Part III

Artificial Intelligence
1 Introduction

Why do computers need emotional intelligence? Science fiction often portrays emotional computers as dangerous and frightening, and as a serious threat to human life. One of the most famous examples is HAL, the supercomputer onboard the spaceship Discovery, in the movie 2001: A Space Odyssey. HAL could express, recognize and respond to human emotion, and generally had strong emotional skills – the consequences of which were catastrophic. However, since the movie’s release almost 40 years ago, the traditional view of emotions as contributing to irrational and unpredictable behaviour has changed. Recent research has suggested that emotions play an essential role in important areas such as learning, memory, motivation, attention, creativity, and decision making. These findings have prompted a large number of research groups around the world to start examining the role of emotions and emotional intelligence in human-computer interaction (HCI).

For almost half a century, computer scientists have been attempting to build machines that can interact intelligently with us, and despite initial optimism, they are still struggling to do so. For much of this time, the role of emotion in developing intelligent computers was largely overlooked, and it is only recently that interest in this area has risen dramatically. This increased interest can largely be attributed to the work of [6] and [85] who were amongst the first to bring emotion to the attention of computer scientists. The former highlighted emotion as a fundamental component required in building believable agents, while the latter further raised the awareness of emotion and its potential importance in HCI. Since these publications, the literature on emotions and computing has grown considerably with progress being made on a number of different fronts.

The concept of designing computers to have emotional intelligence may seem strange, but equipping computers with this type of intelligence may provide a number of important advantages. For example, in spite of a computer’s
impressive ability to process huge volumes of data in milliseconds and to perform complex calculations in a fraction of a second, they still have neither the ability to see or hear us, nor the ability to understand how we are feeling and to adapt themselves accordingly. Users often experience feelings of frustration at computers when they display obscure error messages, behave in erratic ways, and frequently crash. We may feel like venting our anger and frustration towards the computer, but it does not have the ability to respond in a constructive way. However, a computer that has some form of emotional intelligence would be able to detect that the user is feeling frustrated and angry, and would be in a position to take productive steps to alter this.

Such computers could use a number of strategies to help alleviate feelings of anger and frustration, such as opening a dialogue with users to ascertain the source of their emotions, apologizing for any mistakes made and working with the user to resolve them, and through expressions of empathy and understanding at the user’s emotional state. Recent research has suggested that people who have damaged the emotional components of their brain find it difficult to make decisions as they cannot associate any emotion to a decision (in other words, would a particular course of action result in positive or negative feelings? [32]). Such a disability can have a destructive effect on people’s lives as they consistently make poor decisions. This suggests that instead of computers becoming more unpredictable and irrational through having emotional intelligence, they would instead act and behave more rationally and predictably.

So how do we go about giving computers effective emotional skills that aid our interaction with them? This Chapter will provide an overview of what is required to achieve this, as well as the numerous issues involved in doing so. This Chapter is split into three core sections. Section 2 concentrates on the theory and research related to the building of emotional intelligence into computers. It starts by providing an overview of emotion theory, with a particular focus on the concepts and ideas most relevant for building and evaluating emotionally intelligent agents. A detailed perspective of the different approaches used in developing emotional intelligence in computers is then provided, along with a discussion of the limitations of these different approaches.

Section 3 provides an overview of our own work and how it relates to the standard approaches detailed in the previous Section. This includes an overview of what affective embodied agents are, how we respond to synthetic displays of emotion in such agents, research which has suggested that we have social and emotional relationships with computers, a discussion of the importance of conducting longitudinal studies when evaluating interface agents, and a description of the affective embodied agent that we have developed for experimental purposes. The final Section contains a discussion of the application of our approach to the real world by initially discussing areas and problems that affective embodied agents could potentially be useful for. We then provide a detailed example of where such an agent can be used within
2 Overview of Affective Computing

In order to understand how we can give computers effective emotions that aid our interactions with them, we need to start with an understanding of what emotions are and what exactly constitutes emotional intelligence. This section starts by providing an overview of what we currently know about emotions, including what causes them, how we express them, and what influences they have on the way we feel and behave. A detailed overview of the standard approaches used in attempting to incorporate emotional intelligence into computers is then provided.

2.1 What Are Emotions?

Emotion theorists have debated for centuries about what emotions are and what their primary function in human life is. This debate is far from over and there is currently no universally agreed upon definition of emotions. However, many scholars would at least agree that we experience different types of emotions in our everyday lives. An overview of these is provided below.

Basic Emotions

For much of the previous century, emotion scholars generally subscribed to a cultural theory of emotion, where emotions were believed to be culturally-specific learned behaviours that could only be experienced through observing other people expressing such emotions. However, [38] discovered that some emotions are not necessarily learned as previously believed, but are in fact innate and shared across all cultures. In his study, Ekman travelled to a preliterate culture (the Fore, in New Guinea) to ensure that the people there had not been exposed to Western media and had not learned the emotional expressions of Westerners. The subjects were told a number of stories, then asked to choose from a set of photographs of Americans expressing different emotions, the one which most closely matched the story. When tested, the Fore pointed to the same expressions that Westerners linked to the story. For further clarification, some Fore people were videotaped displaying facial expressions appropriate to each of the stories. After returning home, the experiment was completed in reverse by asking Americans to link the Fore faces to the different stories. The judgements of both the Fore people and the Americans again matched. These were named ‘basic emotions’, and while researchers often disagree about how many basic emotions there are, many would agree that anger, disgust, fear, joy, sadness and surprise can be classed as basic emotions.
Culturally Specific Expressions of Emotions

There are also cultural variations in the way in which humans express emotion. For example, [38] investigated the different emotion display rules that Americans and the Japanese have. In this experiment, both American and Japanese men were videotaped whilst watching some video clips. The clips varied as to whether they displayed neutral or pleasant events (such as a canoe trip) or less pleasant events (for example, nasal surgery). There were two showings of the video clips: one where subjects watched the clips on their own and another where subjects watched the clips with an interviewer present. When subjects watched the clips in private, similar expressions were noted in both American and Japanese subjects. However, when the interviewer was present, Japanese subjects smiled more and showed less disgust than the American subjects. When the videotapes were watched back in slow motion the researchers noticed that when the interviewer was present, Japanese subjects actually started to make the same expressions of disgust as the Americans did, but they were able to mask these expressions very quickly afterwards. Therefore, it appeared that the American and Japanese participants actually experienced the same basic emotions as these were automatic responses hardwired into their brains. It was only a few hundred milliseconds later, that the Japanese subjects could apply their learnt cultural display rules and override the automatic response.

It has also been suggested that some emotions are culturally specific. For example, [65] reported on an emotion that is experienced by the Gururumba people of New Guinea that is not believed to be experienced from people of other cultures. This is known as the state of ‘being a wild pig’ and people who experience this state can become aggressive and often start looting, but rarely is anyone actually hurt or anything of importance stolen. This state is considered as normal among the Gururumba, as a way of relieving stress and maintaining mental health across the community.

Higher Cognitive Emotions

[56] has argued that in addition to basic and culturally-specific emotions, there are also ‘higher cognitive emotions’. These emotions are similar to basic emotions in that they are universal, but there are also variations on the way that they are expressed and experienced by different cultures, and there is also no single facial expression associated with them. Higher cognitive emotions also take longer than basic emotions to both develop and pass away. For example, consider romantic love. This emotion usually develops gradually in people over a period of weeks and months, while surprise (a basic emotion) is typically a very quick reaction to an event. Surprise also has a single universal facial expression associated with it, while there is no single universal facial expression for love. It is suggested that emotions such as love, jealousy, pride, embarrassment and guilt should be called ‘higher cognitive emotions’, because
these emotions typically require more processing in the cortex of the brain. This essentially means that these emotions can be influenced more by cognitive thought processes, while basic emotions are more reactive in nature.

**Neurological Model of Emotion**

The model of Fig. 1 has been developed for some emotions (in particular, fear), based on work in neuroscience where it was found that fear is controlled by two different pathways in the brain [65]. Furthermore, the following three key regions of the brain were identified as being associated with fear: the thalamus, the limbic system (in particular, the amygdala) and the cortex [65]. Sensory input is initially received by the thalamus from the environment and transmitted simultaneously across the *low* road to the limbic system and up the *high* road to the cortex. The relevance of the inputs to an individual’s concerns (in other words, their needs and goals) are then continually assessed by the limbic system, and if an input is evaluated as relevant, signals are sent both to the body for physiological reaction and to the cortex for processing. The first pathway (the thalamic-limbic) is the quicker of the two, and forces us to react to potential dangers. In being quicker, it is prone to make more errors and can often be initiated by false alarms, such as hearing a door slam. The second pathway (the thalamic-cortex) is slower, but more accurate, and can override feelings of fear evoked from the first pathway.

![Fig. 1. LeDoux’s neurological model of fear [65]](image-url)
Primary, Secondary, and Tertiary Emotions

Emotions aroused from the first pathway are referred to as ‘primary emotions’, in other words, our hard-wired primitive emotions [32]. Primary emotions are typically reactions to stimuli such as outrage, being startled, or sexually stimulated. By contrast, ‘secondary emotions’ are defined as those emotions that require more cognitive thought, such as grief, frustration and pride. One patient – ‘Elliot’ (who had acquired damage to his frontal cortex as a result of a brain tumour) – was used to illustrate the difference between primary and secondary emotions. Elliot’s primary emotions still appeared to be functioning correctly as he could, for example, still be startled by a loud bang. However, if he saw a disturbing scene depicting a human head exploding, he knew cognitively that he should feel shocked, but physiologically there was no response where normally there would be. Elliot’s limbic-cortical pathway had been damaged, and as a result he knew that he should feel certain emotions, but did not.

It has argued that there also exist ‘tertiary emotions’, these being emotional states that involve a partial loss of control over thought processes. When experiencing a tertiary emotion, it can be hard to concentrate on anything else, making it particularly difficult to attend to important and urgent tasks. Humiliation, infatuation, guilt and excited anticipation can be viewed as examples of tertiary emotions [97].

2.2 Emotions and Moods

A major problem in emotion research is the lack of a common language. Terms such as emotion, moods, drives, sentiments and attitudes are often used interchangeably by researchers and it can be unclear what is being referred to at times. These terms have meanings of their own and have been discussed at length in the literature [40]. Here we will focus primarily on the relationship between emotions and moods, since distinction between the two can be particularly difficult (people often use similar words, such as ‘happy’, to describe both). One obvious difference between the two is the duration for which each lasts. Despite disagreement about exactly how long emotions last, [39] suggests that they are very brief in comparison to moods and typically last a few seconds or minutes at most, whereas moods tend to last for hours or days.

[51] distinguishes between emotions and moods by arguing that emotions are ‘intentional’ and involve relationships between people and objects: “one is afraid of something, angry at someone, happy about something.” Moods, however, are ‘nonintentional’ and experienced more generally than emotions. Unlike emotions, they are not directed at any object in particular (although an object does have the potential to indirectly cause moods).

[33] suggests that emotions and moods can be distinguished through a functional analysis of each. Some emotion theorists have argued that the main
function of emotion is to bias the action we take in reaction to a particular situation. These emotions prepare the body to act quickly to these events and are usually very brief. However, the key function of moods is to bias cognition over extended periods of time. [33] further suggests that moods are always present and can affect our evaluation of events encountered both internally and externally. For example, someone in a positive mood is likely to view everything more positively, while somebody who is in a negative mood is likely to view everything more negatively.

Moods also appear to lower the threshold for experiencing other mood-related emotion. For example, an individual in an irritated mood can become more readily angry than they usually would. Situations or objects that would not normally cause such anger can do so more easily because of the mood of the person [39].

2.3 Expression of Emotion

Humans can express emotion in a variety of ways, the primary ones being written language, facial expressions, speech, and body language (such as posture and gait).

Written Language

Written language is a powerful medium for expressing emotion. People often express their emotions through stories, poetry and personal letters. People can literally state how they are feeling using emotive words such as ‘happy’, ‘sad’, or ‘ecstatic’. The colour, size, and shape of words can also be manipulated to add emotional emphasis to content (for instance, by animating text [106]). Symbols such as emoticons – for example, :-) or :-( – can also be used to convey emotion, and are particularly popular within domains where emotional information is lacking, such as email, instant messaging or text messaging.

Speech

Another powerful method for communicating and expressing emotion is through speech. In some scenarios, it is the only channel available for communication (for example, telephone conversations). Speech can also provide other information about a speaker such as their identity, age and gender. People can also use speech to simply communicate the emotions they are experiencing. Pitch (level, range and variability), tempo and loudness are considered the most influential parameters for expressing emotion through speech [4]. [75] have defined the general characteristics of a range of basic emotions (Table 1).
Table 1. Summary of emotional effects in speech (relative to neutral speech)

<table>
<thead>
<tr>
<th></th>
<th>Anger</th>
<th>Happiness</th>
<th>Sadness</th>
<th>Fear</th>
<th>Disgust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speech rate</td>
<td>faster</td>
<td>slower</td>
<td>slower</td>
<td>faster</td>
<td>slower</td>
</tr>
<tr>
<td>Pitch average</td>
<td>higher</td>
<td>higher</td>
<td>lower</td>
<td>higher</td>
<td>lower</td>
</tr>
<tr>
<td>Pitch range</td>
<td>wider</td>
<td>wider</td>
<td>narrower</td>
<td>wider</td>
<td>wider</td>
</tr>
<tr>
<td>Intensity</td>
<td>higher</td>
<td>higher</td>
<td>lower</td>
<td>normal</td>
<td>lower</td>
</tr>
<tr>
<td>Voice quality</td>
<td>breathy,</td>
<td>breathy,</td>
<td>resonant</td>
<td>irregular</td>
<td>wide,</td>
</tr>
<tr>
<td></td>
<td>chest tone</td>
<td>blaring</td>
<td>resonant</td>
<td>voicing</td>
<td>downward</td>
</tr>
<tr>
<td>Articulation</td>
<td>tense</td>
<td>normal</td>
<td>slurring</td>
<td>precise</td>
<td>normal</td>
</tr>
</tbody>
</table>

Facial Expressions

Facial expressions are one of the primary ways in which we can detect emotions in others. [41] have detailed the typical facial features that are associated with six basic emotions with the mouth, cheeks, eyes, eyebrows and forehead making up the core components of the face that are used to express emotion. [42] have also produced the Facial Action Coding System (FACS), which details the specific set of muscular movements for each of the basic emotions. FACS helped to develop the Facial Definition Parameter (FDP) set and the Facial Animation Parameter (FAP) set which were designed according to the ISO MPEG-4 standard to enable the animation of faces, expressions, emotions, and lip movement. Humans are particularly adept at recognizing emotion in facial expression, and research has shown that people can accurately identify the emotional expressions of faces represented by as little as 37 lines, concentrating on the eye-brows, eyelids and mouth [44].

Gestures and Body Language

An overview and explanation of the meaning of different head, hand and body movements is provided in [52]. For example, a vertical (up and down) ‘head-nod’ often displays agreement or comprehension while listening. Clenched fists can signal an aroused emotional state, such as fear, anger, or excitement (for instance celebrating your team scoring at a sports event). Another example is arm-crossing, which is seen as a self-comforting and stimulating posture that is unconsciously used to ease anxiety and social stress [52].
2.4 Influence of Emotion on Human Behaviour

Attention

Emotion and attention are closely related. Paying attention to something can trigger an emotion while an emotion can influence what we focus our attention on. When an emotion is triggered it focuses our attention and mental focus onto an external object or event that produced the emotion [82]. For example, when we are angry we focus on the thing that angered us; when we are frightened we concentrate on what scared us; when sad we focus on what upset us.

Moods can also influence attention by focusing thoughts on the object or event that caused the mood. For example, when feeling upset, depressed or down, we tend to focus our thoughts on what made us feel this way. However, we can still experience moods without our attention being focused on anything in particular. For example, being in an anxious mood when walking down a dark alley at night helps us to keep alert for any potential signs of danger [45].

Numerous studies have focused on the effects of anxiety on attention. Anxiety narrows attention to whatever has caused the anxious feelings and little attention is given to almost everything else. Researchers have examined the effects of anxiety on attention through an experiment known as the ‘emotional Stroop test.’ [98] found that if people are asked to look at the printed text of colour names that were printed in a different colour from the text (for example, the printed text ‘red’ in a blue colour) and were then asked to name the colour of the text for each word, they take longer when the colour of the word and the colour of the print do not match. When the colour of the text and the printed word are mismatched it causes confusion and thus it takes longer to say the colour of the text.

The idea of the emotional Stroop test is that the words shown are both neutral and (potentially) emotionally arousing, to test whether it takes longer to name the colour of the words which are emotionally arousing. For example, [47] found that subjects who had been victims of rape were slower at naming the coloured words that were related to rape. This suggests that the anxiety caused by seeing a word associated with a traumatic experience focuses attention on that word, making it difficult to focus on other details such as the colour of the print.

Memory

Emotions and moods influence what we remember. We are able to recall events that are associated with either a strong positive or negative emotional reaction more easily than neutral events. For example, [24] reported on five experiments where groups of students watched a set of fifteen colour slides of what someone might see when walking to work. All groups of students saw the same slides,
except for the eighth one, of which there were three variants, namely: (i) a woman riding a bicycle, (ii) the same woman carrying the bicycle over her shoulder, and (iii) the same woman lying on the side of the road as if she had been hit by a passing car. After viewing the slides, students were then asked to recall what they had seen. Results found that people who had seen the woman lying on the side of the road could remember details like the colour of her coat more accurately than other groups. However, they struggled to remember other (peripheral) details, such as the colour of the car in the distance as well as the other groups.

The mood that we are in when attempting to remember something also influences our ability to recall it. For example, [12] illustrated that when we are in a happy mood, we seem to be able to recall pleasant events more easily than unpleasant ones. The opposite appears to apply when we are in a sad mood. In this experiment, subjects were asked to recall and describe incidents from when they were a child. The following day, when the subjects were in a neutral mood, they were asked to rate each incident as ‘pleasant’, ‘unpleasant’, or ‘neutral’. The next day, happy or sad moods were induced in subjects and they were then asked to recall as many of their incidents as possible. Results found that people who had been induced into a good mood could remember more incidents that they classed as ‘happy’, but remembered less of the ones they classed as ‘sad’. A similar (opposite) effect was also found for people who had been induced into a sad mood. This effect is often referred to as ‘mood-congruent recall.’

Judgement and Decision Making

Emotions also have a strong influence on our judgement and the decisions we make. For example, one experiment [2] suggested that our judgement of other people is often influenced by the mood we are in when we meet them. In this study, same sex subjects were paired together to practice a job interview. Unknown to subjects was that their partners were actually helping the experimenters. The subjects were chosen to be the interviewers while their partners were the interviewees. Subjects were put into a good or bad mood by the experimenter by giving them problems to solve and then commenting on their performance, telling them that they had either performed much better than others, had performed averagely, or had done far worse than other people. The subjects were then asked to interview their partner through asking a set of pre-scripted questions, such as “What are your most important traits?” The interviewee replied with positive (for example, “I’m ambitious and reliable”) and negative answers (such as “I’m impatient”). After the interview, the interviewers were requested to assess the interviewee on both work and personal aspects. It was found that subjects who were in a good mood had a tendency to rate the interviewees more positively and were more likely to employ them, while the subjects in a bad mood had a tendency to rate people
more negatively and were less likely to hire people [2]. This is despite the answers received by subjects being the same.

Creative Problem Solving

Moods have been found to have an influence on problem solving. For example, in one experiment [58], subjects were induced into either a good or bad mood and then asked to solve Dunker’s candle task [36]. Given only a box of thumbtacks, the goal of this problem is to attach a lighted candle to the wall in such a way that no wax falls to the floor. It was found that subjects who were put in a good mood before the start of the task were more successful at solving this problem [58]. Another study which suggested the influence of emotions and moods on problem solving was that of [59]. In this study, medical students had either positive, negative, or neutral moods induced, and were then asked to diagnose patients based on their X-rays. Results from this study found that subjects who had a positive mood induced were able to make the correct diagnosis faster than subjects who had either negative or neutral moods induced.

Persuasion

Emotions also play a vital role in persuading people to do things. [71] investigated this by questioning students about whether or not they were in favour of gun control. Half of the students had a positive mood induced by watching a short comedy show, while the other half watched a more neutral programme about wine. Both groups were then provided with an argument about gun control that contradicted their own view on the subject – people who were in favour of greater control were presented with an argument against further restrictions, while people against greater control read an argument in favour of this. Half of the subjects were also presented with strong arguments, while the other half were provided with weak arguments. Furthermore, some subjects were informed that the person presenting the argument was a first-year student, while others were told that an expert was making the argument. Some subjects were also given only a short period of time to read the argument, while others were allowed to take as long as they desired. Once subjects had finished reading the argument, they were tested again to see if there were any changes in their view on the subject area. Results found that subjects were generally more influenced by the strong arguments than the weak ones. However, there was only a small difference for subjects who were put into a positive mood and had only a short period of time to read the argument, while the other groups found the weak arguments much less persuasive.

Emotional responses can also be used to manipulate the emotions and perceptions of others, for their own purposes. For example, sales people often try and build rapport through appearing empathic and understanding of their
potential customer’s needs and concerns to make themselves appear more likeable. By making themselves appear more friendly, warm and likeable, they can increase the likelihood that people will comply with their requests [25]. Advertisers often attempt to play with our emotions to help sell their products. They use emotionally evocative images and music alongside the presentation of their product, in the hope that we will associate positive emotions with it. The same is also true when attempting to persuade people to stop participating in potentially dangerous and harmful things – for example, hard-hitting television advertisements which contain highly evocative graphical images of car crashes to warn about the dangers of drink driving. The hope here is that viewers will associate strong negative emotions with such behaviour and thus avoid doing it.

2.5 Emotional Intelligence

The notion of emotional intelligence was first introduced by [95], and later popularized by [53]. Emotional intelligence is defined as: “...an ability to recognize the meanings of emotion and their relationships, and to reason and problem-solve on the basis of them. Emotional intelligence is involved in the capacity to perceive emotions, assimilate emotion-related feelings, understand the information of those emotions, and manage them.” [72]

As can be seen from the above definition, the concept of emotional intelligence has been divided into four different areas to create a four-branch model, these being [73]:

- Accurately perceiving emotion
- Using emotions to facilitate thinking
- Understanding emotional meanings
- Managing emotions

Goleman’s Emotional Competence Framework, on the other hand, divides emotional intelligence into five core competencies [54]:

- **Self Awareness:** knowing one’s internal states, preferences, resources and intuitions
- **Self-Regulation:** managing one’s internal states, impulses, and resources
- **Motivation:** emotional tendencies that guide or facilitate reaching goals
- **Empathy:** awareness of others’ feelings, needs, and concerns
- **Social skills:** adeptness at inducing desirable responses in others

Goleman suggests that the above emotional intelligence capacities make up a hierarchy in which they build on each other [54]. For example, self-awareness is essential for self-regulation and empathy, while self-regulation and self-awareness are crucial for motivation. All four preceding competencies are required for social skills.
These different categorizations are not contradictory; instead, they reflect slightly different perspectives from the researchers as to the focus and extent of emotion, and serve to illustrate that emotions are complex things with multiple effects on ourselves, on our perceptions of the world and others in it, on our desires and actions, and on our behaviour and responses.

2.6 Approaches Used in Developing Emotionally Intelligent Computers

So how can we build emotionally intelligent computers? The previous Section discussed some of the core competencies required for humans to be considered emotionally intelligent. Therefore, if we wish to simulate human emotional intelligence, computers will also need to be adept in these areas. But this is problematic. For example, one of the major disadvantages that computers have over humans is that they do not have the sensory organs of humans – such as eyes and ears – for recognizing emotional responses in others. Recent progress has been made in building emotional voice recognition software and applications that can track subtle facial movements and measure physiological signals associated with emotion, but much of this work is still in its infancy. This Section provides an overview of the different approaches being taken with regard to building emotionally intelligent computers.

Computational Emotion Models

The goal in developing a model of emotion is to enable machines to evaluate events and objects in such a way that they exhibit believable emotional reactions to what has been evaluated (in other words, an emotional response similar to that of a human). For these emotional reactions to be convincing, emotion models should enable computers to express emotions believably at both the right intensity and at the appropriate time. The following references provide an overview of work that has been completed in this research area [20, 21, 23, 35, 84, 87, 103, 104].

Appraisal theories have had a strong influence on the development of computational models of emotion. The term ‘appraisal’ refers to the evaluation of antecedent events that result in a particular emotion being experienced. The model most often used to incorporate emotion into agents (that is based on appraisal theory) is the OCC model [83], which is a computational model of emotion that contains 22 emotion categories based on valenced reactions to the consequences of goal relevant events, actions of another agent (as well as itself), or according to the attractiveness of objects. The model also provides variables for determining the intensity of an emotion.

The model, however, does have its limitations. [5] suggests that this model provides a useful starting point for incorporating emotion into agents, but is too complex for creating believable characters. For example, if facial
expressions are used as the medium to express emotion, it then becomes very difficult to map the 22 emotional categories of the OCC model to the 6 facial expressions identified by [38] as being used to convey emotion. Therefore, when the model is used in this context, it needs to be simplified to match the abilities of the interface agents. It has been further suggested that the OCC model requires extended features, including a history function, a personality designer, and the interaction of emotional categories (in other words, how the emotional value of an event should affect the current emotional state of the agent) [5].

An alternative model is that of [55], who have developed a domain-independent model based on a framework of appraisal and coping which is used in the design of autonomous virtual humans. The usefulness of this model has been demonstrated with a Mission Rehearsal Exercise (MRE) system that trains people for peacekeeping activities.

Computational models of emotion are often tested visually through the use of embodied agents and virtual worlds. Advances in 3D graphics have enabled developers to create realistic embodied agents that can be used for testing purposes to examine whether emotion models are providing the desired emotional responses (see, for example, [85]).

Detecting Emotions to Aid Interaction

Knowing whether a user is experiencing frustration, satisfaction or some other emotional state provides the computer with the opportunity to intelligently adapt itself in an attempt to enhance its interaction with people. However, simply detecting user emotions is far from easy and even if achieved, there is then perhaps the larger issue of how should computers appropriately adapt themselves to these emotional states? For computers to be able to express useful emotions, they need to be able to understand how a user is feeling. This section provides an overview of the different ways in which a computer can detect human emotion.

Autonomic Responses

Emotion can be measured (to an extent) through measuring automatic physiological activity such as heart rate, blood pressure, blood pulse volume, respiration, temperature, pupil dilation, skin conductivity and muscle tension. Emotion can also be measured through neurological changes, with the most common measure for this being the electroencephalogram (EEG). However, while it is now relatively easy to measure many of the above, it is still very difficult to distinguish between different emotions. For example, a number of different emotional reactions such as fear, anger, surprise and happiness involve an increase in heart rate [17]. Therefore, when an increase in heart rate is observed by a computer, it has no way of knowing which of these emotions is being experienced. Despite problems such as these, some success has
been achieved through the use of multiple measures of autonomic signals. For example, [88] achieved 81% recognition accuracy on eight emotions by combining a variety of measures such as facial muscle tension, respiration, skin conductance and blood pressure volume.

Another study with promising results was that by [94] who reported on an experimental system that aimed to automatically recognize user frustration from physiological signs of skin conductivity and blood volume pressure. In this study, subjects played a competitive computer game where they had to efficiently and accurately solve as many visual puzzles as possible, in order to win a cash prize. To induce frustration in subjects, the computer game experienced a deliberate delay, at irregular intervals, in which the mouse appeared not to work. Whilst playing the game, the subject’s skin conductivity and blood volume pressure were measured to observe if frustration that was likely to be caused by the game (namely, when there was a delay) could be told apart from times when the game was less likely to cause frustration (in other words, when the game was running without any delays). It was found that this approach worked significantly better than having a random guess at when the game might cause frustration. Additionally, results found a correlation between the mouse clicking behaviour of subjects and frustration-eliciting events.

Lie detectors – so beloved of older police and spy dramas – provide us with an example of a physiological stress measurement, with the assumption being that under stress, galvanic skin response is altered and can easily be detected. Their accuracy is critically dependent on the skill of the operator, and even then is able to be fooled by practiced participants.

**Facial Expression**

Another potential way for computers to detect emotion in users is through monitoring facial expressions. FACS [41] is often the foundation used by designers when attempting to give machines the ability to recognize facial expressions [102]. One approach that has attracted a lot of interest and has provided some promising results is that of pattern recognition of different images, with recognition accuracy approaching 100% with some basic emotions [27, 43, 68, 70]. Another method for recognizing facial expressions that has had some success is facial electromyography (EMG). EMG signals have shown promise in being able to distinguish between different basic emotions [18].

**Speech**

Speech provides another opportunity for computers to detect a user’s emotional state. As mentioned previously, our voices can express emotion through changes in speech such as pitch range, speech rate and rhythm [77]. Few systems have been built which attempt to autonomously detect emotion from
speech, but some have shown promise, such as [1] and the ASSESS (Automatic Statistical Summary of Elementary Speech Structures) system [26]. Autonomous extracting emotional content from speech can be a difficult process. For example, [71] conducted a study that examined autonomous detection of a small set of emotions expressed (in a highly emotive fashion) in an echo-free and quiet environment. The authors mention a number of issues in attempting to do this, such as having to create large databases of emotional content, using a method that produces appropriate emotional content for analysis (such as getting people to read emotive text, as opposed to using spontaneous emotional speech) and assessing the quality of emotional speech. A detailed review of emotion recognition systems is provided in [27].

**Questioning Users**

Another approach for determining the emotional state of a user is to simply ask them. An often-used approach is to ask subjects to choose an emotional adjective that best describes the way they are feeling. Profile of Mood States (POMS) [75] is an adjective-based measure of mood that is often used. Another example is the Differential Emotion Scale (DES) [60] which is a questionnaire that contains twenty-four emotional adjectives that people rate on seven-point scales as a means of detailing their affective feelings. Other questionnaires are based on dimensional theories of emotion where the assumption is that emotion can be described through two different dimensions: arousal and valance (see, for instance, [64]).

Using questionnaires such as these to determine the emotional states of users raises a number of issues. For example, people often find it difficult to articulate how they are feeling, and using a single adjective to do this can make it more difficult for them. Also, if questionnaires are used after the completion of an experiment to determine the emotions experienced, then, as previously discussed, people’s memories are likely to have been influenced by the emotions they experienced. Asking subjects how they are feeling during the experiment is likely to interrupt that emotion and thus influence their response.

**Simulating Human Expressions of Emotion**

This Section provides an overview of the three main ways in which computers can simulate emotion: (1) through written language and manipulation of static text, (2) through synthetic or recorded speech, and (3) through the use of embodied agents which can simulate human facial expressions and body language.

**Emotive Text**

A number of studies have shown that emotive textual content displayed by a computer can have a significant impact on our perceptions, behaviour and
performance. For example, subjects in [48] played a guessing game with a text-based interface and received one of three differing types of feedback during the interaction: sincere praise, flattery (insincere praise) or generic feedback. In the sincere praise and flattery conditions, the computer would display responses like “your question makes an interesting and useful distinction”, or “you seem to have an uncommon ability to structure data logically”. In the generic feedback condition, subjects simply saw a message that said “begin next round”. The flattering comments made by the interface agent were found to have a similar effect as flattery from another person, even though subjects were fully aware that their participation was with a computer. In this case, subjects found the interaction with an agent that flattered them to be more enjoyable than with one which did not. That is, the textual content displayed by the computer had a significant influence on user’s perceptions and emotions.

Another example of how emotive text can influence people is a study which found that computers have the potential to alleviate feelings of frustration [62]. In this study, subjects participated in a game which froze at random intervals (to frustrate subjects) when competing for a cash prize. To help ease the subject’s frustration, an interactive ‘affect support’ agent was designed in the form of a text-based questionnaire. Subjects were split into three groups, with each group interacting with a different type of agent: a support agent, an agent that allowed subjects to ‘vent’ their anger, and an agent which ignored their feelings completely. During the first phase of interaction, subjects initially played the game and then interacted with one of the agents. After this interaction, subjects were then asked to play another version of the game (which did not freeze) for at least another three minutes. After this time had elapsed subjects were free to continue playing or to leave.

In the ignore condition, subjects were asked close-ended questions that did not involve emotions or provide an opportunity to report a problem like web delays. In the vent condition, subjects were asked open-ended questions that gave them the opportunity to report the relevant problem, as well as their emotional state. In the affect-support condition, subjects were asked mostly the same questions as in the vent condition; however, after the computer asked how frustrated the user was feeling, the computer gave feedback based on the user’s reported frustration level. Feedback included comments like, “wow, it sounds like you felt really frustrated playing this game”, and “that must feel lousy. It is no fun trying to play a simple game, only to have the whole experience derailed by something out of your control.” It was found that subjects who had initially interacted with the support agent, spent significantly more time in the second phase interacting with the computer that had tried to frustrate them, than subjects who interacted with agents that had either ignored their feelings completely or allowed them to ‘vent’ their frustrations. This experiment used simple plain text to manipulate subjects’ behaviour.
Emotive Speech

There has been a lot of interest in speech interfaces over the last decade with the intelligibility of synthetic speech nearing that of human speech [78]. Incorporating emotion into speech has proved to be quite a challenge, although [19] illustrated that synthetic speech can contain recognizable affect by copying the effects of emotion on human speech. Computers do not always need to use synthetic speech to communicate with users – they can also be programmed to use recorded human speech, which can be used to convey emotion more clearly (for example, through a happy or sad voice). The choice of words used by a computer can also be used to give an indication of its feelings. For example, when asking a computer to do something, if it replies with “if I must”, as opposed to “of course, no problem”, this can suggest how the computer feels.

Facial Expressions

As mentioned previously, research has consistently provided evidence that humans are capable of identifying and distinguishing between different basic emotions (independent of their culture) including anger, fear, joy, sadness and surprise [38]. The FACS system [42] (and other similar systems) which detail the specific set of muscular movements required for the facial expression of each basic emotion, have been used by researchers as a basis for giving embodied agents emotional expressions. Embodied agents that have used systems like this include Baldi [11] and Perlin’s responsive face [86]. Research has also provided evidence that despite current technology not being sufficiently advanced to dynamically generate facial expressions exactly the same as human ones, humans can still consistently identify the facial expressions being displayed. For example, [3] used Baldi (Fig. 2) to test whether or not an embodied agent’s emotional expressions were as convincing as human expressions. It was found that the emotional expressions of Baldi were as convincing as human expression and that knowledge about the source of the emotional expression had no major impact upon the convincingness. Although Baldi is an animated agent, some studies – such as [13] – have successfully used still images to get embodied agents to express emotion.

Body Language and Gesture

While the relationship between emotion and gestures is not as well understood as that of facial expressions and emotions, a number of affective embodied agents can still use body language and gestures to convey information. An exercise advisor named Laura [10] uses a range of non-verbal behaviours including hand gestures, body posture shifts, gazing at (away from) the user, raising and lowering of eye brows, head nods, and walking on and off the screen. Laura also has the ability to convey immediacy behaviour and when expressing empathy can appear nearer to the screen to show an empathic
facial expression. Other embodied agents that use body language and gestures to communicate with users include Herman the Bug [66] and the Real Estate Agent (REA) [9].

2.7 Ethics

In order for computers to build social and emotional relationships with users, they require certain capabilities to allow them to detect and manipulate user emotion, as well as being able to express emotional states of their own through different channels. This raises numerous ethical and technical issues, many of which have been discussed in the literature [89]. In this Section, we highlight some of the main issues involved.

Genuine Emotional Expressions

One ethical issue that arises from incorporating affective capabilities into computers is whether or not emotional support offered by computers is genuine? That is, does it matter that when computers express or communicate emotion to users that they do not actually feel the emotions as humans would? Looking to human-human interaction, it would suggest not, as we often interact with people who are trained to use certain relational strategies to build trust with us, despite them not genuinely feeling sympathetic or empathic toward us. For example, social workers, nurses, general practitioners (doctors), and psychotherapists are all trained to use certain relational strategies, such as empathy, to enhance relations. Also, consider a help desk assistant who has
to deal with numerous queries every day and who is trained (and expected) to empathise with each customer’s individual problem. Are these expressions of emotion genuine or are these people just performing their everyday tasks? At times they may build a genuine rapport with a customer and feel bad that the product purchased by the customer is faulty, but on most occasions it is likely that they are empathising since this is what is expected of them, both by the customer and their employer.

[87] uses the scenario of a dog greeting its master to suggest that expressed emotions do not necessarily have to be authentic to meet some of our basic emotional needs. When the master arrives home the dog is often happy and will start wagging its tail. However, if the master appears to be sad, dogs somehow have the ability to recognize this and they will often put their heads down and flick back their ears in response to their master’s emotional state. The master, in seeing the empathic response, will often change their posture and begin to feel a little better. Once the dog recognizes this, it too will raise its head and start wagging its tail. It is not known how dogs can perceive the emotional states of others, or whether they have their master’s best interests at heart, but this simple interaction often has the effect of meeting some of the simple emotional needs that we as humans have.

**Should HCI Replace Human-Human Interaction?**

Another important question is that of whether HCI should ever replace human-human interaction. For example, in the future, should teaching agents replace human teachers? At present, it is hard to argue in favour of computers replacing important roles requiring social interaction, as they do not have the social and emotional intelligence required. They struggle in building rapport with users and cannot inspire or motivate people outside of a narrow social dialogue. Technological advances over the coming years may change this, resulting in more socially astute agents, but would this ever warrant replacing their human equivalent? They would likely be cost-effective, require little maintenance, and would not complain about how much they get paid. However, while it is often easy to envisage fully embodied and socially competent agents; conversing with people in natural language, it is not so easy to predict how people would respond to such entities. People may feel uncomfortable interacting with such agents and reject the technology outright. Alternatively, they may find it novel, entertaining, and a natural way to interact, and thus embrace such agents. Using computers to help supplement the roles that humans perform would perhaps be more practical and useful. Agents that can help with exam revision, explain more about particular illnesses after you have visited the doctor, or help you practice important interviews or presentations, could potentially be of use.
Manipulation

One issue which arises from building computers with affective capabilities, is the opportunity for manipulation [29]. Computers that can accurately and reliably detect emotional states have access to some very personal and private information, which could potentially be used to manipulate how we feel. Recent work has illustrated that agents which are programmed to be empathic toward the user are perceived as more caring and trustworthy [1, 10]. In human-human interaction, someone who we perceive to care about us can have more of an influence over our behaviour and we generally trust information more when it is from such a source [25]. Therefore, caring computers may have increased persuasive powers that can be used to influence us. Is it acceptable for agents to manipulate (and possibly deceive) people in this way to help companies sell more products? Perhaps, as long as the user feels they have received good value for their money and do not feel manipulated. Human sales people often present the products they sell in their best light, even when they are fully aware that the product has certain features that are not desirable for the customer. Most people are aware of this and while they may not be overly keen about it, they generally do not mind if they feel that they have received good service and value for money. The same is likely to apply with computers; if users feel that they have received a good deal and service then they will be happy, otherwise, if they feel manipulated and cheated, they will be unhappy and unlikely to return with their money.

Negative Emotions

Assuming that computers will one day have the ability to detect user emotion, should they try to eliminate all (so-called) ‘negative’ emotions and attempt to make a user feel better on a consistent basis? A problem with this question is that it is hard to define what is meant by ‘negative’ emotions, and in any case, if there was an appropriate definition, negative emotions are not necessarily all bad. [16] are investigating how an embodied teaching agent can help users work through frustration, which is often regarded as a negative state. However, the ability to work through frustration is essential in learning environments, as the adage ‘no pain, no gain’ suggests. This is particularly clear when observing people playing computer games, in which a difficult passage of the game is attempted again and again until the user manages to crack the techniques needed; the frustration felt there serves to motivate them to continue until they succeed. The skill in designing good games comes in pitching the level of difficulty such that the frustration levels are not too great to cause the player to give up, but hard enough so that their sense of achievement and relief is sufficiently high. Thus, computers should not necessarily try to restrict users from experiencing certain emotional states, but instead should attempt to help them understand and make use of their emotions, to help them achieve their goals. For example, a computer could help alleviate anger through teaching
users anger management strategies. In essence, computers would be helping
user’s to build their *emotional intelligence*.

**Privacy**

Privacy of emotional data is another issue raised from computers detecting
emotion. If a computer detects that a user is suicidal, should it inform some-
body, such as the person’s doctor, the police or a friend? If the user is just
feeling a little depressed after a hard day, should the computer contact a
friend or family member in an attempt to cheer the person up? Or should
it not interfere? These are hypothetical questions as computers are still not
capable of accurately and reliably detecting human emotion, nonetheless, if
computers do one day have this ability, then how responsible the computer is
for managing the user’s emotional state becomes an important issue.

**Human Relationships**

Another important concern surrounding computers and their attempts to
build social relationships with people is whether or not they will have an
impact upon people having healthy social relationships with others. Many
argue that we should be spending more time away from our computers and
should be interacting more with other people. This is a valid point, but it could
be argued that it is unlikely that just because a computer becomes more con-
siderate and makes more of an effort to consider your feelings (through raised
emotional intelligence), that people will want to spend more time interacting
with it. For example, people often interact with pets, but while they meet
some of the basic emotional needs that we have, most people still crave the
company of others. However, the research of [63] – highlighted previously –
suggests that people may be more willing to spend time interacting with com-
puters that have some form of emotional intelligence. Thus, it remains difficult
to predict how people will respond to emotionally intelligent machines.

**3 Evaluating Affective Embodied Agents**

This Section provides an overview of embodied agent research in the field of
affective computing. We start by providing an overview of the use of embodied
agents and research that has looked at incorporating emotion into them. We
then move on to discuss research which has looked at how people respond to
simulated displays of emotion and the effects it has been reported to have on
them. Following this, we discuss the importance of evaluating interface agents
of all types over extended periods of interaction, and then proceed to discuss
an embodied agent that we have developed which is capable of simulating
emotional facial expressions.
3.1 What are Affective Embodied Agents?

Terms such as ‘embodied agents’, ‘virtual humans’, ‘interactive characters’, ‘software agents’, ‘interface agents’, and ‘intelligent agents’ are among many that are often used interchangeably when talking about similar entities. On many occasions, this can lead to confusion and difficulty in understanding exactly what is being referred to. Therefore, it is important to clarify what is meant by the term ‘embodied agent’ for the purposes of this Chapter. Embodied agents are essentially animated or static entities that are based on a computer screen and attempt to interact with users in some way. They can use a number of techniques to interact with users including written language, speech, gesture, facial expressions, head nods, and eye gazes. These agents can also have a variety of different representations (for instance, human, alien, paperclips, dogs, cats, and so on). Affective embodied agents are agents that exhibit, express and/or act on emotion. They are often based on an emotional model that determines their emotional reactions, but this is not always the case. A wide range of affective embodied agents have been developed over the last decade including the pedagogical agents Cosmo [65] and Herman the Bug [67], Steve [94], PPP Persona [105], Gandalf [101], MACK [22], Olga [7], Laura [8] and the REA [9].

3.2 Psychological Responses to Simulated Emotion

In order to understand if the emotions that designers have incorporated into an embodied agent actually aid an interaction, it is important to understand how people respond to synthetic displays of emotion. How do we respond to synthetic displays of joy, happiness, sadness, frustration, fear and anger? Can we catch emotions from computers? Do we like agents that are always happy, or does this annoy us after a while?

Social-Emotional Relationships with Computers

Numerous studies have suggested that we interact with computers as though they are social entities. [92] developed the Computers Are Social Actors (CASA) paradigm, which implies that the social rules that apply in human-human interaction also apply to HCI. The reason for this, they suggest, is that our ‘old brains’ have not evolved to deal with current technology and therefore we treat all media as if it were a social entity. It may seem a little strange to suggest that we respond to computers like people, but it has been shown that the response is particularly strong and often unconscious. Even when we are consciously aware that the entity is not human (for instance, a computer or television) the response is still not weakened.

For example, [81] suggested that humans are polite to computers. Research completed in social psychology has found that interviewers who ask about their own performance are likely to receive more positive feedback than if
feedback is received from another source. This study tested if the same polite-
ness rules also applied to human-computer interaction. The study involved
subjects completing a task on a text-based computer and upon completion
they were interviewed about the performance of the computer by either the
same computer, a pencil-and-paper questionnaire, or a different but identi-
cal computer. Similar to that of human-human interaction, results found that
subjects evaluated the computer more positively when the computer asked for
feedback about its own performance, compared with subjects who evaluated
the computer through a pencil-and-paper questionnaire or another computer.

Another study found that we seem to attribute personalities to computers
and also respond to those computer personalities as if they are human [80].
In this study, properties associated with dominance and submissiveness were
incorporated into computers using just plain text. It was found that subjects
not only recognized the computer’s personality, but also reported being more
satisfied with the interaction they had with the computer that shared a similar
personality to their own. Again, this finding is similar to human-human inter-
action, where research has found that people tend to prefer interacting with
other people who have a similar personality to their own. Similarly, [79] found
the same attraction using computer-generated speech by incorporating the
properties associated with introversion and extraversion. When the person-
ality of the computer voice matched the personality of the subject, subjects
reported the voices as being more attractive, informative, and trustworthy.
Moreover, they were more likely to buy books reviewed by the computer.

Simulated Emotion

Our tendency to respond to computational entities as social actors suggests
that we may well respond to synthetic displays of emotion in a similar way
to human emotion, and a number of researchers have been investigating this.
One of the main approaches used to investigate this is to compare different
types of emotionally expressive agents with each other. For example, [13]
examined how we respond to both self-oriented and other-oriented empathic
emotion. Subjects played a blackjack game and were matched up with an
agent that either exhibited or lacked self-oriented or other-oriented empathic
emotion. The agent was a static photograph of a human face, which could
communicate with subjects via a speech bubble next to the photograph. When
a round of the game had finished, the agent would always communicate to
the subjects an evaluation of it’s own performance (for instance, “I’m glad I
won”), and then followed that with an evaluation of the subject’s performance
(for example, “I’m glad you won”). Also, in the conditions where empathic
emotion was used, the agent’s evaluation of the subject’s performance included
an emotional response: the agent would express negative emotion if the user
lost and positive emotion if the user won. The results from this study found
that people generally preferred the agents that were empathic to them more
than ones which were not.
Another approach is to compare an emotional entity with a different type of entity. For example, [100] used a card matching game to compare the impact of an emotional face and a 3D arrow on a subject’s eye movements and response times. The arrow and the face were both used to provide feedback to the user during the game. For example, through pointing or gazing at the player whose turn it was next. Results from this study found that the emotional face elicited more eye contact from subjects than the 3D arrow. The authors therefore concluded that the emotional face was more engaging to subjects than the arrow.

There have been a lack of studies which have explicitly tested an emotional agent against an unemotional one. In many related studies, emotional agents are used, but the incorporation of emotion into the agent is not the main focus of the study. Therefore, the potential impact of simulated emotion has to be inferred from the reported results. This can make it particularly difficult to attribute any of the effects found to the inclusion (or exclusion) of emotion in agents. For example, [66] examined the effect of different types of animated agents on the learning performance and experience of middle school children by asking them to design a plant that would be able to survive in a particular environment. The children received varying levels of help from the animated agents and the results of the experiment found that a fully expressive agent (that is, an agent which offered advice using both animation and speech) was perceived to be equally as entertaining as a muted agent (in other words, an agent which offered no advice whatsoever). However, the incorporation of emotion was not explicitly tested in this experiment, so caution must be applied when analyzing the results.

3.3 Evaluating Agents over Extended Interactions

Very few studies have focused on how we respond to emotionally expressive embodied agents over extended periods of interaction. As discussed above, some recent studies have suggested that we seem to perceive emotional agents as more likeable and trustworthy than unemotional agents, but does this effect remain consistent over five, six, seven or forty separate interactions? The Microsoft Office Paperclip was an emotionally expressive agent that many people tended to find novel to interact with initially, but after further interactions, it began to frustrate people and was ultimately rejected by users. As we move more towards managing computer systems rather than directly manipulating them, we will work more closely with agents in everyday activities as they undertake tasks on our behalf. We are likely to start interacting with them on multiple occasions spanning days, weeks and months. Therefore, we need to understand in more detail how our perceptions towards affective embodied agents change over numerous interactions and extended periods of time.
are some of the few researchers who have started to investigate this space. They developed an embodied exercise advisor named Laura, which attempted to maintain a relationship with subjects who interacted with the agent daily over the period of a month. People who were not completing required levels of exercise recommended for United States’ adults (namely 30 minutes or 10,000 steps per day) were chosen as subjects, in an attempt to help them improve their exercise habits through interacting with Laura. A variety of different strategies were used by the agent to help maintain a relationship with subjects, including social, empathic and polite communication, talking about the relationship, humour and appropriate forms of address. Laura also used a range of non-verbal behaviours, as discussed earlier. Results from this study found that subjects liked Laura more when they interacted with the relational version as opposed to a non-relational one (that is, where no relational strategies were used).

A similar effect was found by [69], who asked subjects to use a mobile health device for eight days and then examined the effect it had on subjects’ perceptions and behaviour. Subjects were split into two groups: one group interacted with an empathic version of the device for four days and then switched to the non-empathic device for the final four days, while the other group did the opposite. The system made use of a text-based agent which would interrupt subjects at different times of the day to discuss issues relating to their health. The empathetic agent would make empathic comments when interacting with the subject while the non-empathic agent would not. Results found that a significant number of subjects who were asked which device they would like to continue interacting with at the completion of the study, stated that they would prefer to continue interacting with the empathic device. Subjects also reported that they felt less stress when interacting with the empathic device.

3.4 Our Affective Embodied Agent

In order to investigate our responses to synthetic displays of emotion in embodied agents, we have developed our own for testing purposes (Fig. 3). Agents such as these used to be costly to develop in both terms of time and expense; however, it is now possible to easily develop such agents using affordable software which automates much of the process [90]. Our agent simulates the role of a human health professional through making use of many of the skills and strategies that human health professionals use (discussed in the next Section). The agent can move its head, speak (via a recorded voice), and can display a wide range of (facial) emotional expressions. There are a number of applications that can be used to develop agents such as these, but one of the most popular for specifically building virtual characters is Poser [37]. We used Poser 5 for developing our agent, along with Mimic 3 [34], which is compatible with Poser and can be used for automatically generating facial animation and lip synchronization from imported audio files containing recorded
speech. As we are conducting our experiments over the World Wide Web, we converted the animations produced by Poser and Mimic to the Macromedia Flash format, so that we can incorporate the animations into a web page.

4 Application of Affective Embodied Agents

Affective embodied agents have often been touted as one of the primary ways in which we will interact with computers in the future. Advocates of embodied agents believe that they will make an interaction more natural and engaging, while opponents believe that they will raise expectations of what the computer is capable of, and thus hinder interaction [30]. The future of agents such as these is still unclear, as many different fields of research need to mature sufficiently before we can really assess their potential. The agents that have been developed to date are unable to interact naturally with people, and as a result they quickly lose credibility. Areas where embodied agents seem to have found their niche is within computer games and simulations. These are likely to be areas where affective embodied agents will be of real use, unlike work-based tasks where an agent of this sort is not really required (as exemplified by the Microsoft Office Paperclip). Another area where affective embodied agents could be of use is where human relationships are known to be important. For example, in the behaviour change domain, the relationship between a helper and client has been shown on numerous occasions to be fundamental in helping people to change problematic behaviour. In this Section, we detail our research into how an affective embodied agent could be used to simulate the role of a human health professional to help people change problematic behaviour such as eating, smoking, and exercising.
4.1 Affective Embodied Agents for Behaviour Change

Behaviour change is one domain where affective embodied agents may prove useful. Changing problematic behaviour in humans can often be a long and difficult process. Exercise regimes, healthy dieting, smoking cessation, and a number of other behaviour change plans are regularly initiated with much enthusiasm, but all too often are abandoned before the new behaviour replaces the old. People who have difficulties in changing unhealthy behaviour often seek professional advice to help them achieve their behavioural change goals. The effective management and use of emotion in a therapist-client relationship is essential to building a strong working alliance, which is critical for increasing the likelihood of a successful outcome [61]. Therapists need to make use of a wide range of skills and theory-based health strategies to help evoke emotions in clients that enhance motivation toward behaviour change. These skills and strategies could potentially be utilized by computational agents. While the most effective way of helping someone to change problematic behaviour is often a face-to-face interaction with a highly-trained and experienced (human) health expert, this approach can only have a small impact within a large population of people, as therapists are limited in the number of people they can see and help. Attempts to automate such behaviour change techniques have been applied through using a wide-range of media (for instance, desktop computers, telecommunications and mobile devices) to a number of different behaviours (such as nutrition, exercise, and smoking) with varying degrees of success [14, 49, 50, 57, 93]. For example, MoodGym [76] is a Cognitive Behaviour Therapy (CBT) website aimed at young people for the treatment of depression and anxiety and/or as an adjunct to therapy.

Therapists and Counselling Services have also started to provide computer mediated counselling and therapy through the use of email, instant messaging, video-conferencing, and virtual environments [62, 99], but there is still a limit on the number of people a single therapist can help. One potentially fruitful avenue that has received little attention to date is in the development of affective embodied agents that attempt to closely simulate the actions of a human therapist. Working on the premise that we treat computers as social actors [92], agents that can closely match the actions of human therapists may be able to provide many of the psychological benefits (for example, evocation of constructive emotions in clients which encourage motivation) that result from interacting with therapists. Agents of this type may also be used to help therapists in their everyday tasks. For instance, they could be used to automate the initial assessment of a client’s symptoms and to assess which type of therapy (if any) might potentially help clients most.

Computer mediated therapy provides a number of advantages over more traditional forms of face-to-face therapy and many of these advantages are also likely to apply to synthetic therapists. For example, [46] suggests that computer mediated and online interventions provided by therapists can be
of great help to people who are unable to visit therapists because of physical (disabled, say), personal (for example, sexuality) or geographical issues. Moreover, some people might like the anonymity that interacting with a synthetic therapist would offer as it would enable them to avoid the anxiety related to disclosing uncomfortable feelings and emotions to human therapists and may encourage them to be more open, expressive, and honest about how they feel. Therefore, an online interaction with a synthetic therapist may provide an important opportunity to those who have reservations, fears or doubts about a face-to-face interaction with a human therapist.

4.2 Behaviour Change Models

Our approach in getting affective agents to simulate the skills and strategies that human health professionals use is to make use of a behaviour change model. The four most commonly used behaviour change models are the Health Belief Model, Theory of Reasoned Action/Planned Behaviour, Social Cognitive Theory, and the Transtheoretical Model (TTM) [91]. Initial work in this area has concentrated on using the TTM and has had limited success. [10] made use of the TTM when designing Laura and despite finding that subjects did more exercise whilst interacting with the agent, after the experiment had reached its completion, subjects tended to return to their old habitual exercise patterns. However, the fact that people did change their exercise behaviour whilst interacting with the agent highlights the potential for computational agents to influence people’s behaviour.

Overview of TTM

The TTM works on the assumption that behaviour change involves people moving through a number of different stages before change is achieved. The main stages of the model are:

- **precontemplation** – when people have no intention of changing their behaviour,
- **contemplation** – when people intend to change within the next six months,
- **preparation** – when individuals intend to take action within the next month,
- **action** – people who have done something to change their behaviour within the past six months, and
- **maintenance** – when the desired change has remained for at least six months.

Whilst in the **maintenance** stage, there are two possible outcomes: (1) a relapse into old behavioural patterns, which usually results in moving back into one of the other stages (most often **contemplation**), or (2) termination of behaviour, which is said to take place when strong urges to return to old behavioural patterns no longer exist. As well as assessing each stage of change, the model
also defines other core constructs including change processes (activities that are used to help progress through the stages), decisional balance (the ability to weigh the pros and cons of changing a behaviour), and self-efficacy (the confidence felt about performing an activity). The model suggests that certain change processes are more useful at different stages. This information is particularly helpful for therapists as they can potentially help their clients more effectively through assessment of which stage a client is in, and then emphasizing the appropriate change processes for that stage.

Stage-matching (linking the correct process with the correct stage) increases the likelihood that a person will effectively progress through the different stages of change. Conversely, linking the wrong process with a stage increases the probability that people will relapse and return to their old behavioural patterns. Making use of the model within a clinical setting initially involves assessing which stage of change a client is at. This can be completed by using a number of different methods, including staging algorithms, which assess the stage people are at through the use of questionnaires [31]. The next step is to provide the client with advice and information that is appropriate for the stage they are at. For those who are in the early stages of change, it is imperative to concentrate on the need to change, not necessarily on how they intend to change. For those in the later stages, interventions should focus on strategies that will help maintain the new behaviour.

Use of Emotion in TTM

The use of the TTM in therapy can have a huge influence on the emotions that people experience. The processes recommended for use in the pre-action stages, such as consciousness raising, dramatic relief, and self re-evaluation, all have the potential to evoke constructive emotions and increase motivation to change problematic behaviour. By constructive emotions, it is not necessarily meant that attempts are made at only eliciting typically positive emotions (for instance happiness or satisfaction), but that emotions that are often perceived to be negative (such as fear or anxiety) can also help the change process. For example, the consciousness raising process might induce emotional feelings of fear and anxiety at the health risks associated with a high fat diet and the increased likelihood of premature death. However, these emotions do not always have a derogatory effect; they can spur people into action and help motivate them to change their unhealthy behaviour. Conversely, processes such as dramatic relief and attempts at increasing self-efficacy encourage people to focus on experiencing positive emotions such as satisfaction, pleasure, and fulfilment to help increase people’s confidence about changing their behaviour.

Whilst some processes concentrate specifically on evoking beneficial emotions, others increase the likelihood that helpful emotions will be experienced at a later date. For example, the processes of increasing self-efficacy, social
re-evaluation, and the minimization of barriers, are all unlikely to initially evoke intense emotional responses, but their emphasis in the pre-action stages increases the likelihood of progress through the stages of change and thus the experiencing of constructive emotions that facilitate change. In the action stages, the processes concentrate more on inducing emotional feelings of determination and resolve. Processes such as coping with relapse and building ‘helping’ relationships focus on using strategies that will help people to feel motivated during the difficult maintenance stage. Other processes such as self-liberation and increasing self-efficacy are all about concentrating on the positive emotional feelings that changes in behaviour evoke, in an attempt to aid motivation toward behaviour change goals. Like the pre-action stages, there are also processes such as reinforcement and enhancing the benefits of change, which directly attempt to help people feel emotions of satisfaction and achievement, and thus facilitate forward movement through the different stages of change.

Using TTM with Synthetic Therapists

Agents that are able to autonomously and correctly determine at which stage of change a person is in, and effectively apply the appropriate processes, have the potential to induce helpful emotions in people that will enable them to change their behaviour. However, an agent will also need to consider the impact of its own emotional expressions on the emotional feelings evoked in clients. For example, if a therapist was to respond with strong emotional expressions of disappointment, frustration, and anger at somebody who consistently relapses into old unhealthy behavioural patterns, this could have a detrimental effect on how motivated that person feels and might result in emotional feelings of shame, distress, and hopelessness. These feelings could escalate and inevitably result in the client leaving therapy altogether. Conversely, if a therapist’s emotional responses to the relapses of clients were more supportive, understanding, and encouraging (for example, empathic responses), this could have a more positive impact on the emotional feelings experienced by clients and thus their future behaviour. While this is a very basic example of how the emotional expressions of a therapist can influence the emotional feelings in clients, it is clear that a therapist’s emotional expressions can have a huge influence on how successful therapy will be. For example, in physician-patient interactions, [15] found that patients generally prefer physicians who express more positive emotion. The same is also likely to apply with agents that play the role of a therapist. It is not enough for them to be able to correctly assess at which stage a client is in and to emphasize the correct processes; they also need to be able to deliver their interventions in a manner which is helpful and appropriate for the client.

Despite the effective management and manipulation of emotions in a therapist-client relationship being of fundamental importance, the role of
agent emotion simulation (within a behaviour change domain) has not been explicitly studied or tested. While [10] incorporated emotional capabilities into their agent, they did not explicitly test whether it had any impact on the interaction. Instead, they tested the incorporation of a number of different relational strategies (as discussed above) into their agent, which makes it difficult to ascertain the individual impact that emotion had on subjects. Several recent studies have suggested that simulated emotion can have a psychological impact on subjects, but it is still largely unknown how strong that response is [28]. For example, a number of studies have suggested that we generally seem to rate emotional agents more positively than unemotional agents [13], but how strong is this influence? In human-human interaction, we are more likely to act on the advice offered by a person we like and trust than someone we dislike and distrust [25]. Does the same apply in agent-human relationships? More research is required to understand how simulation of emotion influences people's attitudes and emotions, and whether these responses can be beneficially manipulated to help assist people with behavioural change.

5 Summary

This Chapter has discussed the busy research area of affective computing, with a particular focus on how we can build emotionally intelligent computers that can aid our interactions with them. We started by detailing emotion theory that was most related to the building of emotional computers through introducing the notions of basic, culturally-specific and higher cognitive emotions. We then highlighted the influence that emotions can have on our attitudes and behaviour, with particular emphasis on how they can influence our attention, memory, judgement and decision-making capabilities and creative problem solving skills. The means by which we express emotion through written language, speech, facial expressions and body language were also described. To conclude Sect. 2, we detailed the different approaches taken when attempting to build emotionally intelligent computers. These included building computational models of emotion, enabling computers to autonomously detect user emotion, and simulating human emotional expressions (through 3D graphics, synthetic speech, and so forth), as well as highlighting some of the ethical issues involved in building emotional computers.

In Sect. 3 we discussed research related to evaluating affective embodied agents over extended periods of interaction. This included defining what was meant by the term ‘affective embodied agents’ and discussing research which has investigated how we respond to synthetic displays of emotion. Following this, we highlighted the importance of conducting longitudinal studies when developing emotionally intelligent agents and also described our own affective embodied agent that we have developed for experimental purposes.
In Sect. 4 we discussed the application of our approach to the real world by describing how such an agent could make use of a behaviour change model to simulate a human health professional, to help people change problematic behaviour such as smoking, eating, and (lack of) exercise.

When attempting to build emotional capabilities into computers, it is essential to consider how this will influence their functioning and our interactions with them. Emotional computers present both opportunities and dangers and it is imperative that we concentrate on how we can develop applications and systems that aid interaction, and discuss fully the issues and concerns related to the dangers of such computers. The goal of building emotionally intelligent computers is an extremely complex and difficult one, but nonetheless, a worthy goal that can enhance human-computer relationships, making them more productive, satisfying and enjoyable.

References


Resources

1 Key Books


2 Key Survey/Review Articles


http://emotion-research.net/deliverables HUMAINE (Human-Machine Interaction Network on Emotion) deliverable Dxx: Proposed exemplar and work towards it:


3 Organisations, Societies, Special Interest Groups

CHIL (Computers in the Human Loop)
http://chil.server.de/servlet/is/101/

COSY (Cognitive Systems for Cognitive Assistants)
http://www.cognitivesystems.org/

Design and Emotion Society
http://www.designandemotion.org/
Enactive Interfaces (EU Network of Excellence)
http://www.reflex.lth.se/enactive/

HUMAINE (Human-Machine Interaction Network on Emotion)
http://emotion-research.net/

International Society for Research on Emotion
http://isre.org/prd/index.php

SIMILAR (The European taskforce creating human-machine interfaces SIMILAR to human-human interfaces)
http://www.similar.cc/

Virtual Human (Anthropomorphic Interaction Agents)

4 Research Groups

Affective Computing at MIT Media Lab
http://affect.media.mit.edu/

Cognition and Affect Project at University of Birmingham (UK)
http://www.cs.bham.ac.uk/research/projects/cogaff

Geneva Emotion Research Group
http://www.unige.ch/fapse/emotion/

LeDoux Lab, New York University
http://www.cns.nyu.edu/home/ledoux/

Relational Agents Group, Northeastern University
http://www.ccs.neu.edu/research/rag/

RITL (Center for Research of Innovative Technologies for Learning, Florida State University)
http://ritl.fsu.edu/

Virtual Reality Lab, Swiss Federal Institute of Technology
http://ligwww.epfl.ch/
5 Discussion Groups, Forums

The Emotion Forum
http://homepages.feis.herts.ac.uk/comqkc/emotion.html

Emotional Intelligence Information Website
http://www.unh.edu/emotional_intelligence/

Facial Action Coding System (FACS) Manual
http://face-and-emotion.com/dataface/facs/description.jsp

Facial Expressions Resources Page
http://www.kasrl.org/facial_expression.html

Socially Intelligent Agents
http://homepages.feis.herts.ac.uk/comqkd/aaai-social.html

Stanford University Persuasive Technology Lab
http://captology.stanford.edu/

Virtual Humans
http://www.ordinarymagic.com/v-people/

6 Key International Conferences/Workshops

http://www.affectivecomputing.org/2005/

ACE 2006: Agent Construction and Emotions: Modeling the Cognitive Antecedents and Consequences of Emotion
http://www.ofai.at/paolo.petta/conf/ace2006/

Theories and Models of Emotion (HUMAINE Workshop – 2004)
http://emotion-research.net/ws/wp3

From Signals to Signs of Emotion and Vice Versa (HUMAINE Workshop – 2004)
http://emotion-research.net/ws/wp4

Data and Databases (HUMAINE Workshop – 2004)
http://emotion-research.net/ws/wp5

Emotion in Interaction (HUMAINE Workshop – 2005)
http://emotion-research.net/ws/wp6/
Emotion in Cognition and Action (HUMAINE Workshop – 2005)
http://emotion-research.net/ws/wp7

Emotion in Communication (HUMAINE Workshop – 2005)

http://emotion-research.net/ws/wp9/

7 (Open Source) Software

Croquet (Software for creating 3D collaborative multi-user online applications)
http://www.opencroquet.org/

Emofilt (Simulate emotional arousal with speech synthesis)
http://felix.syntheticspeech.de/publications/emofiltInterspeech05.pdf

FEELTRACE (Tool for rating the emotion expressed in audio-visual stimuli)
http://emotion-research.net/download/Feeltrace%20Package.zip

OpenAL (Cross Platform 3D Audio)
http://www.openal.org/

OpenGL (Graphics API)
http://www.opengl.org/

OpenMary (Open Source Emotional Text-to-Speech Synthesis System)
http://mary.dfki.de

TraceTools (Tools for tracing the presence of emotion)
http://emotion-research.net/download/ECatPack.zip

8 Data Bases

8.1 Multimodal Databases

Belfast Naturalistic Database
http://www.idiap.ch/mmm/corpora/emotion-corpus
ISLE project corpora
http://isle.nis.sdu.dk/

SMARTKOM
http://www.phonetik.uni-muenchen.de/Bas/BasMultiModaleng.html#SmartKom

SALAS
http://www.image.ntua.gr/ermis/

8.2 Face Databases

AR Face Database
http://cobweb.ecn.purdue.edu/âleix/aleix_face_DB.html

CMU Facial Expression Database (Cohn-Kanade)
http://vasc.ri.cmu.edu/idb/html/face/facial_expression/index.html

CMU PIE (Pose, Illumination and Expression) Database
http://www.ri.cmu.edu/projects/project418.html

CVL Face Database
http://www.lrv.fri.uni-lj.si/facedb.html

Psychological Image Collection at Stirling
http://pics.psych.stir.ac.uk/

Japanese Female Facial Expression (JAFFE) Database
http://www.kasrl.org/jaffe.html

Yale Face Database
http://cvc.yale.edu/projects/yalefaces/yalefaces.html

Yale Face Database B
http://cvc.yale.edu/projects/yalefacesB/yalefacesB.html