Empathic Embodied Interfaces: Addressing Users' Affective State

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Abstract. In this paper, we report on our efforts in developing affective character-based interfaces, i.e. interfaces that recognize and measure affective information of the user and address user affect by employing embodied characters. In particular, we describe the Empathic Companion, an animated interface agent that accompanies the user in the setting of a virtual job interview. This interface application takes physiological data (skin conductance and electromyography) of a user in real-time, interprets them as emotions, and addresses the user's affective states in the form of empathic feedback. We present preliminary results from an exploratory study that aims to evaluate the impact of the Empathic Companion by measuring users' skin conductance and heart rate.

1 Introduction

The idea of a computer 'sensing' the user's autonomic nervous system (ANS) activity is becoming increasingly popular in the human–computer interface community, partly because of the availability of affordable high-specification sensing technologies, and also due to the recent progress in interpreting users' physiological states as affective states or emotions [Picard, 1997]. The general vision is that if a user's emotion could be recognized by a computer, human–computer interaction would become more natural, enjoyable, and productive. The computer could offer help and assistance to a confused user or try to cheer up a frustrated user, and hence react in ways that are more appropriate than simply ignoring the user's affective state as is the case with most current interfaces.

Our particular interest concerns interfaces that employ embodied agents, or life-like characters, as interaction partners of the user. By emulating multi-modal human–human communication and displaying social cues including (synthetic) speech, communicative gestures, and the expression of emotion, those characters may also trigger social reactions in users, and thus implement the "computers as social actors" metaphor [Reeves and Nass, 1998,Bickmore, 2003]. This type of 'social interface' has been demonstrated to enrich human–computer interaction in a wide variety of applications, including interactive presentations, training, and sales (see [Prendinger and Ishizuka, 2004] for a recent overview).

In this paper, we propose an interface that obtains information about a user's physiological activity in real-time and provides affective feedback by means of a life-like character. The interface is intended to *address* the user's emotion by showing concern about user affect, sometimes called *empathic* (or *sympathetic*) behavior. Empathic interfaces may improve human–computer interaction or, put differently, leave users less frustrated in the case of a stressful event related to the interaction [Klein et al., 2002]. Potential application fields include software (assuming unavoidable software-related failures), computer-based customer support, and educational and tele-home health care systems. The web-based (virtual) job interview scenario described in this paper serves as a simple demonstrator application that allows us to discuss the technical issues involved in real-time emotion recognition as well as the implementation of an empathic agent.

This paper also aims to illustrate two approaches to using human physiology to *evaluate* empathic embodied interfaces. Following [Ward and Marsden, 2003], we distinguish between (i) the paradigm that measures short-time (<5 seconds) physiological changes in response to specific events, and (ii) the paradigm that performs comparisons of ANS readings across longer (>5 minutes) periods of time under different control conditions. While the first mentioned approach is applicable to situations where experimental conditions can be tightly controlled (see Sect. 3), interactions for which tight control conditions are not possible can be evaluated by following the latter approach (see Sect. 5).

The rest of this paper is organized as follows. In Sect. 2, we describe work related to our own. Section 3 reports on the result of our previous study showing that empathic embodied feedback may reduce (deliberately frustrated) users' level of arousal. Section 4 is dedicated to introducing the Empathic Companion. There, we first describe our system for real-time emotion recognition, and then explain how physiological signals are mapped to named emotions. The final part of Sect. 4 discusses the decision-theoretic agent that is responsible for selecting the Empathic Companion's actions. In Sect. 5, we illustrate the structure an interaction with the Empathic Companion in the setting of a virtual job interview, and discuss preliminary results of an experiment that recorded users' physiological activity during the interaction. Section 6 concludes the paper.

2 Related Work

A review of the literature suggests that it is possible to distinguish at least five modes of usage of a user's physiology for (affective) interfaces: (i) A user's physiological data can be used to *track* the impact of the interface on the affective state of the user. As shown in [Ward and Marsden, 2003], recording users' physiological data and associating them with interface events is an important methodology for testing software, e.g. to measure the effect of different types of web page design. (ii) A user's ANS activity can be used in order to *reflect* (or 'mirror') the user's affective state by means of an embodied agent. In this way, the user may gain insight into his or her physiological responses. This type of application has been shown to bear considerable relevance for tele-home care systems [Lisetti et al., 2003]. (iii) The user's physiological state can play a key role in selecting strategies to *adapt* the interface. When the user's frustration is detected, an interface agent can try to undo the user's negative feeling. A main application field of adaptive interfaces are tutoring systems that aim at tailoring their behavior in accord with the student's affective state and learning goal [Conati, 2002]. (iv) User bio-signal data can be used to *address* the user's affective state. Major work has been done by [Bickmore, 2003] who proposes the term 'relational agents' to investigate animated agents that are designed to develop and maintain long-term, social-emotional relationships with users. Specifically, he describes an agent that addresses human affect in the role of an health behavior change assistant. The Empathic Companion application illustrated in this paper also falls under this category. (v) A user's physiological responses may become increasingly important to *learn* the user's situation-dependent affective responses and hence allow for the acquisition of predictive user models [André and Müller, 2003]. Learning of emotional behavior is also crucial for the previously described relational agents that are intended to enable fertile interactions with human users over extended periods of time [Bickmore, 2003].

The investigation of [Klein et al., 2002] is most closely related to our work on empathic interfaces. They describe the design and evaluation of an interface implementing strategies aimed at reducing negative affect, such as active listening, empathy, sympathy, and venting. The resulting affect–support agent used in a simulated network game scenario could be shown to undo some of the users' negative feelings after they have been deliberately frustrated by simulated network delays inserted to the course of the game. The Emphatic Companion interface differs from the one used by Klein in two aspects. *First*, the user is given feedback in a more timely fashion, i.e. shortly after the emotion actually occurs, and not after the interaction session, in response to the subject's questionnaire entries. While providing immediate response to user affect is certainly preferable in terms of natural interaction, it assumes that affect is processed in real-time. Hence, in order to assess a user's emotional state in online, we implemented a system that takes physiological signals of the user during the interaction with the computer. *Second*, affective feedback to the user is communicated by means of a life-like character, rather than a text message. Although the study of Klein supports the argument that embodiment is not necessary to achieve social response, it has been shown that embodied characters may boost the tendency of people to interact with computers in a social way, the so-called 'persona effect' [van Mulken et al., 1998].

3 Empathizing with a Frustrated User

In this section, we want to mention the main result of a previously conducted study that had the purpose of evaluating the effect of empathic embodied feedback on deliberately frustrated users [Prendinger et al., 2003]. The impact of a life-like character's empathic response was measured by comparing the skin conductance readings of subjects that received empathic feedback with the skin conductance of subjects that did not.

A simple mathematical quiz game was implemented where subjects are instructed to sum up five consecutively displayed numbers and are then asked to subtract the i-th number of the sequence ($i \leq 4$). The instruction is given by the "Shima" character, an animated cartoon-style 2D agent, using synthetic speech and appropriate gestures (see Fig. 1). Subjects compete for the best score in terms of correct answers and time. Subjects were told that they would interact with a prototype interface that may still contain some bugs. This warning was essential since in some quiz questions, a delay was inserted before showing the 5th number. The delay was assumed to induce frustration as the subjects' goals of giving the correct answer and achieving a fast score are thwarted. The version of the game using the empathic agent, an apology as depicted in Fig. 1 was shown to subjects, while in the other (non-affective) version the occurrence of the delay was ignored by the animated instructor. The main result of this experiment can be summarized as follows: *If an embodied character shows empathy to a deliberately frustrated user, then the user's skin conductance is significantly lower than when the character does not display empathy, as compared to the period of induced frustration (the delay period).* If the level of skin conductance is interpreted as the user's level of stress or frustration, then this result indicates that empathic feedback may undo some of the user's negative emotions. Since the parameters in the study were tightly controlled, it was possible to apply the first type of evaluation paradigm described in [Ward and Marsden, 2003], namely, the identification of short-term ANS changes in response to specific interface events.

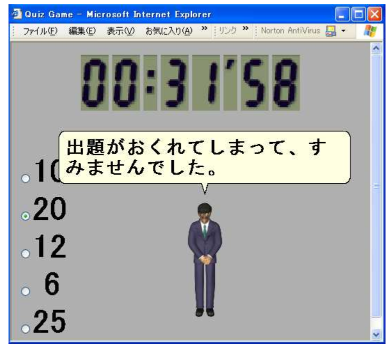

Fig. 1. Shima character: "I apologize that there was a delay in posing the question."

4 Addressing Users' Affective State

The Empathic Companion is a life-like character that was developed in the context of a web-based job interview scenario, where it addresses the user's emotion resulting from an interview situation (see Fig. 2). Being interviewed is likely to elicit emotions in the user, especially when the interviewer (Fig. 2, left) asks potentially unpleasant or probing questions, such as "What was your final grade at university?" or "Are you willing to work unpaid overtime?", and comments pejoratively upon the interviewee's (i.e. the user's) unsatisfactory answer. In order to emphasize the training aspect of the interview situation, the user is led by a companion agent (Fig. 2, right) that addresses the user's (negative) emotions

Fig. 2. Job Interview Scenario.

by giving empathic feedback, e.g. "It seems you did not like this question so much" or "Maybe you felt a bit bad to be asked this kind of question". The user is told that the companion is invisible to the interviewer and present for his or her comfort only. Although a web-based (virtual) interview cannot induce the stress level of a face-to-face or phone interview, it provides a convenient training platform for job seekers.

4.1 System Architecture for Real-time Emotion Recognition

Since the Empathic Companion application assumes real-time emotion recognition, the system architecture depicted in Fig. 3 has been implemented on the Windows XP platform. Below, we will explain each of its components.

Data Capturing. The user is attached to sensors of the ProComp+ unit from [Thought Technology, 2002]. The ProComp+ encoder allows to use input from up to eight sensors simultaneously. Currently, we only use galvanic skin response (GSR) and electromyography (EMG) sensors. Sensor input is digitally sampled by the ProComp+ unit and transmitted to the computer via a fiber-optic cable using the RS232 COM port. Although the ProComp+ unit enables data sampling up to 256 samples/second, GSR and EMG signals allow for a much lower rate, at 20 samples/second. Data capturing is achieved by a module written in Visual C++ that employs the ProComp+ data capture library.

Data Processing. When prompted by the application (i.e. interface events), the Data Processing component retrieves new data every 50 milliseconds, stores and evaluates them. Given the baseline information for skin conductance (GSR signal) and muscle activity (EMG signal), changes in ANS activity are computed by comparing the current mean signal values to the baseline value. The baseline

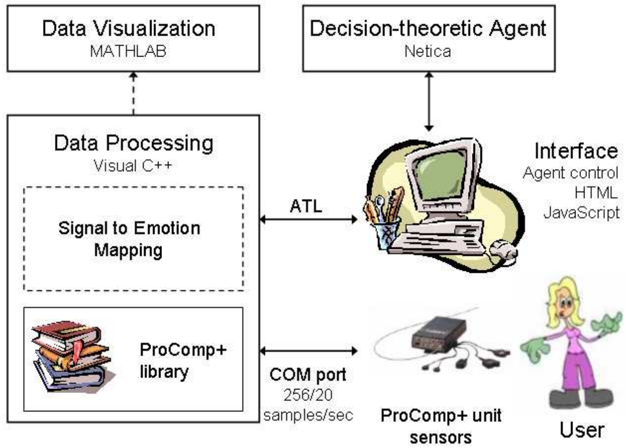

Fig. 3. System architecture.

is obtained during an relaxation period preceding the interaction. The current mean value is derived from a segment of five seconds, the average duration of an emotion [Levenson, 1988]. If skin conductance is 15–30% above the baseline, is assumed as "high", for more than 30% as "very high". If muscle activity is more than three times higher than the baseline average, it is assumed as "high", else "normal". Emotions are hypothesized from signals using a Bayesian network (as part of the decision network discussed below), but optionally, a "Signal to Emotion Mapping" module is available, if no decisions are required on the interface side.[3]

The connection between the Data Processing component and the User Interface is established by the Active Template Library (ATL) which requires functions including *Init* (initializes the ProComp+ encoder), *Start* (initializes data retrieval), *Finish* (de-allocates memory), *GetBatteryLevel* (retrieves current battery level), and *DataTransmission* (assigns data to variables).

User Interface. The User Interface component contains the job interview scenario and runs under Internet Explorer 5.5 (or higher). It is written in HTML and JavaScript and utilizes the Microsoft Agent package [Microsoft, 1998] to control the verbal and non-verbal behavior of characters. This package includes an animation engine to trigger about 50 pre-defined 2D animation sequences and a text-to-speech engine.

Decision-theoretic Agent. A decision network is used to combine bio-signals and other facts about the interaction, and relate them to emotions as well as agent decisions.

[3] This module is used in another application, the *Emotion Mirror*, where the user's emotions are reflected back to the user. The mirror metaphor is realized by an animated interface agent that displays the user's presumed emotion both verbally and non-verbally. The aim of this application is to facilitate the training of emotion management and regulation [Prendinger et al., 2003].

The decision-theoretic agent will be discussed in Sect. 4.3. Before that, we will explain the interpretation of the user's physiological activity as emotions.

4.2 Relating Physiological Signals to Emotions

[Lang, 1995] claims that all emotions can be characterized in terms of judged valence (pleasant or unpleasant) and arousal (calm or aroused). Figure 4 shows some named emotions as coordinates in the arousal–valence space. The relation between physiological signals and arousal/valence is established in psychophysiology that argues that the activation of the ANS changes while emotions are elicited [Levenson, 1988]. The following two signals have been chosen for their high reliability (other signals are discussed, e.g. in [Picard, 1997]). Galvanic skin response (GSR) is an indicator of skin conductance (SC), and increases linearly with a person's level of overall arousal [Lang, 1995].

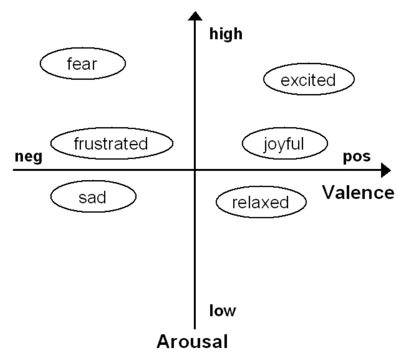

Fig. 4. Some named emotions in the arousal–valence space.

Electromyography (EMG) measures muscle activity and has been shown to correlate with negatively valenced emotions [Lang, 1995].

4.3 Decision-theoretic Agent

The decision-theoretic agent is responsible for deriving the user's emotion given physiological data and the valence of the user's answer (to the question of the interviewer), and to suggest an appropriate action. The agent is implemented with Netica from [Norsys, 2003], a software package that allows solving decision problems and provides convenient tools, including an API in Java, which has been used to implement the agent.

The decision network depicted in Fig. 5 represents a simple decision problem. A decision-theoretic agent selects actions that maximize the outcome in terms of some utility function [Jensen, 2001]. The subnet consisting only of chance nodes is the Bayesian network used to derive the user's emotional state. It relates physiological signals (GSR, EMG) and the user's answer to arousal and valence which are employed to infer the user's emotional state by applying the model of [Lang, 1995]. The probabilities have been set in accord with the literature (whereby the concrete numbers are made up). "Relaxed (happiness)" is defined by the absence of autonomic signals, i.e. no arousal (relative to the baseline), and positive valence. "Joyful" is defined by increased arousal and positive valence, whereas "Frustrated" is defined by increased arousal and negative valence. The node "Answer" in the network represents situations where the user gives a 'positive answer' (that satisfies the interviewer's question) or a 'negative answer'

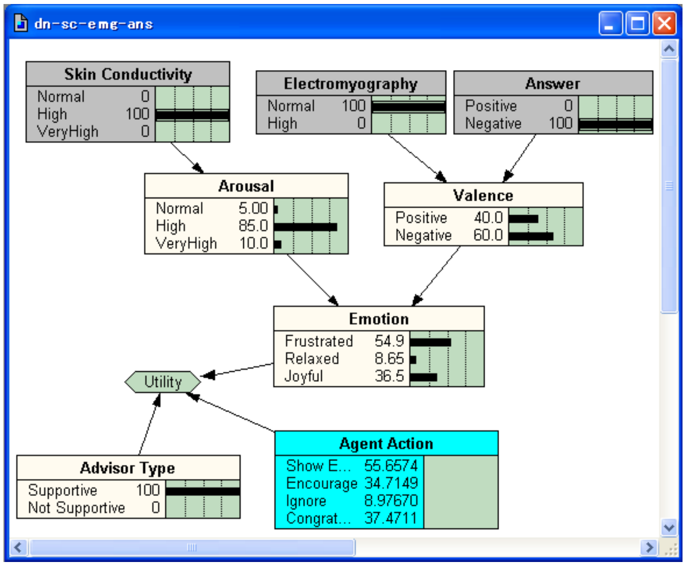

Fig. 5. Simple decision network.

(that does not satisfy the interviewer's question). This ('non-physiological') node was included to the network in order to more easily hypothesize the user's positive or negative appraisal of the question, as the user's EMG value changes (in this application) are often too small to evaluate valence.

Besides nodes representing probabilistic events in the world (chance nodes), decision networks contain nodes representing agent choices (decision nodes), and the agent's utility function (utility or value node). The decision node in Fig. 5 lists some possible actions. If the advisor type is supportive, the utility function is set to give priority to empathic responses.

- *Show Empathy*: The agent displays concern for a user who is aroused and has a negatively valenced emotion, e.g. by saying "I am sorry that you seem to feel a bit bad about that question".
- *Encourage*: If the user is not aroused, the agent gives some friendly comment, e.g. by saying "You appear calm and don't have to worry. Keep going!".
- *Ignore*: The agent does not address the user's emotion, and simply refers to the interview progress, by saying, e.g. "Let us go on to the next question".
- *Congratulate*: If the agent detects the user is aroused in a positive way, it applauds the user ("Well done!", "Good job! You said the right thing", etc.).

"Advisor Type" is a deterministic (rather than chance) node that allows us to characterize the agent as supportive or non-supportive. If set to "Not Supportive", the "Ignore" action is selected for all inputs. This node is needed to compare empathic vs. non-empathic versions of the companion.

5 Interacting with the Empathic Companion

In an interaction session with the Empathic Companion, the user is seated in front of a computer running the job interview, with the GSR sensors attached to two fingers of the non-dominant hand, and the EMG sensors attached to the forearm of the same body side. The baseline for subsequent bio-signal changes is obtained during an initial relaxation period of one minute, where the user listens to music from Caf del Mar (Vol.9), as the mean of GSR and EMG values.

5.1 The Structure of the Interview

An interview session is composed of (interview) episodes, whereby each episode consists of four segments.

- *Segment 1*: The interviewer agent asks a question, e.g. "Tell me about your previous work experience".
- *Segment 2*: The user chooses an answer from the set of given options (see Fig. 2, lower part), by clicking on the button next to the selected answer, e.g. the user admits the lack of experience by clicking the lower button.
- *Segment 3*: The interviewer responds to the user's answer, e.g. "Then you are not the kind of person we are looking for" or "I am happy to hear that you have extensive experience in the field".
- *Segment 4*: The companion agent responds to the emotion derived from the data gathered during the third segment and the user's answer given in the second segment.

The entire interview session contains ten episodes, and concludes with the interviewer agent's acceptance or rejection of the user as a new employee of the company, depending on how many 'credits' the user could collect.

5.2 Exploratory Study

While a questionnaire method is certainly possible to evaluate the impact of the Empathic Companion agent, we are using physiological data to assess the user's perception of the interface. Since the ProComp+ unit cannot be simultaneously employed for real-time data assessment and monitoring, the second author of this paper has designed a signal processor that reads users' skin conductance (SC) and heart rate (HR). Like EMG, heart rate also correlates with negatively valenced emotions. Since SC and HR are slowly changing signals, it was sufficient to set the signal processor to 2 samples/second.

Observe that unlike the experiment reported in [Prendinger et al., 2003], tight experimental controls are not practicable in the job interview application as the interaction is not designed to invoke specific emotions at specific moments. In particular, depending on their answers to the interviewer's questions, users may receive positive or negative feedback. Facing a comparable situation – users' physiological responses to different web page designs – [Ward and Marsden, 2003]

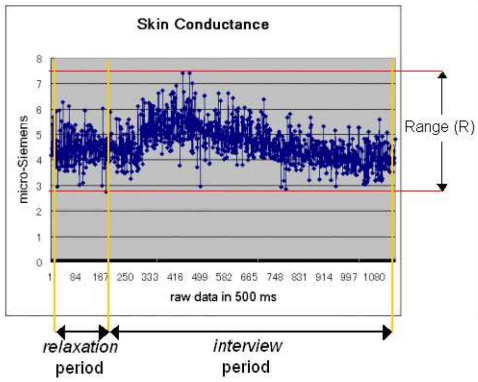

Fig. 6. Sample SC data of subject interacting with the Empathic Companion.

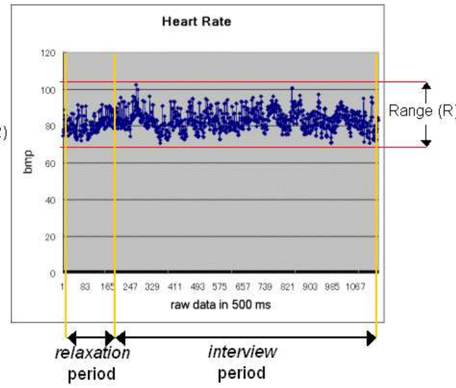

Fig. 7. Sample HR data of subject interacting with the Empathic Companion.

thus propose to compare signal values for whole interaction periods rather than for specific interface events. Following this paradigm, we hypothesize that, averaged over the entire interaction period, the presence of a (supportive) Empathic Companion will have users with lower levels of arousal and less negatively valenced affective states. As the control condition, the "Not Supportive" advisor type is used (see Fig. 5), where the "Ignore" action is always selected.

We conducted an exploratory study on the overall effect of the presence of the Empathic Companion. The subjects are connected both to the GSR sensors of the ProComp+ unit with the first two fingers of their non-dominant hand,[4] and to the second author's unit that provides a wristband for SC (using the dominant hand) and an ear-clip to measure HR. The SC and HR data for one subject performing the interview with the (supportive) Empathic Companion agent are shown in Fig. 6 and Fig. 7, respectively. In the study, participants were 10 staff and students from the University of Tokyo, aged 23–40, who were randomly assigned to the "Supportive" and "Not Supportive" version of the Empathic Companion application, abbreviated as Em and NEm, respectively (5 subjects in each version). In the following, "AM_{relax}" refers to the (arithmetic) mean of the signal values obtained during the initial relaxation period, whereas "AM_{int}" refers to the mean of the interview period. "Range" refers to the range of data points of the whole interaction period.

First we compared AM_{relax} and AM_{int} without distinguishing between the two versions. For HR, AM_{relax}=77.83 and AM_{int}=82.05, and for SC, AM_{relax}=6 and AM_{int}=7.81. However, none of those results were statistically significant. A possible reason might be that a significant signal change only occurs after the interview starts, and the difference between the relaxation and interview periods gradually diminishes during the rest of the interview. While it is not representative, the pattern of SC data depicted in Fig. 6 indicates this tendency.

[4] For simplicity, the EMG sensors have not been used.

Then we compared the *Em* and *NEm* versions by applying the equation $(\text{AM}_{int} - \text{AM}_{relax})/\text{Range}$. The intuition here is that a smaller value indicates that the character has a more calming effect on the user (SC) or decreases negative feelings (HR) to a higher extent. Our observations, however, do not show this. In the case of SC, the mean value of *Em* is 0.11 and 0.08 for *NEm* (contrary to our expectation). For HR, the mean value of *Em* is 0.04, and that of *NEm* is 0.06. Hence there is no significant positive effect of the supportive companion. If this result remains to hold for a larger number of subjects, we may say that empathic character behavior does not have an impact on the affective state of users. However, it is worth noting that the current application (the job interview) has the empathic character interact with the user only in a very limited way. Most of the time, the user interacts with the interviewer, whose behavior is the same in both versions. Therefore, we consider to design another experiment that allows a more direct comparison between the *Em* and *NEm* versions. For instance, the character could perform as a virtual medical health assistant that asks the user about his or her health-related lifestyle, and then comments on the user's answer in a neutral or empathic fashion.

Certainly, other reasons could be responsible for the lack of significance of our results. (i) The responses intended to have a calming effect on the user might actually not do so. (ii) Increased arousal might also be interpreted as positive arousal, especially for users performing well in the job interview. (iii) Heart rate might not be a reliable indicator of negative valence for all users. These and other issues will addressed in our future work.

6 Conclusions

This paper describes the Empathic Companion, a character-based interface that takes physiological signals of the user in real-time and addresses user emotions derived from those signals. A virtual job interview serves as an exploratory application scenario. While results of statistical significance could not be obtained in the current setting, previous findings indicate the frustration-reducing effect of empathic feedback [Klein et al., 2002,Prendinger et al., 2003]. Thus we expect that the Empathic Companion will be beneficial in applications where negative feelings are involved or likely to occur, such as online customer support or computer-based education. A particularly interesting application field is tele-home health care where the Empathic Companion may play a crucial role in addressing patients' affective and social needs [Lisetti et al., 2003]. In the near future, we plan to implement a more straightforward use of the Empathic Companion, i.e. in the role of the main and only interaction partner of the user rather than a secondary interlocutor as was the case in the interview scenario. We will also consider to use text-based (empathic) feedback in order to compare "persona" vs. "no persona" conditions.

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