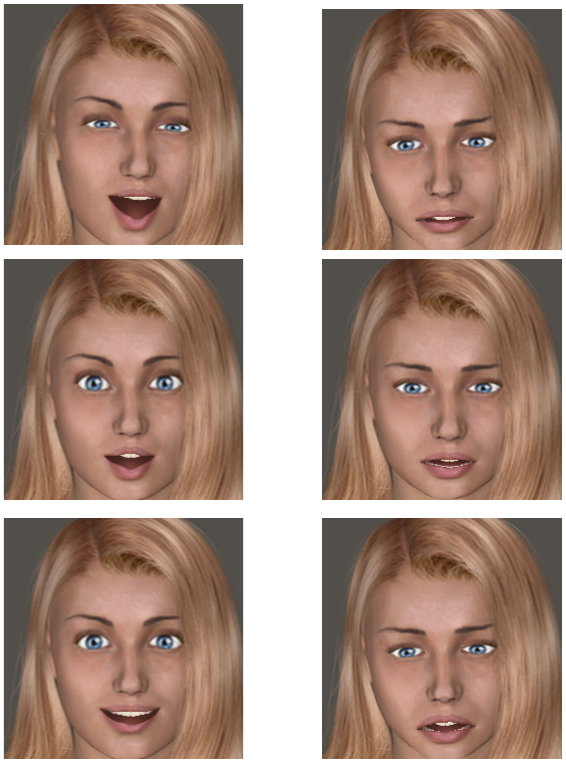

Fig. 3b The IVA Mira

Figure 3. Modeled IVAs' heads, expressing emotional states such as happiness, uncertainty, pity, disappointment and sadness

warned that they are expected to treat the IVAs as their colleagues - classmates, who are at their working place at the moment and who are likely to have personal problems or be very

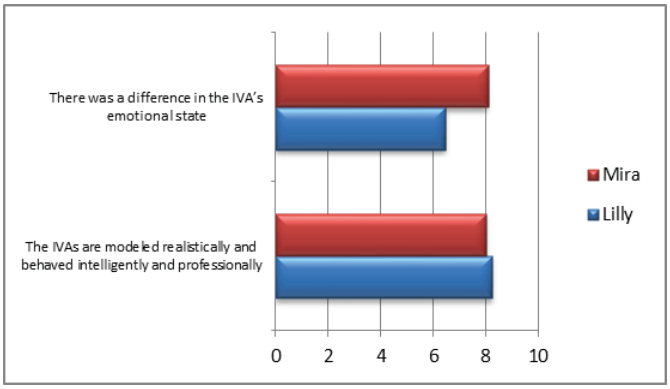

Figure 4. Assessment of the IVA's truthfulness

tired. The task in front of the users was to assess the IVAs' emotional state, to tell whether it changes in the course of the experiment, to explain the reasons for the showed or restrained happiness, sadness, annoyance or uncertainty (in case they are able to notice any). The users were told that the observation should last about 7-8 minutes per IVA, during which the program simulates about 50 days in the IVAs' life and the events happening within these days. Having this in their minds the users could give suggestions about what the reasons for the observed emotional states were. If they want, the users could ask the IVA's how they feel, why they are so happy, whether they have problems and what the problems are. They can also encourage them or pass remarks.

6. Experimental Results

The users defined Lilly as a girl of action, authoritative, reserved, ambitious and more restrained than Mira.

They defined Mira as extremely friendly, more extrovert than Lilly, ready to share her problems and sometimes sad or disappointed with personal problems.

Finding differences in the IVA's emotional state

All the users gave a maximum or close to the maximum assessment mark for the IVAs in relation to their professionalism, intelligence and truthfulness (*figure 4*).

The participants in the experiment noticed the difference in the agents' emotional states during the simulation. They distinguished the days when the IVA were really happy and they just took pains to show consideration, happiness and politeness

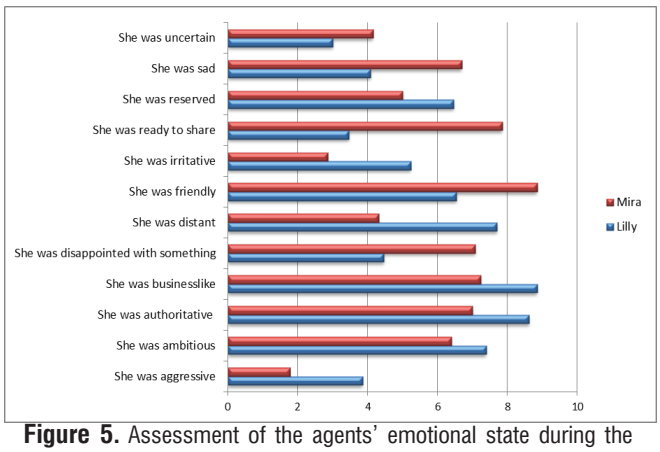

Figure 5. Assessment of the agents' emotional state during the days of the experiment

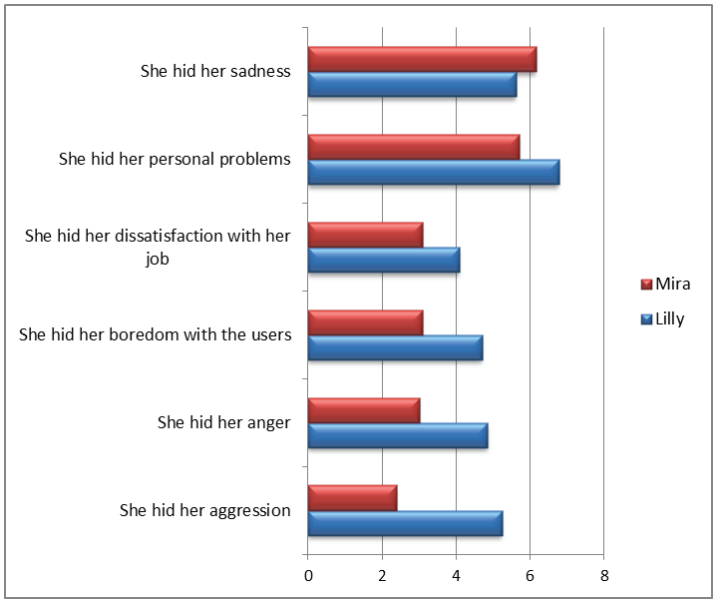

Figure 6. Investigation of the users' opinions about the restrained emotional states and the possible reasons, causing them

while feeling differently and perhaps hiding disappointment with something, sadness, anger or just tiredness (*figure 5* and *figure 6*).

The users tended to suppose that the restrained emotional state is due to the IVA's personal problems, not related to the present context. To a lower degree they suppose that the agents restrain their boredom with their work or with the communication with the users (*figure 6*).

Most of the users were interested in the IVAs' problems and insisted on finding out what they are. They wished the IVAs to solve them successfully; they sympathized the IVAs and were very disappointed when Lilly did not share her problems in spite of their insistence (*figure 7*). Only one from the users expressed the opinion that „Lilly's problem is deeply hidden in her herself", while expressing at the same time admiration for her authoritativeness, self-confidence and he wanted to become friends only with Lilly.

The great majority of the participants in the investigations preferred to make friends with Mira, five of them wanted to make friends with both on-line administrators. Only one of the participants has pointed that he is not interested in the IVAs' problems. Three users have chosen the option „I don't think the IVAs have problems". These users are obviously skeptics, who do not want to perceive the modeled IVAs as really functioning persons and, according to them this is just a program. However, 90% of the users accept the IVAs as social persons and have expectations related to their behavior and their relationships in the process of communication (*figure 7*).

The conclusion is that the more friendly and extrovert characters, ready to share and show their real emotions, speaking more and interested in the problems of the others are preferred and they gain more sympathy and make more friends.

The higher speed of speaking, the shorter answers, the quickly passing as shade frowning, and the nodding aside are related to restrained aggression, distance, and ambition even though they are mixed with smiling and positive nodding.

On the contrary, the slower speed of speaking, the sad eyes together with wishes for success, idioms and smiles are related to restrained sadness and evoke sympathy and willingness to help.

7. Conclusion

The paper investigates the social behavior of an IVA with PRE-ThINK architecture. A scenario is proposed, allowing for clearing out and revealing the following: the agent's decision making mechanism; the mechanism of origination and assessing thoughts, related to the alternative actions for each situation; the mechanism for achieving optimal time apportionment in order to achieve the best possible coping with the assigned tasks. The origination and the influence of the primary emotions such as happiness and sadness is also cleared out for building and investigating the secondary emotions such as relief, confidence, prestige, uncertainty, confirmed fear, disappointment. The peculiarities of the program system, as well as of the IVA's PRE-ThINK architecture together with the conducted experiments are described and explained.

In order to investigate social behavior two virtual agents are modeled, communicating with the users in a different way and sometimes hiding their real emotions and temper.

Masking (restraining) an emotional state is modeled by introducing mimics, not corresponding to the emotional state, which the IVA tries to express, as well as by change in the loudness and the speed of speaking.

What is investigated is: how the users accept the different social behavior, expressed by the IVAs; whether they recognize the change and discrepancies in their behavior. The results

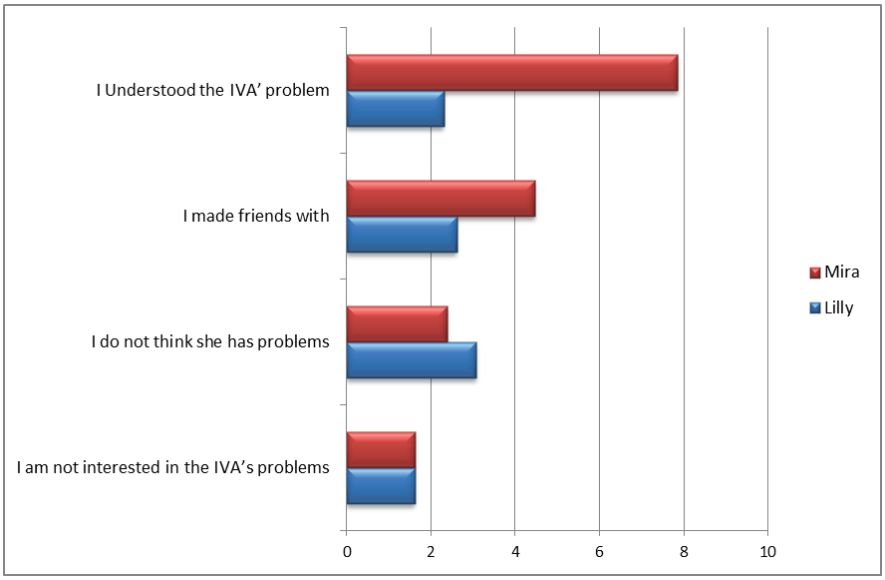

Figure 7. Perception of the IVAs as socially functioning persons

show that the users can recognize the restrained sadness, happiness, disappointment, distance, authoritativeness, the IVA's willingness to make friends with them or to stay reserved. They prefer a friendlier IVA, clearly showing their real emotional state, ready to share their problems and aspire to making friends with them.

90% of the users accept the IVAs as socially functioning persons and have expectations related to them.

The future development of the program system could offer realization of new situations in which the agent forms new principles and new behavioral rules.

Creation of a more complex situation is envisaged, in which the IVA's goals will be related to different needs to a different extent. The decision making will be more complicated and more realistic then.

Tracking the way the IVA gains experience in communication with the users of the site will be a subject of another investigation together with the way she learns to be polite and businesslike regardless of her problems, successes and failures.

It is assumed that, together with the further development of the system, it could be possible to realize a backward investigation, i.e., to predetermine the decisions, taken in a problematic situation in order to build a model of the investigated person.

The investigation of a collaborative or competitive behavior in a multi-agent system for similar scenarios would be also of great interest.

Another direction for further development is to investigate how the various ways of communication with users would influence the ranking of the IVA. Is it better for her to be more businesslike if the user is interested in what is going on when he has understood from the IVA's multimodal behavior that something is going wrong or that she is extremely happy?

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