Simulated Emotion in Affective Embodied Agents

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Abstract. An important strand of research that is often neglected in the field of affective computing is that of how users respond to simulated displays of emotion. We present an overview of the few studies that have explicitly investigated this space and discuss a number of issues related to simulated emotion research. An overview of our own work in this area is then provided, along with forthcoming studies that we plan to conduct. We conclude with a number of suggestions of where future research in this space should focus.

1 Introduction

An important strand of research that is often neglected in the field of affective computing is that of how users respond to simulated displays of emotion. How do we respond to synthetic displays of happiness, sadness, anger, frustration and fear? Can we catch emotions from users? How do we respond to computer empathy and sympathy? With interface designers increasingly incorporating emotion into their interfaces through a variety of modalities (e.g. textual content, speech, video and facial expressions in embodied agents), it is imperative that we understand in detail the impact of simulated emotion on computer users.

A number of recent studies have investigated user responses to simulated emotion through the use of embodied agents – screen-based entities that attempt to closely simulate humans to make interactions with computers more natural and engaging [6]. Recent research into embodied agents has predominantly focused on their use in situations where human-human relationships are important, such as teaching [5], exercise and nutritional advisors [2, 7] and simulations [11]. Such agents have also been used in computer games for a number of years [15] and are now widely utilized in online virtual environments such as Second Life [20] and There.com [21].

Research into online virtual environments and games that utilize embodied entities suggests that the social rules and norms that apply in human-human interaction also apply in human-computer interactions (e.g. [23]). Therefore, our interactions with embodied entities in virtual environments appear, to some extent, to mirror our social interactions with others in the physical world. Numerous studies conducted in the last decade within other computing domains also support this reported effect – that is, interactions in both physical and virtual worlds are governed by similar social rules and norms [19]. As emotional expression plays a pivotal role in human-human interactions, the social nature of virtual environments and our interactions with embodied agents strongly suggests that emotion will likely be of importance in HCI.

As such, designers of embodied agents have been investigating how to incorporate emotional capabilities into agents to enable them to express simulated human emotions and have been examining the effects it has on user attitudes and behavior.

Several recent studies have suggested that we respond to simulated emotion in a similar way to human emotion (e.g. [2, 4]) - this is unsurprising considering our reactions to the computer generated characters developed by Disney and Pixar. Whilst these characters cannot dynamically interact with their audience during the film, they still have the potential to rouse strong emotional and social responses. However, while it is clear that users may respond to simulated emotion in a similar way to expressions of human emotion, it is less clear which emotions are best utilized in which domains and how best they should be expressed. For example, how do users respond to more cognitive emotions such as frustration, humiliation and guilt? How important is it to simulate mixed emotions – sometimes we are a bit happy and a bit sad at the same time – how do we simulate this and is it even necessary to do so in HCI? Is the simulation of so-called "negative" displays (e.g. frustration, fear and anger) of emotion necessary in HCI? There are many important questions such as these to which we currently have little understanding and very few answers.

This paper will discuss the main issues involved in studying the effects of emotion simulation on users. We start with an overview of the main studies in this area and describe many of the issues when attempting to make comparisons between related research. We also focus on issues that generally apply to the majority of studies that have investigated the effects of emotion simulation that need to be addressed in future research. We then provide an overview of our research in this space and conclude with suggestions for future research areas that will help to take this important and often neglected aspect of affective computing forward.

2 Related Work

While there have been many studies that have focused on the simulation of emotion in artificial intelligence (e.g. developing computational models of emotion) computer graphics (e.g. real-time rendering of emotions), and HCI (e.g. examining the impact of affective embodied agents), very few studies have explicitly investigated how we respond to simulated displays of emotion. There have been a large number of studies over last decade that involve an interaction with an affective agent, but emotion is often not the primary area of investigation of such studies. In this section, we start with an overview of more recent studies that have primarily focused on the effects of simulated emotion on users. We then move on to identify and discuss a number of general issues with research in this space.

2.1 Emotion Simulation Studies

A number of recent studies have suggested that we respond to simulated emotion in a similar way to human emotion. For example, Brave et al. [4] examined our responses to simulated emotion by asking subjects to play a casino-style blackjack game with an agent that exhibited either self oriented or other-oriented empathic emotion. The agent

was essentially a static photograph of a human that communicated with the user through the use of speech bubbles. Results from the study found that subjects perceived the agent which was empathetic toward them as more likeable, trustworthy, supportive and caring than the agent which was not empathetic toward them.

Bickmore and Picard [2] found a similar effect when evaluating their embodied exercise advisor "Laura" which attempted to build and maintain a relationship with users over the period of a month. Laura used a number of relational strategies that humans use to establish and maintain relationships, including expressions of empathy, politeness, humor, appropriate forms of address, and discussion about the relationship. Results from this study found that subjects generally perceived Laura more positively when they interacted with the relational version as opposed to the non-relational version (i.e. the condition where no relational strategies were used).

Fabri [10] examined the impact of simulated emotion by asking subjects to discuss a moon survival scenario through the use of a "Virtual Messenger." When using the virtual messenger, subjects were represented by three dimensional animated avatars and could see both their partner's representation on the screen, and a small image of their own representation. Subjects were represented by either an emotionally expressive or unemotional avatar - results found that subjects who interacted with the emotionally expressive avatar felt more involved in the task than those who interacted with the unemotional avatar. However, in contrast to the studies above, subjects appeared to enjoy the interaction with non-expressive avatar more.

Prendinger et al. [18] investigated the effect of simulated empathy on users through measuring their galvanic skin response and blood pressure whilst playing a mathematical game. One group of subjects interacted with an empathetic agent during the game while another group interacted with a non-empathetic agent. In a number of the questions asked during the game, a short delay was experienced by subjects – in the empathy condition, the agent would be empathetic toward the user when this happened, while the other agent would do nothing. It was found that the incorporation of empathy helped reduce galvanic skin response in subjects, but did not significantly reduce how frustrated subjects felt whilst playing the game.

These studies illustrate that simulated emotion can influence user attitudes and perceptions - however, our understanding of exactly how they influence users and how simulated emotion can best be utilised to enhance HCI is still relatively superficial.

2.2 Issues with Emotion Simulation Research

One of the primary issues with emotion simulation research is the lack of studies that have explicitly compared an emotional agent against an unemotional one. Numerous studies have made use of emotionally expressive agents in their experimental systems, but emotion is often not the main focus of the study (e.g. [17], [16], [22], [2]). Attempting to compare and analyse such studies from an emotion simulation perspective becomes problematic as inferences have to be made and this can lead to uncertainty about whether or not reported effects were down to the manipulation of emotion. For example, Van Mulken et al. [22] conducted an experiment with two different conditions – one that made use of an animated agent to present information

and one where an arrow was used instead of the agent to present the information. This is most likely a fair comparison from the author's point of view, but when attempting to evaluate such a study from an emotion simulation angle it becomes an unfair comparison. Emotional expression is not the only variable that has been manipulated here – the functionality of the two conditions is also significantly different. Therefore, while many studies have utilised affective embodied agents for experimental purposes, it is problematic when attempting to compare the majority of these studies from an emotion simulation perspective. More studies that explicitly compare an emotional and unemotional agent are required to further our understanding of the effects of simulated emotion.

Another issue with emotion simulation research is that many of these studies do not check the emotional expressions of their agent prior to conducting their primary experiment. Failure to take this essential step before testing the effects of simulated emotion can cause problems as it is not clear whether or not subjects perceive the emotional expressions as expected. For example, consider the difference between a genuine smile and a social smile – the primary difference between the two is that a *genuine* smile (i.e. a duchenne smile) involves the movement of the orbicularis oculi muscle near the eyes, while a *social* smile does not [9]. We have found from own studies (described in next section) that users put a great deal of emphasis on the eyes when interacting with affective embodied agents. The application we used to develop our embodied agent did not allow us to manipulate the muscle around the eye – therefore, when we wanted the agent to simulate being genuinely pleased to see the user, we found that subjects often perceived these *welcoming* smiles more as social ones, and therefore perceived them as slightly false and patronising. This highlights how small details can easily alter perceptions of emotion and the amount of attention to detail that researchers need to pay when simulating human emotion – it should not be assumed that emotions will be perceived as expected. As Hook argues [13], they should be checked and tested before conducting primary experiments.

Another issue is the importance of researchers being explicit about what constitutes emotional expression in their study, and where, when and how it was expressed. Even in studies where emotion is main component being examined, researchers often do not include sufficient detail regarding this. Important information includes detailing exactly which emotions were expressed, at what times they were expressed, which model of emotion was used, and how the emotions were displayed (i.e. through textual content, speech, animated bodily and facial expressions, or combinations of these). The majority of studies where emotion has been incorporated into embodied agents tends to focus predominantly on basic emotions such happiness, sadness, joy, fear, surprise and anger [8]. Very few studies have investigated the impact of more cognitive emotions such as frustration, humiliation and guilt. The main reason for this is most likely down to the fact that these emotions are more difficult to simulate – all basic emotions have a unique facial expression associated with them, while cognitive emotions tend not to.

A further issue that has rarely been discussed in the field is that of mismatched emotional expressions. For example, many studies that use embodied agents equip them with the ability to express emotion through bodily and facial expressions, but also provide them with a synthetic and monotone voice. As we discuss in the following section, this can result in a mismatched emotional expression – for

example, you may have a happy facial expression with a monotone synthetic voice. This mismatch has occurred in a number of studies, yet very few researchers have discussed the impact of it or the influence it may potentially have on their results. From our own investigations, we have found that users have very strong reactions to mismatches in emotional expressions and find them to be particularly tedious, frustrating and annoying.

An important question that is related to this research is whether or not all emotions are of interest to HCI. For instance, why would a computer ever need to express fear, frustration, or disappointment? Perhaps frustration or disappointment might be used by a sports coaching agent as a means for motivating an individual who has not adhered to their strict fitness regime, by attempting to make them feel guilty. An expression or statement of fear might be used by a security agent to add urgency in getting the user to patch software that has vulnerable holes located within it. Emotions which are typically perceived as being more negative should not be ignored and thought of as harmful to HCI, but instead, should be utilized by interface designers (along with other more positive emotions) to produce a desired or beneficial outcome for the user.

How do users respond to simulated emotion in embodied agents over multiple and extended interactions? This is another area that has been neglected and aside from Bickmore and Picard's work [2], there have been no other major longitudinal studies with affective embodied agents. The majority of experimental studies that utilize embodied agents often require a single short interaction that typically lasts less than an hour. These short interactions often result in agents expressing one emotion at a time – for example, they are either happy or sad at any one time, but never a mixture of the two. This approach misses the main point about how emotions arise and are expressed – as Boehner et al. state [3]:

"…emotions are constructed and experienced as individuals act in and through their culture and social interactions. So what we feel is not simply a pre-existing fact, but something that develops over the course of conversations and interactions with one another. We work out what we feel through expressing it and through seeing how others react. We negotiate our feelings with ourselves and with others, over time crystallizing meanings for us of what may initially be vague, confusing, and ambiguous sensations."

Emotions, therefore, are often constructed through interactions and conversations with others over time and are shaped by culture. This suggests that for users to have meaningful social and emotional interactions and relationships with agents, they must have the opportunity to interact with each other over time. There is a real need for more longitudinal studies in this space to help us understand this further – how should emotional expression adapt over time? How can agents "co-construct" emotional experiences with users? How do users respond to simulated emotion over time – does it remain novel and engaging, or does it become tedious and tiresome for users?

3 Using Affective Agents for Behavior Change

As highlighted in section 2, a number of recent studies have suggested that we perceive emotionally expressive agents as more likeable, trustworthy, supportive and caring than unemotional agents. But how strong are effects such as these? Do they remain consistent over two, three, four or fifty interactions? In human-human interaction, we are more likely to act of the advice of people we like and trust rather than people we dislike and distrust. Does the same principle apply in HCI? That is, if we perceive emotionally expressive agents to be more likeable, trustworthy and caring than unemotional agents, can they potentially influence user attitudes and habitual behavior more effectively over extended periods of interaction? To investigate this we have built an embodied agent (Fig. 1.) that simulates the role of a human nutritional coach and are currently investigating the following questions: (1) are emotionally expressive agents perceived more positively than unemotional agents? (2) can emotional agents help motivate people to change unhealthy habits more effectively than unemotional agents over extended periods of interaction? (3) how do our perceptions of emotional agents change over multiple and extended interactions?

Fig. 1. Rachael – Our embodied agent

3.2 Experiment 1

We recently conducted a study that examined subjects' perceptions of the agent's emotional expressions. Additionally, were also interested in how people perceive mismatched expressions – for example, if the agent has a happy face and a concerned voice, what do users perceive? Does the visual or audio channel dominate user's perception of emotion? Does inconsistency lead to confusion and extra cognitive load? We tested for four different emotions: happiness, warmth, neutral, and concern – we chose these emotions as a number of studies have found these to be the ones most frequently displayed in therapist-client interactions [1, 12]. The experiment had a within-subjects repeated measures design with twenty-four different conditions. There were four static facial expressions (happy face, warm face, neutral face, concern face), four audio only expressions (happy audio, warm audio, neutral audio, concern audio, and sixteen animations (four where the face and audio matched, and

twelve where they were mismatched). We used a measure from [1] to assess how subjects perceived the emotional expressions (see Fig. 2.). Subjects were also asked to answer three questions related to their general opinions of the agent.

Sixty eight subjects participated in the experiment and we found that they could correctly recognize the emotions in the static facial expressions, but had difficulty with the audio only expressions. With regard to the matched emotions, subjects were able to recognize happy and warm animations, but the neutral animation was rated a little low on all scales, while the concerned emotion appeared to be rated more as sadness than concern. Mismatching of faces and voices in the animations significantly influenced subjects' perceptions. While neither channel (visual nor audio) seems to dominant when identifying emotional expressions, it appears that with this particular set of animations, subjects rated them higher on all measures when a happy or warm face was in the animation, or when a happy or warm voice was used. Surprisingly, this was also true of the of the "concern" measure: subjects rated animations with happy or warm dimensions as more concerned than animations with neutral and concern dimensions. There were some strong responses to the mismatched facial expressions with many subjects venting their frustration. Also, subjects put a lot of emphasis on the eyes when rating the emotional expressions. Some thought that smiles were false and patronizing as the orbicularis oculi muscle around the eye did not move, while others stated that they liked how the eyes were used to emphasize emotions (even though we did not intentionally use the eyes to express emotion).

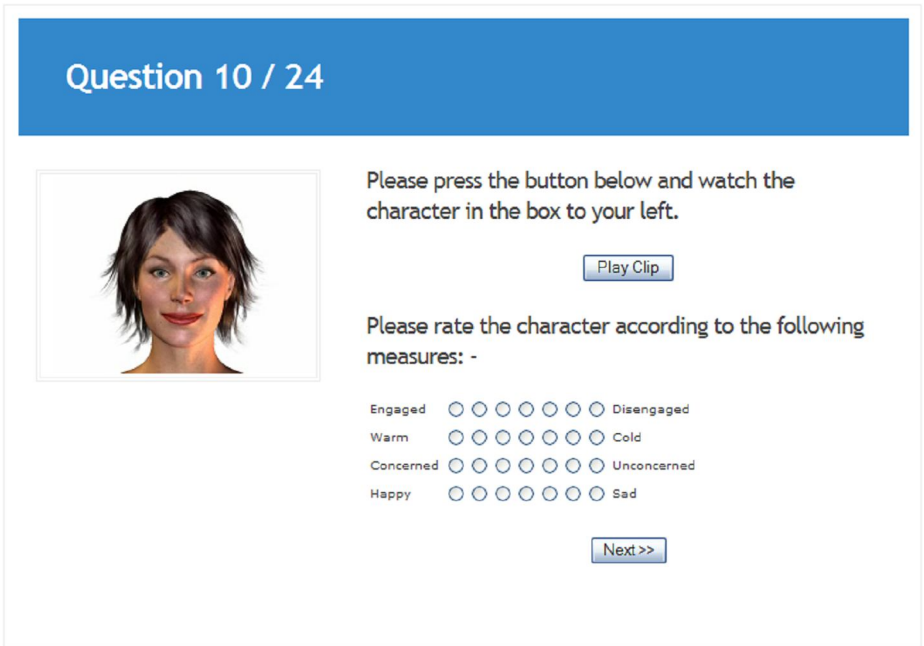

Fig. 2. Screenshot of first experimental system

3.3 Experiment 2

After gathering feedback on the embodied agent and confirming that subjects could correctly recognize the emotional expressions of the agent, we conducted another web-based experiment that involved around a ten minute interaction with the agent. The experiment had a between-subjects design with two different conditions – emotion and no-emotion. Emotion was manipulated through facial and vocal expressions – for example, in the emotion condition, the facial expressions alternated between happiness, warmth, concern, and neutral facial expressions, depending on the context of the conversation, while in the no-emotion condition, the facial expressions always remained neutral. Also, in the emotion condition, the speech rate, pitch average and pitch range were faster, higher and wider than in the no-emotion condition.

The interaction with the agent attempted to simulate a 'first session' with a human health professional [14] – the interaction started with the agent introducing itself and attempting to build rapport with the subject through the use of small talk. The agent then clarified both its own role and the role of the subject during the interaction, and followed this by asking subjects about their dieting history and current eating habits. The agent then moved on to discuss the pros and cons of both the subject's current diet and in changing their diet, and then talked about options the subject has for improving their dietary habits. The interaction concluded with the agent attempting to get an initial commitment for change and then terminating the interaction appropriately. Subjects were able to respond to the agent's utterances by selecting from a list of pre-scripted responses (Fig. 3.). It is important to note that the dialogue between conditions was exactly the same – it was just the way in which it was presented (i.e. either in an emotional or unemotional manner) that differed. The measures were taken from a similar study by Brave et al. [4] and were a mixture of ten point semantic differentials (adjacent pairs) and ten point Likert scales. These scales were used to measure caring, likeability, trustworthiness, intelligence, how positive subjects felt when using the system, and how supported subjects felt. After completing the interaction, participants were given a number of online health-related articles that they could view for as long as they desired. At the end of the experiment, subjects were asked to answer eight open-ended questions that focused on things that annoyed them about the agent, things they liked about the agent, whether the agent was better or worse than interacting with just a website, and their general thoughts regarding the system.

Fifty subjects completed the experiment (twenty five in each condition) and results found that subjects perceived the emotional agent as significantly more emotionally expressive than the unemotional agent. While this was an expected finding, it was important to test so that any subsequent effects could potentially be attributed to our manipulation of the emotional expression. Further to this, the agent was also perceived as significantly more likeable and caring than the unemotional agent. All other measures were not significant. Feedback gathered from the open-ended questions provided a number of further insights into what subjects thought of both the agent and system. Subjects in the no-emotion condition frequently complained about the unemotional nature of the agent – they described its voice as "slow", "boring", "monotonous", and "unenthusiastic." On the other hand, the comments regarding the

emotional agent were generally more positive – subjects liked the "realism" of the agent and often cited the agent's ability to express emotion as something they liked. Others commented on the "pleasant" and "friendly" voice and stated how they liked the general appearance of the agent. However, a few subjects commented on how they did not like the "fake perkiness" of the agent. In both conditions, subjects stated that they would have liked more options to choose from answering the agent's questions and also would have liked an option to skip answering certain questions. Subjects also wanted further feedback after the interaction with Rachael had been completed, as well as more health-based resources to use.

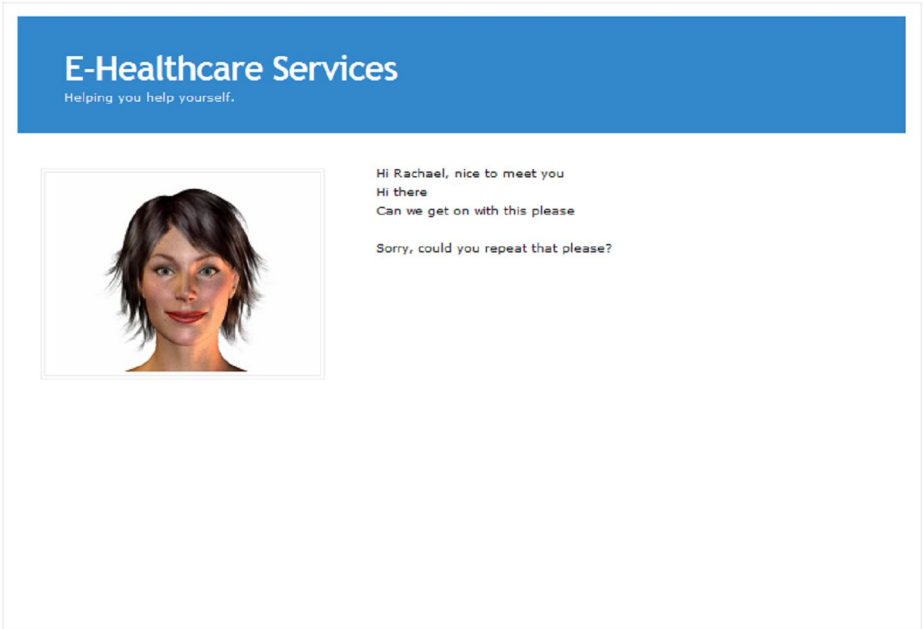

Fig. 3. Screenshot of second experimental system

3.4 Future Experiments

We are currently working on a longitudinal study that will investigate whether simulated emotion has any influence on an agent's ability to help motivate people to change poor dietary habits over multiple and extended interactions. The experiment will be eleven weeks in length and will involve subjects logging into the system daily to record how many portions of fruit and vegetables they have consumed the previous day. Once they have provided this information, they will be able to access a resource area where they will be able to view their progress over time (through the use of graphs) and to make use of a number of other resources such as a BMI calculator, a

calorie counter, a weight monitor, and other tools. At the end of every week, they will have an interaction with the agent to discuss their progress and to set goals for the next week. These interactions will last around 5 minutes. The first phase of the experiment will last seven weeks and will involve eight interactions with the agent. Subjects will then be requested not to use the system for another four weeks – after these four weeks have elapsed, subjects will be asked to provide information about their current fruit and vegetable consumption. This data will be used to assess if any changes that occurred during the interaction with the character have remained.

In conjunction with the longitudinal study, we also plan to run another experiment - this will focus on recording the dialogue with a human actress and then replacing the current agent with this. The main motivation for this is related to comments regarding lip synchronisation from the first two experiments – feedback collected from subjects suggests that they find inaccurate lip synchronisation to be particularly annoying and frustrating to interact with. Such responses could potentially be influencing the finding of subtle effects that were expected, but not found in previous experiment explained. Therefore, by recording an actress, the issue of lip synchronisation will be removed. From this experiment, we expect to see more positive comments from subjects regarding the agent and system in general, and potentially more significant effects than were found in experiment two.

5 Conclusion

The studies highlighted in this paper have started to investigate how users respond to simulated displays of emotion, however, we still have little understanding of how simulated emotion influences user attitudes and behaviour, and whether or not it can be utilised to help produce beneficial and practical enhancements to HCI. Future studies need to concentrate on a number of important areas.

More research is needed that explicitly compares emotional and unemotional agents – while this appears obvious, there are very few studies that have actually performed this test. Without such studies, we have to make comparisons between studies where emotion is not the main focus of the experiment – as discussed in the paper, this is problematic and can lead to a number of issues. In addition to this, more studies need to examine how users respond to simulated emotion over multiple and extended periods of interaction. The majority of studies conducted in this area to date require subjects to have a single and short interaction with an affective embodied agent – as result, it is unclear how we respond to affective agents over time. How do users respond to simulated displays of emotion over multiple interactions? Does it keep them engaged, or do they find it false and patronising? Are emotional agents more effective than unemotional agents at motivating change in user attitudes and behaviour over extended lengths of time? Further to this, there also needs to be a change of focus from that of whether or not emotional agents are better than unemotional agents, to one where we concentrate on which emotions, used at which times, and expressed in which ways, enhance (or hinder) HCI. Too many studies have focused purely on the so-called basic emotions of anger, disgust, fear, happiness, sadness and surprise. More focus needs to be given to cognitive emotions – both in

how to effectively simulate them and in how users respond to them. These emotions play an important role in our lives and should not be neglected.

Understanding user responses to simulated emotion is an important research area that has received little attention to date. As more and more users become familiar with using embodied entities as a means for collaboration and interaction with others in virtual spaces, it is imperative that we understand in detail how simulated emotion influences user attitudes and behaviour. Early studies in this area have illustrated that simulated emotion can influence users in a number of ways, but research now needs to move beyond this, so that we can understand more clearly how affective agents can build effective social and emotional experiences with users that can be utilised for beneficial and practical purposes.

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