E-AI an Emotion Architecture for Agents in Games & Virtual Worlds

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Abstract

Characters in games and virtual worlds continue to gain improvements in both their visual appearance and more human-like behaviours with each successive generation of hardware. One area that seemingly would need to be addressed if this evolution in human-like characters is to continue is in the area of characters with emotions. To begin addressing this, the thesis focuses on answering the question "*Can an emotional architecture be developed for characters in games and virtual worlds, that is built upon a foundation of formal psychology?* Therefore a primary goal of the research was to both review and consolidate a range of background material based on the psychology of emotions to provide a cohesive foundation on which to base any subsequent work. Once this review was completed, a range of supplemental material was investigated including computational models of emotions, current implementations of emotions in games and virtual worlds, machine learning techniques suitable for implementing aspects of emotions in characters in virtual world, believability and the role of emotions, and finally a discussion of interactive characters in the form of chat bots and non-player characters. With these reviews completed, a synthesis of the research resulted in the defining of an emotion architecture for use with pre-existing agent behaviour systems, and a range of evaluation techniques applicable to agents with emotions.

To support validation of the proposed architecture three case studies were conducted that involved applying the architecture to three very different software platforms featuring agents. The first was applying the architecture to combat bots in Quake 3, the second to a chat bot in the virtual world Second Life, and the third was to a web chat bot used for e-commerce, specifically dealing with question and answers about the companies services. The three case studies were supported with several small pilot evaluations that were intended to look at different aspects of the implemented architecture including; (1) Whether or not users noticed the emotional enhancements. Which in the two small pilot studies conducted, highlighted that the addition of emotions to characters seemed to affect the user experience when the encounter was more interactive such as in the Second Life implementation. Where the interaction occurred in a combat situation with enemies with short life spans, the user experience seemed to be greatly reduced. (2) An evaluation was conducted on how the combat effectiveness of combat bots was affected by the addition of emotions, and in this pilot study it was found that the combat effectiveness was not quite statistically reduced, even when the bots were running away when afraid, or attacking when angry even if close to death.

In summary, an architecture grounded in formal psychology is presented that is suitable for interactive characters in games and virtual worlds, but not perhaps ideal for applications where user interaction is brief such as in fast paced combat situations. This architecture has been partially validated through three case studies and includes suggestions for further work especially in the mapping of secondary emotions, the emotional significance of conversations, and the need to conduct further evaluations based on the pilot studies.

For Cath and Emily

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My parents for being supportive throughout my career, and my wife Catherine and baby daughter Emily for inspiring me to complete this work.

List of Abbreviations

AI	Artificial Intelligence
ANN	Artificial Neural Network
E-AI	The Proposed Emotion Architecture
EAD	Emotional Alert Database
EEA	Emotionally Enhanced Agents
FACS	Facial Action Coding System
FPS	First Person Shooter
FSM	Finite State Machine
GOAP	Goal Orientated Action Planning
HCI	Human Computer Interaction
HLSL	High Level Shader Language
NPC	Non Player Character
OCC	Ortony Clore Collins (Emotion Theory)

Table of Contents

List of Tables

List of Figures

Note Some figures have been removed from this published Thesis for copyright reasons.

Chapter 1: Introduction

Modern games and virtual worlds lack any real implementation of emotions in the characters inhabiting their worlds, and thus encounters between users and these characters adds little to increase user interaction or believability (Slater et al 2006). These characters don't get annoyed by failed goals, show satisfaction for a kill against a tough enemy, run away in fear, or become happy that someone has revisited them to continue a conversation. Some developers such as Bungie Studios (HALO), Blizzard Entertainment (World of Warcraft), and PF.Magic (Virtual Petz) have used techniques such as finite state machines (FSMs) in HALO (Butcher et al 2002) and scripted behaviour in the World of Warcraft (Slater et al 2006) and Virtual Petz (Stern et al 1998), to provide characters with a hint of emotions such as surprise, anger and fear. This means these characters are merely responding to a small set of conditional changes after which their behaviour is altered (i.e. run away) along with a corresponding facial change, and so they will always respond the same way given the same situation.

Virtual worlds such as Second Life developed by Linden Lab, are seeing a greater incorporation of non-player characters (NPCs) whose purpose is to provide information and interactive experiences for the user, often called chat bots (Burden et al 2008), the problem is that these characters have no emotional responsiveness either. This limited and often absent approach in both games and virtual worlds has the effect that in-world character behaviour can seem repetitive and lacking in the subtlety of emotional changes. There are several possible reasons why developers are reluctant to incorporate more (if any) agent emotions in their applications including:

1. *Developer knowledge* - Game developers have spent considerably more time developing auditory and visual aspects of games rather than A.I. behaviour systems, and therefore knowledge in areas such as emotion modelling and relevant A.I. techniques for implementation is lacking.
2. *Technologies* - Virtual worlds are often based on gaming technologies and as such usually only follow technologies included in games, in many respects they are often behind in new technology support.
3. *Differing of scientific ideas* - Currently, over a century since Darwin first published "The Expression of Emotion in Man and Animals" (Darwin 1872) there is still much debate in the scientific community surrounding emotions. Therefore it may not be clear to developers, which theories and research can and should be incorporated.

4. *Believability* – Developers may not know what role believability (Selvarajah et al 2005) plays in emotionally enhanced characters and the worlds they inhabit.

The purpose of this research is to investigate the area of human emotions and to integrate a range of this research into an architecture in such a way that it can be incorporated into characters in games and virtual worlds to attempt to answer the question:

"*Can an emotional architecture be developed for characters in games and virtual worlds, that is built upon a foundation of formal psychology?"*

In order to answer this question, a number of research objectives have been identified:

1. Research needs to be undertaken in order to gain a better understanding of the psychology of human emotions.
2. Existing implementations of computational models of emotions need to be investigated specifically on their underpinning psychology theory.
3. The findings from the psychology of emotions needs to be integrated in order to present an emotion architecture suitable for characters in games and virtual worlds. This would need to include suitable A.I. and machine learning techniques that could be used to model aspects of the emotions.
4. Evaluation techniques need to be identified that are suitable for any subsequent implementation.
5. Finally aspects of the architecture need to be integrated into software solutions to support validation of the architecture i.e. can a developer implement the architecture into their solution, and can this then be used by an end user.

1.1 Scope of Research

The potential scope of a research project involving games, virtual worlds, characters with emotions, believability and interaction means that there are numerous directions the work could take. To this effect the scope of the work is predominantly involved with supporting the research question, as such the following definitions and boundaries are being followed:

Emotions

There are clearly two aspects to emotions:

- Characters that respond to, and seem to have the appearance of human emotions.

- The users' emotional response during interaction (Brave et al 2005).

This research does not involve the latter, though its presence in the field is of course acknowledged, and much work has occurred in the area such as "Emotioneering" (Freeman 1999). Therefore the clear direction of this work is in adding emotions to characters and evaluating the user experience of these characters.

Believability

Though adding emotions to characters in games and virtual worlds can, and is considered adding to their believability (Bates 1994), the research presented here is not concerned with trying to evaluate whether emotional characters are believable. Instead the subject of believability is covered in the literature review to put into context the role of emotions in believable characters.

A.I.

Artificial Intelligence is a broad term, which for this research applies to all work involved in making characters behave in a more human like way. This is often achieved their behaviour/actions appearing more human-like (Slater et al 2006) (Slater et al 2007).

Agent & Character

The definition of agent is very context dependant, but for this project it involves any human-like character in a virtual world, game or web application that is controlled by the software rather than the user. The term agent and character in the context of this work are interchangeable.

Bots & Chat bots

Bots, short for robots, is a term used to refer to the computer controlled characters in many first person shooters. Chat bots, in the context of this project include chat systems connected to a back end expert system. These chat interfaces return suitable answers to questions and often have a human like appearance accompanying the actual box the user types the chat into. In e-commerce solutions, chat bots provide information to users when they visit a virtual corporate location.

A discussion of chat bots takes place during the literature review, to provide context for their inclusion.

NPCs
Traditionally characters in games that provide help or guide player.

1.2 Overview

Chapter 2 presents a foundation of research that will be used to underpin the development of the emotion architecture. The chapter begins with an investigation into the formal psychology terminology such as emotions and moods. The discussion then presents research that builds upon these findings, to present what is formally accepted as the framework of human emotions such as how many emotions people have, what are the triggers and how long do they last. The discussion moves on to investigate several computational models of emotions including Cogaff (Sloman et al 1995), Tok (Reilly et al 1992) and Emile (Gratch et al 2003), each of which includes evaluations of their underlying emotional basis. This continues with an investigation into suitable A.I. and machine learning techniques such as fuzzy logic and finite state machines that could be used by developers wishing to implement emotions into their characters. Finally the literature review concludes with both an investigation into believability, with a particular emphasis on the state of the art and the role of emotions in supporting believability, and an investigation into chat bots.
Chapter 3 begins with an investigation into suitable evaluation techniques, which could be used by developers to validate their final emotional implementations. This is followed by the methodology that will be followed for the remainder of the work.

Chapter 4 builds upon the literature review to specify an emotion architecture called E-AI.

Chapter 5 presents three developer focused case studies that integrate aspects of the architecture into suitable platforms including Id Software's Quake 3, Linden Labs Second Life and finally a web chat bot using the Macromedia Flash CS3 platform. Each case study includes evaluations based on recommendations made in Chapter 3, and statistical analysis of the data collected.

Chapter 6 rounds off the research by reflecting back to the original research question and objectives to critically evaluate whether the proposed architecture and implementations meet the requirements laid out in Chapter 1.

Chapter 2: Literature Review

The approach taken for the literature review is to examine five areas considered to be involved when approaching the addition of emotions to characters, as illustrated in Figure 3.

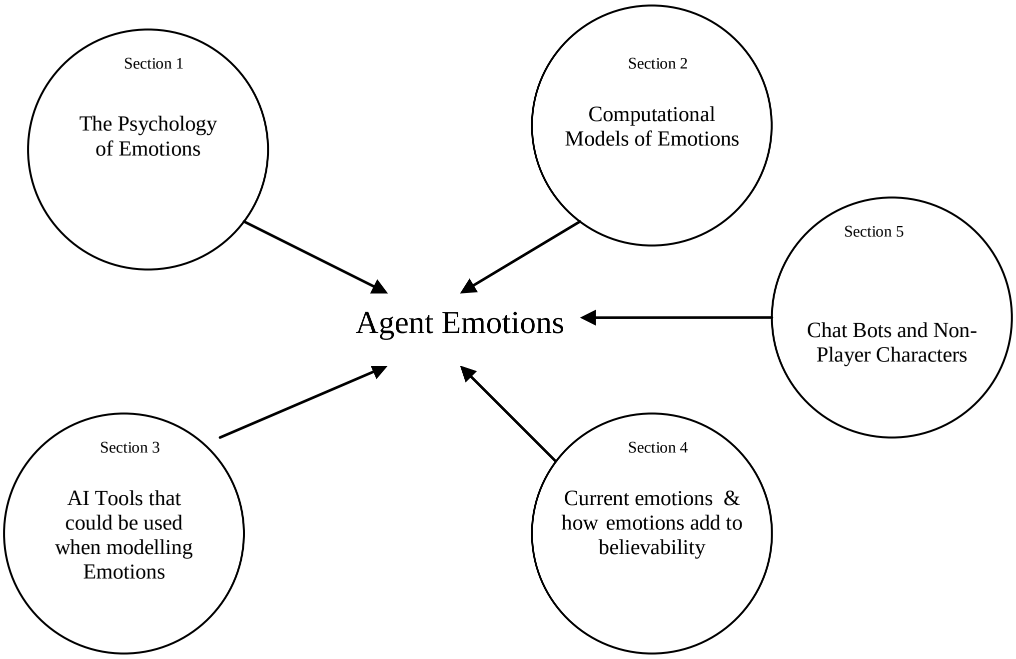


Figure 3. Five Aspects Related to Characters/Agents With Emotions

These five areas relate directly to the first three research questions identified in Chapter 1 and the first of these sections is intended to present a cohesive overview of the psychology of emotions paying particular attention where conflicting theories occur, so that these can be resolved where possible. This section is also intended to underpin later work, in that it forms part of the original contribution of the research as a whole, by presenting a foundation of psychology suitable for researchers developing computational models of emotions. Equipped with a foundation of supporting psychology research, section two focuses the investigation onto existing computational models of emotion. This direction is needed in order to identify any models that already exist and their underlying psychology basis. This research includes theoretical models of emotions, and architecture specific models that feature integrated A.I. components. The third section of the review is intended to explore A.I. methods and techniques applicable to modelling aspects of characters (agent) emotional behaviour. This area seems fundamental to any implementation of emotions, simply because any subsequent software model of emotions would need to interface with any presently incorporated A.I. Section four presents a review intended to define believability in the context of this work, and also to discover the current state of the art in character emotions in games and virtual worlds in order to improve upon it. Finally the literature review closes with a discussion on chat bots for completeness.

2.1 The Psychology of Emotions

According to Clore et al (Clore et al 2000), a widely supported theory of the 'purpose of emotions' is that emotions evolved to allow primitive man to engage in survival orientated behaviour when confronted with dangerous situations, and according to Damasio (Damasio 2000) to also motivate behaviour towards supporting homeostasis. As a consequence of this motivation, Crawford et al (Crawford et al 2002) suggest that emotions help direct attention and cognition towards the emotional stimuli. According to Clore et al, as social skills were developed, emotions changed to allow humans to register and react to events without automatically committing them to actions that may not be the best course in social situations.

Because emotions are an integral part of the human identity, it is possible for most people to identify through introspection their own perceptions of emotions, and to observe and recognise what they define as emotions in others. According to Le Doux (Le Doux 1998), a difficulty is that emotion awareness is only achieved once the unconscious emotion-activation causes a physiological change such as an increased heart rate. Le Doux proposes that this phenomenon is called feelings and often leads to the labelling of the experience as a particular emotion. Unfortunately we cannot experience other people's feelings and therefore emotion classification based on reported feelings remains subjective. This subjective and ambiguous nature of emotions means that it is extremely difficult to achieve consensus on general emotion related terms. People can, and do actively discuss many terms related to emotions such as feelings, personality and moods. The emotion terminology problem has been highlighted in previous research including Morgan et al (Morgan et al 1988) where studies conducted on common descriptions of emotions show variations in terminology understanding. Much of the debate that has encompassed emotion terminology has led some researchers such as Plutchik (Plutchik 1980) to publish 'emotional dictionaries' that involve common words and their emotional significance. Some of the more widely used terms related to emotion have been summarised into a glossary of terms in Appendix 2.

To add further clarity to the terminology issues, there is some evidence that:

1. Emotion activation can occur as a consequence of the detection of a stimulus or from the recall of an emotionally significant memory.

2. Emotions are appraised (Power et al 1997) against an emotion alert database (Ekman 2004). This database according to Ekman includes the triggers, thresholds and intensities of the emotions and corresponding stimulus.
3. That an emotional response can be automatic which relies on unconscious processing; this is referred to by Plutchik (Plutchik 1980) as *autonomic arousal*. During this process new stimulus triggers to emotions can be learned or reinforced.
4. Some emotions have visible indicators which are referred to by Ortony et al (Ortony et al 1990) as *physiological effects*.
5. That according to Plutchik (Plutchik 1980), there is a *motivation* or *impulse* to react to emotional stimuli e.g. the 'fight of flight response' evident from the emotion of fear.
6. That according to Damasio (Damasio 2000), *feelings* are the realisation of bodily changes brought about by the activation of an emotion and when questioned, individuals can sometimes report on their emotional state.

If the previous points are drawn together then:
Emotions are an unconscious reaction to an appraisal of a stimuli deemed to require action, that often cause physiological changes and a motivation to act. The conscious realisation of the changes is commonly called feelings and at this point the person might become aware that they are experiencing an emotion.

This description is supported by the six stage emotional process model proposed by Scherer (Scherer 2005), as shown in Figure 4. This six stage emotional process provides a logical walkthrough of the emotion process from detection of emotionally significant stimulus right through to the actual realisation of an emotional event i.e. feelings.

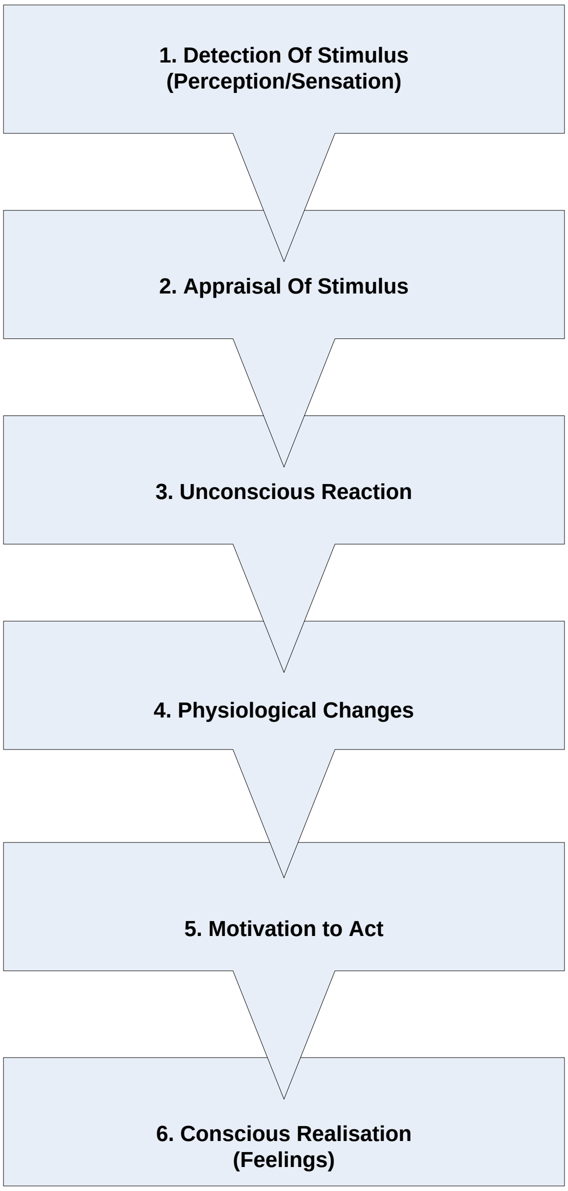


Figure 4. Six Stage Emotional Process Model

2.1.1 Do We Learn To Experience Emotions?

Panksepp (Panksepp 1998) suggests that the physiological appearance of emotions such as fear can be observed at an early age, and according to Ekman (Ekman 2004) this extends across different cultures, supporting the theory that people do not need to learn to appear to be afraid or sad. For example during the first three months of birth, babies exhibit emotions such as:

- Sadness - When a familiar stimulus such as the mother moves away the baby cries.
- Disgust - When given unpleasant food, the baby curls its face and turns its head away.
- Happiness - can be seen facially when familiar faces are presented to the baby.

As already mentioned, Ekman (Ekman 2004) suggests that through methods such as Pavlovian[1] (classical) conditioning that people can add triggers to their 'emotional alert database' throughout their lives. Therefore the answer to the question is that we do not learn emotions, but according to Damasio (Damasio 2000) we do learn new triggers for the emotions that we have.

2.1.2 How Many Emotions Are There?

There is much scientific debate as to how many emotions there actually are, which according to Ortony et al (Ortony et al 1990) is up to infinity depending on what is being described. This variance can present a serious problem when discussing emotions, unless a more manageable view of emotions is taken. Taking this view allows the emotions not to be thought of so much as numerical values, but more as either emotions across *dimensions* as suggested by Dietz et al (Dietz et al 1999), or emotions in *categories* as suggested by amongst others, Damasio (Damasio 2000). The first approach proposes that emotions are *dimensional* i.e. that there are two or three dimensions that cover the range of all emotions. Common labels for these dimensions include valence, arousal and dominance.

- *Valence* range would encompass happy to sad.
- *Arousal* range would encompass calm to excitement.
- *Dominance* range would encompass control to out-of-control.

The second approach specifies a number of emotions that can be *categorised* by terms such as basic, secondary and background. Supporters such as Plutchik (Plutchik 1980), Ortony et al, and Damasio attribute a finite number of emotions to each category to which Damasio suggests there are three categories.

Note: There is a wide range of research supporting the categorical approach to emotions (Plutchik 1980) (Damasio 2000) (Ekman 2004) in both the area of psychology, and also in some computational models of emotions (Ortony et al 1990). With these points in mind, it is intended that a categorical view of emotions forms the basis for any subsequent discussions related to individual emotion classification.

[1] Originally defined by Ivan Pavlov (1849-1936)

2.1.3 A Categorical View of Emotions

Within the categorical approach to emotions, there is much agreement to the existence of six emotions in one category (Ortony et al 1990) (Stern 1999). The name of this category has, and is the subject of much debate, and includes basic emotions by Ortony and Turner (Ortony et al 1990) and universal emotions by Damasio (Damasio 2000). Ekman et al (Ekman et al 2003) suggests that category one emotions begin manifesting themselves soon after birth and *all are visible facially*, such as the curled upper lip and nose wrinkling common with disgust (Damasio 2000), or the raising of the eyebrows common with surprise (Ekman et al 2003).

According to Ekman (Ekman 1998), these category one emotions are often labelled:

- Anger
- Disgust
- Fear
- Happiness
- Sadness
- Surprise

These emotions are not simply single state emotions such as "I am experiencing fear" but according to Ortony et al (Ortony et al 1988), these six emotions have intensities attached to each one such as:

- Anger - ranges from slight irritation to rage or fury.
- Fear - ranges from apprehension to terror.
- Happiness –ranges from contentment to ecstasy.
- Surprise – ranges from startle to an extreme emotion of surprise.
- Sadness to Grief.
- Disgust to Loathing.

Potter-Efron (Potter-Efron 2004) suggests that these emotions can also have discrete states such as anger having sarcasm, blaming and rage.

2.1.3.1 Second Category of Emotions

Ekman (Ekman 1998) suggests that a second category allows the developing person to engage and integrate in a social context such as being able to experience *contempt*, an emotion defined as 'feeling morally superior to another'. Crawford et al (Crawford et al 2002) suggests this category is called social emotions, whereas Damasio (Damasio 2003) suggests secondary emotions, for ease of reference they will be referred to in this work as category two emotions, and include:

- Contempt
- Sympathy
- Embarrassment
- Envy
- Guilt
- Gratitude
- Jealousy
- Admiration
- Pride
- Indignation
- Remorse
- Shame
- Despair.

Ekman (Ekman 1998) proposes that these category two emotions are a blend of category one emotions such as *jealousy* which is defined as a blend of *anger*, *sadness*, *fear* and *disgust* i.e.

- *Anger* at a person i.e. x has something I don't.
- *Sadness* at not having something that x has.
- *Fear* in anticipation that x might get more and I might never have.
- *Disgust* at self for feeling jealous of x.

Ekman (Ekman 1998) suggests that this category of emotions contains emotions that enhance survival by equipping the subject with the ability to both recognise category one emotions in others and to blend category one emotions together to deal with socially fluid environments through the use of both cognitive and auto appraisal mechanisms. Unlike category one emotions, Eysenck (Eysenck 1997) suggests that category two emotions do not always show facially, though some do including embarrassment, shame and guilt that have a tendency to produce a blush response.

2.1.3.2 Third Category of Emotions

Damasio (Damasio 2000) proposes that the third category is called background emotions, and includes:

- Well-being
- Calm
- Tension
- Relaxation
- Fatigue
- Loathing

These are also considered to be a blend of emotions, such as *loathing* being a blend of *disgust* and *hatred* (Eysenck 1997), and according to Damasio, are thought to be emotions related to the way we feel over a period of time.

2.1.3.3 Additional Notes on the Physical Signs of Emotion

Charles Darwin was the first major researcher to carefully look at the role of facial emotions (Darwin 1872), sometimes referred to as expressions. These expressions can be thought of as two categories, micro and macro expressions. Micro expressions are very brief, typically less than a second, these emotions are difficult to hide as they are so fast and thus could be overlooked by an observer. Macro expressions last longer than a second (Katsyri et al 2003) and can reflect an unconscious state of mind. Though the face is the primary location to observe some emotions, body language such as movements of the hand, used in conjunction with the face has been shown to reflect emotions in a social context especially after a challenging social emotion has been experienced such as the rubbing of the neck during nervous activity, or wiping of the brow (Sedgwick et al 1995).

2.1.4 Emotion Detection

Ekman (Ekman 2004) proposes that emotions are activated by something that the person senses or is thinking about, often referred to as the stimulus; this also includes according to Ortony et al, consequences of events. Once detection has occurred, an appraisal of the emotional significance is made to identify if it triggers an emotion.

2.1.5 Appraisal

According to Le Doux (Le Doux 1998), when a stimulus is detected, the individual needs to then perform one of two kinds of appraisal, the first is a fast appraisal of threats which can quickly prepare the individual for a fight or flight response, called by Le Doux the low road.

The other appraisal mechanism called by Le Doux the high road, is a more complex appraisal which identifies:

1) The emotional significance of an object i.e. if we like or dislike something.

2) Whether something is useful to us for a current goal or action.

3) The threat level of the object to our mental and physical well being.

The identification along with the appraisal process is a subject of some debate. Some theories include hierarchical approaches such as the OCC (Ortony Clore Collins) model that features twenty two specific triggers grouped into three broad categories (Ortony et al 1998) others use a more general approach such as the nine trigger model proposed by Ekman (Ekman 2004). Both are discussed next.

2.1.5.1 Ortony Clore Collins (OCC) Model

The OCC Model proposed by Ortony et al defines three broad categories that all emotion triggers can be grouped by i.e.

- *Consequences of events* – i.e. I am pleased/displeased that something happened to me or I am pleased/displeased that something happened to someone else.
- *Actions of Agents* – The triggers are thought to relate to standards and take the form of approving or disapproving of something that someone has done, maybe to me, maybe to someone else.
- *Aspects of Objects* – I like or dislike something

The triggers and corresponding emotions are shown in Figure 5[2] and provide a progressively granular view of triggers based on the hierarchical model shown.

[2] diagram from Ortony et al 1998

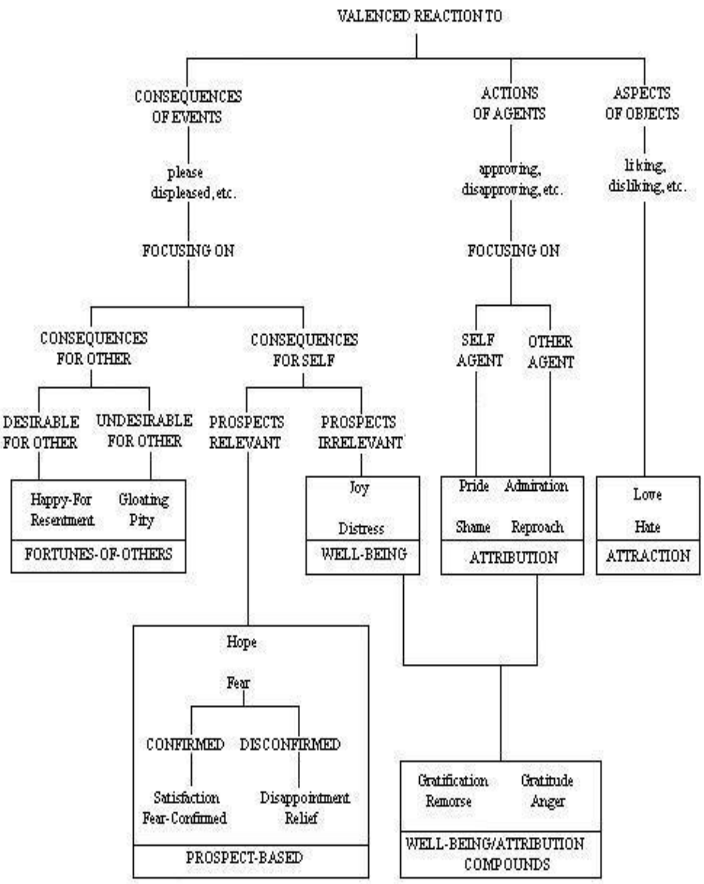


Figure 5. The OCC Model of Emotions

As can be seen, compared to the process suggested by Le Doux in 2.1.5, the OCC integrates the fight or flight response into the general emotion process rather than as suggested having it as a separate process. This would in essence mean that implementations based on the OCC model, would have the same reaction time for fight or flight, as other emotional appraisals, which is not the supported view by Le Doux and others such as Damasio. One interesting point to make, is that the OCC features liking (dislike), approval (disapprove) and pleasing (displeased) as its responses to stimulus which are all similar responses but based on objects, people or events.

2.1.5.2 Nine-Trigger Ekman Model (Ekman 2004)

This model features nine broad categories for all emotional triggers:

1. *Automatic Appraisal* - i.e. interference with goals that causes an automatic emotion such as anger.
2. *Reflective Appraisals* – regretting decisions or entering an emotional state when reflecting on something that happened recently.

3 *Memory of a past emotional appearance*- remembering emotional events triggers an emotional state.
4 *Imagination* – thinking about something emotion related can incite an emotional state.
5 *Talking about past emotional experiences* – that the discussion of emotions brings forth emotions that can result in the manifestation of subsequent emotions.
6 *Empathy* – the triggering of an emotion due to someone else being in an emotional state i.e. pity or anger for someone who is sad.
7 *Others instructing us* to be emotional about something.
8 *Violation of social norms* – could result in anger.
9 *Voluntarily assuming the appearance of emotions* -there is evidence to support the theory that by making facial expressions related to certain emotions can result in a change of emotional state, such as smiling making some one happy.

2.1.6 What is a Mood?

Moods are often confused with emotions but the difference is that emotions only last for a short time, long enough for the individual to react to a stimulus and take some kind of corrective action. Moods according to Damasio (Damasio 1999) are thought to last much longer, possibly a few days, and are usually linked to the slight background presence of a particular emotion. When an individual is in a mood then whatever slight emotion is present will cause easier activation of related emotions, i.e. if someone is in a 'bad mood' then they more easily enter a related emotional state such as anger. Ekman et al (Ekman et al 2003) suggests that this easier inducement may be due to triggers not normally associated with the automatic appraisal of the emotion and can be more difficult to observe due to the lack of facial expressions. A consequence of moods according to Clore et al (Clore et al 2000), is the effect on decision making that can become biased towards the emotion underlying the mood. Moods according to Damasio, could also be the result of unresolved or persistent emotions that have not been overcome fully, and as such are suppressed by the individual to allow 'normal' cognitive functioning. While in a particular mood there is a tendency to respond emotionally to certain stimuli, which ordinarily would not elicit a response.

2.1.7 Personality

Terminology related to personality and emotions are often interchangeable by the lay-person such as aggressive, anxious and moody, which is often used to describe a variety of moods, emotions and personality types. It is not uncommon for personality types such as those used in models of personality devised by Allport (Allport 1961), Eysenck (Eysenck 1965) and Cattell

(Cattell 1965) to include categorisation methods, featuring descriptions of personalities that encompass emotions, i.e. aggressive, passive and anxious that are featured in Eysenck's "dimensions of personality" (Eysenck 1965). This is because according to Plutchik (Plutchik 1980) personality labels are used to describe the common emotional characteristics of a person. This concept has led Plutchik to formulate a list of sixty seven common personality types, along with the corresponding emotions associated with each personality type as shown in Table 1.

Personality Description	**Emotion 1**	**Emotion 2**
Gloomy	Sad	Annoyed
Hateful	Angry	Disgusted
Sarcastic	Annoyed	Disgusted
Withdrawn	Afraid	Angry

Table 1 – An Extract from Plutchik's Emotion/Personality Descriptions.

Though Plutchik suggests that it is feasible to identify certain emotions present with certain personality types, he also proposes that personality models can be used to understand and predict behaviour.

Where theories of personality differ in their approaches are:

- Whether personality can be applied to groups of people, commonly referred to as the *Nomothelic* approach. The models proposed by Eysenck (Eysenck 1992) and Cattell (Cattell 1965) fall into this category. The alternative approach involves unique personalities for individual's, referred to as the *Idiographic* approach. Allport's model falls into this category (Allport 1961).
- What the personality types are called.
- Which emotions make up the personality types and what they choose to call the emotions involved?
- Intensity of emotions that are involved.

Therefore as suggested by Plutchik, the distinction being used in this work, is that emotions are what the individual experiences and personality types are associated with the frequency and blend of emotions in an individual.

2.1.8 Aggression

Aggression is defined as behaviour, rather than an emotion, and is defined by Dollard (Dollard et al 1939) as a behaviour that causes harm either psychologically or physically to the victim. This aggression according to Moyer (Moyer 1976) is either hostile or instrumental (defensive):

- Hostile aggression is an offensive aggression that is directed towards another. This form of aggression is motivated cognitively without an immediate threat, and is often according to Dollard as a consequence of frustration (a more verbal kind of anger) that has led to a more physical form of anger such as rage (see later notes on anger).
- Instrumental aggression is a form of self-preservation aggression that is directed at immediate threats i.e. self defence. This form of aggression may require more calculated actions in order to remove an imminent threat and as such is often classified as a controlled form of aggression.

2.1.9 Category One Emotions Expanded

As there is general consensus on emotions in this category, what follows is a closer look at each of the six category one emotions in order to map them to the model proposed by Scherer as shown in section 2.1.

2.1.9.1 Anger

This emotion has been described by Ortony and Turner (Ortony et al 1990) as a consequence of blaming an object or a person for thwarting a goal, and by Berkowitz (Berkowitz 1993) as a mechanism for dealing with threats (physically and to the ego). The presence of anger is recognizable from its physical characteristics such as face and posture changes as discussed later.

2.1.9.1.1 Anger Focus

Anger is typically focused inwards at ourselves, at someone else, at an inanimate object, or an animal. Also according to Parrott (Parrott 2001), the angry individual often imagines attacking or hurting the cause of their anger.

2.1.9.1.2 Anger Behaviour Stages

Potter-Efron (Potter-Efron 2004) suggests a possible categorical approach to anger, featuring eight escalating stages of behaviour as shown in Figure 6, where the actual type of anger experienced, is dependent on the appraisal of the situation.

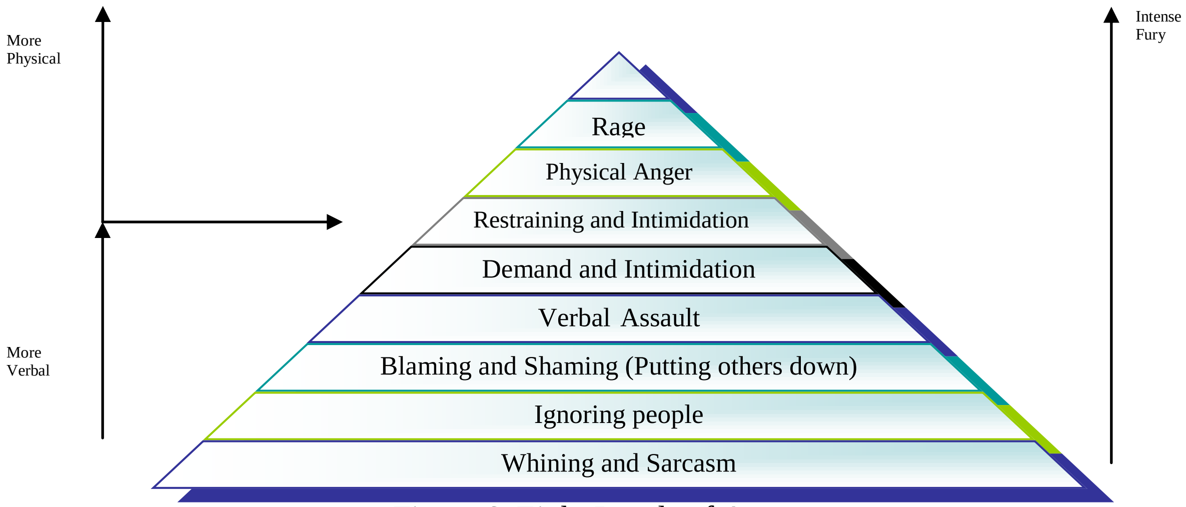


Figure 6. Eight Levels of Anger

Lower, less intense levels of anger, such as "whining and sarcasm" tend to focus more on attacking the stimuli's ego, and as the anger escalates the ego attacks are combined with a more physical approach. Eventually according to Ekman (Ekman et al 2003), a state of rage is entered which has a tendency to always be physical aggression. There is a propensity for anger to become self fuelled, thus much of the behaviour associated with angry individuals is aimed at getting a verbal or physical response back. Any such response will invariably always escalate the anger; examples are physical prompting i.e. pushing someone.

2.1.9.1.3 Annoyance, Frustration and Irritation

The terms annoyance, frustration and irritation are often commonly used when referring to anger, and tend to be more verbal responses that are described below:

- Annoyance: According to Power et al (Power et al 1997), *annoyance* is a less intense form of anger, and can involve goals and actions being affected, but not deliberately so, and probably for the first time. Annoyance can be internalised and rationalised, and as such can be directed at one's self, at an object or other person, and is usually a lower verbal response being suggested as possibly ignoring people. Repeated incidences of annoyance can lead to frustration.

- Frustration: According to Ekman et al (Ekman et al 2003), *frustration* is usually caused by goals/actions being thwarted or interfered with by an external entity, and are usually deliberate. As such, the response is likely to be more verbal such as blaming and shaming. Reoccurring frustration can lead to stronger anger responses such as rage. Research in the area of frustration and aggression is often based on the *Frustration-Aggression Hypothesis* (Dollard et al 1939), which according to Dollard means that frustration invariably leads to both physical and verbal aggressive behaviour if not resolved.

- Irritation is a similar state to frustration but involves reoccurring accidental happenings, and rarely leads to physical anger as such it is a lower verbal anger such as whining & sarcasm.

2.1.9.1.4 Anger Triggers

Combining the triggers mentioned in 2.1.9.1 with the anger behaviour stages discussed in 2.1.9.1.2 and finally the notes on annoyance, frustration and irritation in section 2.1.9.3 a table can be specified as shown in Table 2 reflecting the anger process.

ANGER TRIGGER		POSSIBLE RESPONSE
Goals Violated (Ortony and Turner 1990)	Blaming an object for a failed goal.	Annoyance - Verbal response likely
	Blaming self for a failed goal.	Annoyance - Verbal response likely
	Blaming someone else for a failed goal.	Annoyance if not deliberate - Verbal response likely Frustration if deliberate - Verbal response likely
Physical Threats (Berkowitz 1993)	Threat of physical harm and object can be overcome.	Physical Response likely
	Someone wishing you dead.	
	Being attacked and threat can be overcome.	
	Being assaulted and threat can be overcome including being knocked over or pushed accidentally. Including accidental physical harm.	
	Threats that cannot be easily overcome and are not persistent.	
Threats to What We Believe (Berkowitz 1993)	Seeing one of your social standards being violated.	Verbal response likely
	Observing actions that conflict with your moral values.	
	Ideas and knowledge that are trusted, being challenged.	
	Being removed from decision processes affecting self.	
	Social disclusion/Being ignored.	
	Social rejection.	
	Being sneered at. Being made fun of. Someone calling you names.	
	Being put down Someone acting superior. Telling people how to run their lives.	
	Being insulted.	
	Someone criticizing you.	
Memory Related(Berkowiz 1993)	Remembering angry moments, things that make you angry.	Physiology signs of anger likely. Anger level dependant on strength of memory.

Table 2 – The Anger Process

2.1.9.1.5 The Physiology of Anger

Anger can be observed from a reddening of the face accompanied with changes to the facial muscles as discussed by Ekman (Ekman 2009), such as the raised upper lip. The heart rate increases as a consequence of increased blood flow to the face and hands, causing breathing increases and skin temperature changes. From the body, there is a tendency to move closer towards the trigger stimulus, as well as a tightening of the fists. Verbal responses will be based on the anger behaviour response, as shown in Figure 2.

2.1.9.1.6 Anger Duration

According to Damasio (Damasio 2000), emotions only last a very short time, therefore any affective state following the activation of anger is something other than anger itself possibly a mood. Anger decays slowly if its cause is not resolved, which means that anger triggers are elevated until fully dissipated; this means that people who have experienced an angry event are more easily angered for a time afterwards. According to Ekman et al (Ekman et al 2003), frustration can decay over time if the individual is pre-occupied or can control the frustration. i.e. “saying to self I will not get annoyed”, “cooling off” etc.

2.1.9.1.7 Anger Habituation

According to Potter-Efron (Potter-Efron 2004), individuals have different trigger thresholds for anger, and as with all emotions, anger can become habituated. This habituation means that the individual can be in an ongoing angry state without becoming conscious of it i.e. angry behaviour and affective states seem normal to the individual.

2.1.9.2 Disgust

2.1.9.2.1 Disgust Behaviour

Ekman (Ekman 2001) suggests that disgust is an emotion intended to protect the individual from harmful environmental stimulus such as smoke or natural gasses. Disgust can also be triggered by decaying matter, which might be to protect the individual from potential diseases related to rotting waste.

2.1.9.2.1 Disgust Subjective Feelings

According to Parrott (Parrott 2001), when experiencing disgust the individual may feel nervous tension and some discomfort or nausea.

2.1.9.2.3 The Physiology of Disgust

Ekman suggests that the individual may turn away from the source of the emotion and try to avoid it. Facially, Frith suggests that the nose wrinkles to reduce the intake of smells, while the eyes become narrowed and focused on the source of the stimulus.

2.1.9.3 Fear

Clore et al (Clore et al 2000), describe fear as a reaction to appraisals of threat, and Plutchik (Plutchik 1984) adds that fear allows the individual to run away from danger in order to protect themselves.

2.1.9.3.1 Fear Behaviour

The general fear response according to Schafe et al (Schafe et al 2002) is:

- *Defensive Behaviour* - such as involuntary freezing, believed to have evolved because according to Le Doux (Le Doux 1998) many predators respond to movement, and turning to face the threat.
- *Autonomic Arousal* – Automatic excitation of several body systems such as blood redirection to the muscles in hands and feet to begin fight or flight.
- *Hypoalgesia* - Reduction of pain from ordinarily painful stimuli brought about from the release of opiates into the system.
- *Reflex Potentiation* – Tendency to face target with eyes wide so to fully focus on stimuli. Reflexes increased through an increase in adrenaline and focus of attention.
- *Stress Hormones* released to engage body systems to run or fight.

2.1.9.3.2 The Physiology of Fear

According to Schafe et al, fear can be observed because the individual stops all movement, that Le Doux (Le Doux 1998) summarises as freezing in position. While freezing momentarily, increased perspiration may be visible due to an increased heart rate. Finally the skin may contract, whilst the muscles tense ready to fight or run, where according to Parrott (Parrott 2001) "run" may simply be walking hurriedly away or simply seeking somewhere to hide. Frith (Frith 2009) points out that the eyes go wide to allow a larger visual field, the nose widens to take in more air and to also be able to enhance the sense of smell.

2.1.9.3.3 Subjective Feelings of Fear

Parrott proposes that when an individual is experiencing fear, they might:

- feel nervous, jittery and jumpy.
- be aware that they have a dry mouth and may be sweating.

- be conscious of a butterfly sensation in their stomach.
- be aware they are imagining the worst from the situation.

It is the experiencing of one, or all of these that results in the conscious realisation of fear.

2.1.9.3.4 Fight or Flight Response

Central to the role of fear is the role of the Amygdala a small brain region that according to Damasio (Damasio 2000) 'hijacks' many brain systems when a fear stimulus is present. This hijacking occurs to protect the individual by mobilising many body systems rapidly, without the need for conscious processing, a process called autonomic arousal. Conscious realisation does occur later but this is a consequence of the previously mentioned bodily changes such as 'freezing' and the feeling of butterflies in the stomach. The Amygdala's effect on organs to produce hormones and the hijacking of many systems is called the fight or flight response of fear.

2.1.9.3.5 Anxiety a Variant of Fear

Anxiety is an emotion related to fear. The difference according to Le Doux, is that anxiety is a reaction to a perceived threat whereas fear is a reaction to a present threat. As already stated fear of a present threat involves many automatic responses, until the immediate threat is overcome and thus the individual gains cognitive awareness reasonably quickly, and can take further steps to deal with subsequent threats or reflect on the actions taken. With anxiety the individual cannot resolve the threat and thus the emotion system interferes with the cognitive system to create a mental state of continual fear that the individual's autonomic and cognitive system cannot resolve, thus:

- *Anxiety causes worry* – Le Doux says that the individual perceives the situation as difficult or impossible to deal with and therefore feel continually threatened.
- *Anxiety induces negative thoughts* – Wells et al (Wells et al 1994) describe this as the individual reflecting on negative thoughts such as failing in similar situations previously, and can enter other negative emotional states such as sadness or depression. The individual focuses on failure and foresees failure at overcoming the obstacle or stimulus and thus feelings of self worth are experienced.
- *Anxiety is obsessive* because the individual cannot focus on anything but the perceived threat, their senses become focused on locating threats in their environment a condition called 'Eysenck's hyper-vigilance theory' (Eysenck 1965). Wells et al explains this by saying that anxiety motivates individuals to scan for threats, focusing on other tasks

> becomes difficult and multi-tasking is almost impossible while in the elevated state of vigilance.

Wells et al theorise that a lack of skills to handle many situations might be the root cause of many forms of anxiety such as threats in a social situation causing anxiety due to a lack of social skills, or the fear of failing exams being due to a lack of study/test skills. This lack of skills can present the individual with a growing fear of the oncoming situation, resulting in severe problems when finally faced with the perceived threat because they lack the means to deal with the anxiety provoking situation.

2.1.9.3.6 Panic Disorder

Closely related to anxiety is panic disorder. Panic disorder is diagnosed as a misinterpretation of body sensations such as increased breathing and heart rate brought about by experiences such as slight exertion or excitement. Wells et al continue to say that the subject experiencing panic disorders often misinterprets these bodily sensations as indicators that they are in danger or something is wrong and ultimately links the bodily sensations with negative thoughts and feelings which can ultimately develop into further conditions including anxiety and agoraphobia which is a fear of being afraid.

2.1.9.3.7 Phobias

Phobias are a fear related emotional disorder where the fear of a specific stimuli or situation is in excess of the threat posed. Examples are Arachnophobia a fear of spiders, and Ophidiophobia, a fear of snakes. Le Doux suggests that extended exposure to the stimuli leads from a fear response to a state of anxiety.

2.1.9.4 Happiness

According to Power et al (Power et al 1992), happiness is a consequence of something unexpectedly occurring that has a positive impact on the individual such as a goal or action being completed. This may also be as a consequence of completing on their own something difficult or challenging.

2.1.9.4.1 Happiness Behaviour

Parrott suggest that the individual is friendlier and courteous to others which is a sign of greater social interaction which may extend to doing nice things for others. Whilst happy, the individual has a higher threshold for worrying and annoyance feelings and will usually let them pass while being upbeat and positive in their outlook.

2.1.9.4.2 Subjective Feelings

According to Parrott (Parrott 2001) when experiencing happiness the individual may sense that they are:

- excited and have a more positive outlook.
- more energetic

2.1.9.4.3 The Physiology of Happiness

Parrott (Parrott 2001) suggests that the individual may walk around with a raised head to communicate their happy feeling to others. Their posture becomes more upright and they may move around more quickly, potentially smiling as they do so. Finally they may even hug others to share their feelings of happiness.

2.1.9.5 Sadness

According to Power et al (Power et al 1992), sadness tends to be about the loss of a loved/respected figure in someone's life, and to have evolved to allow individuals to automatically gain support within social groups. Grief is a variant of sadness, where individuals do not resolve sadness immediately after a loss, but retain the unresolved feelings which emerge later. This late emergence of sadness (grief) can lead to anger at the loss of future shared experiences.

2.1.9.5.1 Sadness Behaviour

Parrott suggest that the individual withdraws from social contact, and can be hard to talk to as they do not easily respond. Instead they generally just sit or lie about being as inactive as possible due to a lack of motivation and energy, which means they also do not try to improve their emotional state. According to Power et al, it is the support of social groups that can help to speed up the end of sadness.

2.1.9.5.2 Subjective Feelings

According to Parrott (Parrott 2001) when experiencing sadness the individual may sense that they are:

- tired, run down and low on energy.
- grouchy and easily irritable while reflecting on negative thoughts including self blame.

2.1.9.5.3 The Physiology of Sadness

Dependant on the level of sadness, Ekman suggests that the individual may cry and will generally have a drooping facial expression commonly called a sad expression. Their posture becomes drooped and they move around slowly while looking down to avoid eye contact with others, a sign of social withdrawal.

2.1.9.5.4 Depression

Depression is a condition related to sadness that develops as a consequence of an overwhelming loss in life. Wells et al (Wells et al 1994) propose that the onset of depression as a consequence of loss is not automatic for everyone, and in fact may only occur in around ten percent of cases.

2.1.9.6 Surprise

It has been suggested by Frijda (Frijda 2007), Ekman (Ekman 1984) and Tomkins (Tomkins 1982) that although surprise is often categorised as an emotion, that it is actually a state that precedes the activation of one of the other five category one emotions. This surprise state is normally triggered by an unexpected event, or the appearance of an unexpected stimulus. Furthermore, according to Tomkins events can also include goals or actions that are changed by a stimulus and Sedgwick et al (Sedgwick et al 1995) add that the activation of the surprise response interrupts, and can reset current strong emotional feelings to act like an emotional "circuit breaker". Tomkins continues by saying that the emotion actually activated after surprise, would be dependent on how the stimulus is perceived and how unexpected the stimulus was.

According to Ekman, surprise can be thought of as four different reactions called startle, surprise, interest and shock. Activation of one of these four specific types of surprise, and the subsequent emotion is dependent on the stimulus and encounter as discussed next.

2.1.9.6.1 Levels of Surprise: Startle

According to Ekman the startle response begins within 100ms of a stimulus being presented and is gone within 500ms. This reaction involves the detecting of a stimulus that is close enough to be a physical threat, but was not previously seen approaching, i.e. approached from behind. This also includes unexpected changes to the environment such as sudden darkness. If the stimulus could potentially be harmful (it has a fear response related to it) then a fear response is likely after the startle response has ended.

2.1.9.6.2 Levels of Surprise: Surprise

Ekman proposes that surprise has a longer duration than startle, and is the detection of an unexpected stimulus that has achieved a goal/action, or the unexpected detection of someone that has a positive emotional significance for the individual, such as a related happy emotion. This reaction can involve the detection of a stimulus that is either very close or far away.

2.1.9.6.3 Levels of Surprise: Shock

Ekman proposes that shock is the reaction to an unexpected stimulus that has negative emotional significance for the individual. This reaction might include stimulus that affected their actions or goals in a negative way, and could lead to anger or sadness, depending on the emotional significance of the detected individual. This reaction involves the detection of a stimulus that could be close or far away, or possibly an unexpected event.

2.1.9.6.4 Levels of Surprise: Interest

Ekman proposes that interest is a reaction to an environmental event or a detected object that could help the individual achieve a goal or action. This reaction involves the detection of a stimulus that is either very close or far away, and a current action or goal could be completed by the detected object which could mean a happy response.

2.1.9.6.5 Levels of Surprise: Final Notes

Though each of the four levels of surprise has examples of which emotions might be activated by a particular stimulus and event, it should be noted that the actual emotion will be dependent on any emotional significance the individual has attributed to the stimulus, and the actual behaviour of the stimulus. So that for example with startle, if someone unexpectedly appears from behind, they may experience an initial fear response i.e. freeze, but this may quickly change to happiness if they like the person.

2.2 Computational Models of Emotions

2.2.1 Overview

An investigation into the computational modelling of emotions leads the researcher to many publications of independent work conducted over at least the last two decades. Some of this research, such as the work by Petrushin (Petrushin 2000) in the commercial use of emotion recognition in voices, has been used with some success in call centre queuing systems to detect a range of emotions, including anger and happiness, facilitated through a two-layer back propagated neural network. Other research projects are based on more formal theories of psychology such as Wilson's (Wilson 2000) *The Artificial Emotion Engine*, based on the work of Eysenck (Eysenck 1965) who is known for his work on formalising personality models and Gray (Gray 1971) known predominantly for his study of fear.

Complementing the research on emotional behaviour modelling, is a substantial amount of work in the visual appearance of emotions, such as the work by Eckchlager et al (Eckchlager et al 2005) on the Neural Emotion Eliciting System (NEmESys) which has been used to model the work on facial emotions by Ekman (Ekman 2004) as discussed in section 2.1. This project utilises neural networks that are pre-trained using Goldberg's (Goldberg 1993) 5-factor model of personality.

Projects that combine behavioural changes with corresponding visual changes have also emerged, including the work by Paiva et al (Paiva et al 2002) on the IST Supporting Affective Interactions for Real-Time Applications (SAFIRA) project. SAFIRA predominantly bases behaviour on the OCC model (Ortony et al 1988) of emotions combined with the work of Ekman for visualising facial emotions. According to Paiva et al, the range of emotions that can be modelled include anger, peace, spiritual, warm, happy and sadness which of course reveals that the terminology used to describe the emotions actually is a blend of personality types and emotions and the merging of these together under the term "emotions" could potentially cause some confusion for the developer looking to implement SAFIRA in their agents.

The OCC model has also been investigated by Bartneck (Bartneck 2002) regarding its suitability for a basis of computational models of emotion. Bartneck proposes that the OCC model is best approached as a five stage architecture:

- *Classification* – event, action or object is related to which categories it could affect. Discusses need for a classification and storage system to actually do this classification.

- *Quantification* – Intensity of emotion a history mechanism is discussed to allow for regularity to diminish or increase intensity.
- *Interaction* – classification & quantification define an emotional value that affects the agents current emotional state i.e. how the categories interact when different emotions are present, Bartneck indicates that the OCC model lacks this.
- *Mapping* – twenty two categories in OCC model, expression mapping accordingly.
- *Expression* – facial expressions.

Conclusions reached by Bartneck are that the OCC model is partially suitable for simulating emotions, but has some drawbacks that need attention such as the need for a history function, emotion interaction function, personality designer and that the model requires simplification for developers.

Focusing on computational models of emotions applicable to agents in simulations and games, does provide several popular research projects including:

- Sloman's *CogAff Architecture* (Sloman et al 1995)
- Bates, Loyall and Reilly's *Tok Project* incorporating *Em* (Reilly et al 1992).
- Gratch and Marsella's *Émile* (Gratch 1984)

These three architectures are discussed next.

2.2.2 Cognition and Affect Project (CogAff)

The CogAff architecture proposed by Sloman et al (Sloman et al 1995) is a three-layer architecture, intended to model behaviour in agents for simulation and games. The three layers are intended to break down the processing into more manageable and self contained units as shown in Figure 7. This approach means that simple responses to pre-defined events require much less processing than the agent having to plan a response in the deliberative layer.

Layer	Purpose	Processing
Meta-Management	Contains Reflective Processes i.e. being able to consider if actions taken were appropriate	Increased Processing
Deliberative Reasoning	Deals with Deliberative Reasoning i.e. planning how to respond.	
Reactive Mechanism	Deals with Reactive Mechanisms i.e. predefined automatic responses to events and actions.	Low processing Requirements

Figure 7. Processing Within the CogAff Architecture

Examining the architecture, and particularly the reactive layer, it could be possible to model a fast responsive basic emotion such as fear, as this layer is intended to be able to interrupt and override other processing if given suitable stimulus, i.e. layers 1 and 2. Though the reactive layer can override the other two layers, in general the three layers are concurrently active.

2.2.2.1 A.I. Techniques used for Implementation

Investigations of the architecture show that it uses A.I. techniques such as finite state machines (FSMs), neural networks (which according to Sloman et al (Sloman et al 1999), means that the CogAff architecture is not suitable for agents to learn new behaviours in real time) and condition action rules within the layers. Subsequent behaviour is suggested as being schema based to reduce processing, thus becoming more of a look up facility.

2.2.2.2 The Architecture in Software

The CogAff architecture has been integrated into a software toolkit called SimAgent (Sloman et al 1995), which utilises the Pop-11 programming language to allow developers to create agents for simulations. Sloman et al (Sloman et al 1995) propose that CogAff/SimAgent can be used to model three distinctly different types of agents, a reactive agent, an affective agent and a deliberative agent based upon the layers of the model:

- The Reactive Agents (R-Agents) exhibit simplistic behaviour by simply carrying out instructions such as if agents are hungry they go straight for food, whether it is safe to do so or not. Modelled using finite state machines implemented using rule based systems (Scheutz et al 2000).
- The Affective Agents (A- Agents) differ slightly to the R-Agents as they do not blindly pursue goals, but can in fact alter their behaviour in pursuing their goals if need be, such as if there is a danger in the path, they might go a different way or wait.
- The Deliberative Agents (D-Agents) are the most complex agents, and they can plan behaviour to achieve goals such as considering a range of options and outcomes.

2.2.2.3 Cogaff and Emotions

Later work by Sloman et al (Sloman et al 1999) extended this work to include emotions. This additional expansion of the CogAff architecture seems to broadly map the three categories of emotions discussed in section 2.1 to each of the layers as shown in Figure 9.

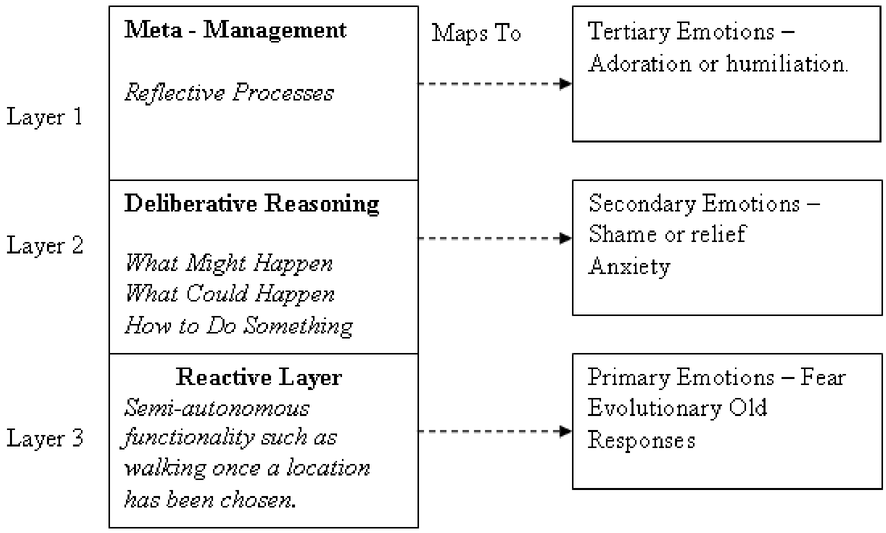


Figure 9. The CogAff Architecture

The underlying psychology linking the additional emotions added to the CogAff architecture was difficult to ascertain, except for casual implications, therefore the first difficulty with using the CogAff architecture for agents in games and simulations is that there is a lack of evidence supporting a firm foundation in formal psychology. It can, of course be assumed that it is in fact based on some elements of psychology, in which case it is possible to support the usage of category one to three emotions, for these additional mappings. A second difficulty is that the general emotion process as shown in section 2.1 is not apparent, and as such it is difficult to actually follow a logical process of detection, appraisal, behaviour, physiology and reflection as proposed by Scherer (Scherer 2005).

2.2.3 Tok Project (featuring HAP & Em)

The Tok project developed by Bates (Bates 1992a) is an integrated A.I. architecture designed to work in a specific virtual world called the Oz environment (Reilly et al 1992) (Reilly et al 1993). Tok has been specifically designed for use in non-real time worlds (Loyall et al 1991a), and features the following aspects:

- a reactivity element called HAP (Loyall et al 1991b) dealing with goal-directed behaviour.
- a module called Em (Reilly et al 1992) that handles emotion, and is based on the OCC model of emotions (Ortony et al 1988).
- some memory functionality.

Tok handles the behaviour aspect of the Oz world inhabitants, and its relationship to Em and HAP is shown in Figure 10.

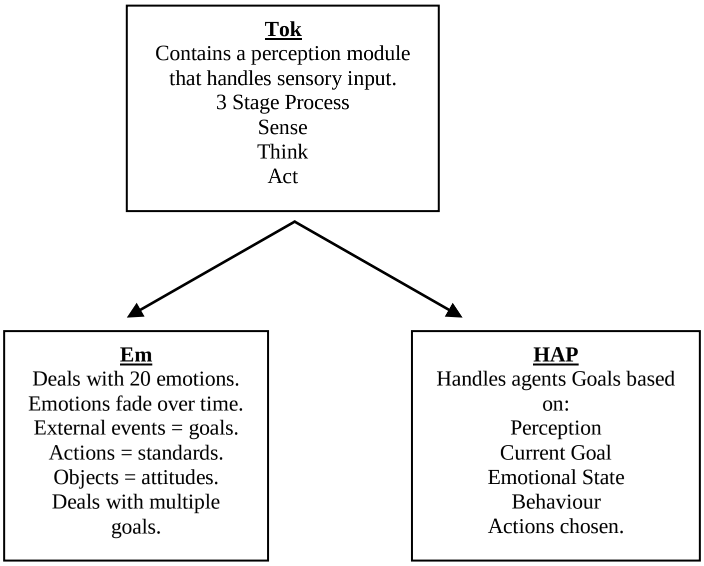


Figure 10. Oz Architecture

2.2.3.1 The Architecture in Software

The Edge of Intention project developed by Bates (Bates 1994) features Tok, and involves creatures called Woggles that incorporate some goal based emotions (based on the OCC model) such as anger (activated when goals were failed), implemented through the Em module. The Woggles responses are mapped to personality traits so that for example, when a specific Woggle becomes alarmed it becomes angry. HAP is used to assign goals and behaviours to the

Woggles, though they cannot plan only react to events within the environment, though it is conceivable that this could be changed. This reactive only approach means that in its current form, Em is best suited to applications where agents are equipped with task orientated emotions i.e. "emotions that arise from the performance of a concrete task" (Gratch et al 2001).

Further software implementations of the architecture by Reilly (Reilly 1996) include *Robbery World*, *Office Politics* and the *Playground* that were all text based applications. These applications were part of a research project by Reilly, intended to address more believable agents through social and emotional aspects of agents, with a focus on interactive drama.

2.2.3.2 The Emotion Aspect

Though Em is integrated into the Tok architecture, it is still valuable to investigate the functionality in regards to dealing with emotion representation. As previously mentioned Em is based on a scaled down version of the OCC model of emotions, and the relevant mappings for these are shown in Table 3.

Emotion	***Cause***
Joy	**Goal success (*)**
Distress	**Goal failure (*)**
Hope	**Prospect of Goal success (*)**
Fear	**Prospect of Goal failure (*)**
Pride	**Action of self approved according to standards**
Shame	**Action of self disapproved according to standards**
Admiration	**Action of other approved according to standards**
Reproach	**Action of other disapproved according to standards**
Love	**Attention to liked object**
Hate	**Attention to disliked object**
Gratification	**Action of self causes joy and pride**
Gratitude	**Action of others causes joy and admiration**
Remorse	**Action of self causes distress and shame**
Anger	**Action of other causes distress and reproach**
(*) Denotes difference from OCC Model	

Table 3 – Em Emotional Aspects[3]

Where:

- **Actions are** judged to be either pleasing or displeasing according to goals.
- **Goals** anything the agent wants to do.
- **Standards** applied to actions as a basis of morality (pride or shame linked i.e. if agent does something morally wrong then emotion activated probable to be shame).

[3] Table from "Building Emotional Agents" Page 7 (Reilly et al 1992)

- **Attitudes** objects (including agents) can be liked (love) or disliked (hate)

The Em architecture has also been used by Reilly (Reilly 1996) in the development of an architecture for artists to help select character emotions. In this project, a questionnaire was used to validate whether or not the project was a success in providing characters with emotions. One interesting aspect of the architecture is the concept of emotions decaying over time, which is consistent with some research in formal emotion psychology (Slater et al 2007). According to Reilly et al (Reilly et al 1992), the emotional decay is managed by lowering the intensity of the current emotion, each cycle that the agent senses, thinks and acts.

2.2.4 Émile

Émile builds upon both the previously mentioned Em architecture and Elliots (Elliott 1992) the *Affective Reasoner* project, to combine fundamentally two aspects of "emotion" found in these projects, appraisal and coping. According to Gratch et al (Gratch et al 2003), appraisal is defined as how the environment or current situation has emotional significance to the agent, and coping is how an agent deals with this emotional significance by the modification of its actions and goals. This is according to Gratch et al, how human beings generally cope with emotions by doing something about the cause of the emotional trigger, a term they call "problem focused coping". With this approach, individuals do not simply think about the situation that caused the emotion, but instead engage in some form of corrective behaviour such as changing their own view of the situation to change its significance, i.e. shifting their responsibility.

2.2.4.1 The Emotion Aspect

Émile is based on the emotional appraisal of plans and goals, providing a framework for modelling appraisal in agents. A significant change from the Em architecture mentioned earlier is that according to Gratch (Gratch 2000), Émile allows agents to observe the emotional states of other agents and alter their own behaviour accordingly. It is ideally suited for applications where agents must plan as well as react, thus allowing a greater scope of realism for agents in simulations. The system is based upon the OCC model of emotions (Ortony et al 1988) which means that it in part; it features an agent's response to goal based planning as well as being able to assess external events that may have goal implications. An addition to the OCC model is the inclusion of emotional intensity linked to how important goals are to agents.

2.2.4.2 The Architecture in Software

The architecture has been implemented in software by combining it with the IPD architecture, proposed by Marsella et al (Marsella et al 2000). IPD provides a visual selection of emotions for agents, and thus complements the behavioural aspects of Émile to allow the developers to create more convincing applications such as the *Mission Rehearsal Exercise* (MRE) developed by Gratch et al (Gratch et al 2001). The MRE was a project to develop a virtual training environment for the armed forces, allowing troops in the field to be able to consider their options in simulated battlefield situations. An example could be how to deal with injured civilians in conflict areas during missions.

2.2.5 Comments on Computational Models of Emotions

One issue that seems common to the projects discussed concerns the usage of emotion related terms such as:

- In CogAff, the names of the emotions in each level, and the levels themselves, do not generally match the descriptions and names identified in section 2.1.3. In fact, some of the names of emotions such as adoration do not match personality types either.
- In Tok, if an agent does not complete a goal, they enter the emotion of distress, but this assumes that distress is an emotion and this is not at all clear, or supported by the review conducted in section 2.1.3. Other ambiguous "emotions" mentioned are joy, hope, satisfaction, disappointment and relief. Also within Tok, it is unclear as to which category if any, these emotions belong to.
- Émile is based on the same underlying emotion system as Tok, which means that it invariably includes similar underlying problems.

As well as common terminology issues, it is unclear from each of the projects, how the logical emotional cycle is followed as suggested by Scherer in section 2.1.3. Gratch et al seemingly have elements of this approach through their appraisal and coping systems which seemingly combine the stages (unconscious reaction), (physiological change), (motivation to act) and (conscious realisation) into the coping element of their systems, but the combination or extent of these implementations is not at all clear.

From the three projects, Tok and Émile are based on the OCC model of emotions, which is understandable because they relied on the same underlying emotion architecture - Em. This coupled with the review by Bartneck supports the OCC as a suitable platform for agent emotion systems based on goals and actions in some instances, but may be limited as it based on a cut down version of the OCC model, so may not be applicable to all goal based application.

In each of the three projects, it was difficult to see recommendations by the proposers as to how these emotional systems could be evaluated, though later work by Gratch & Marsella (Marsella et al 2004) has begun tentatively approaching this issue through the use of techniques such as asking participants in evaluations to agree or disagree as to an agents response in a simulation based against what a real human would do in the same situation.

In closing, one aspect that may need some consideration is that the emotional aspect in the three main projects discussed, is firmly integrated into the agent decision making, and agent behaviour systems making the agent emotion element difficult to separate from the underlying agent control software. Therefore developers wishing to incorporate the emotion aspects of these projects into their own agent detection and behaviour systems may have some challenging issues without a psychology background to rely on.

2.3 Techniques for Modelling Emotions in Characters

2.3.1 Finite State Machines

Finite state machines (FSMs) are commonly used when the developer needs to cycle through different agent's behaviour depending on an external stimulus such as Figure 11:

- an agent that can ***patrol*** when no threat is around
- ***guard*** when an enemy has been detected
- and ***attack*** when threatened

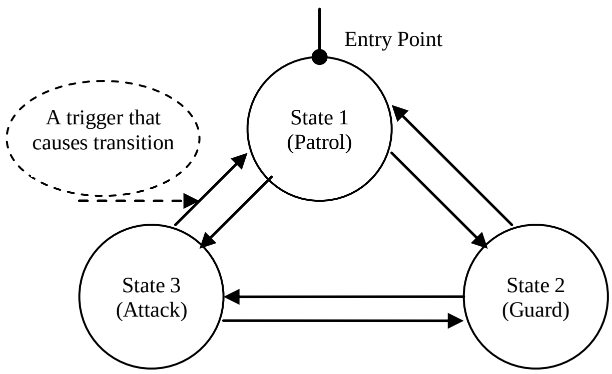


Figure 11. A FSM for Simple Agent Behaviour

The action that causes the transition can vary from a simple variable threshold, to a range of input conditions that can cause a state change. Important notes are that:

- only one state at any time can be active, therefore care needs to be taken to ensure that triggers that cause transitions, do not cause activation for multiple states at once. If this is a possibility, then a priority system needs to be incorporated to ensure dominance of a particular state.
- it is customary to start in a particular state (entry point).
- the state diagram should include all possible changes to a particular state i.e. a finite number of possible states.

In practice, each state could be represented by a series of Case statements as shown in Figure 12.

```
Select Case
{
   Case 1: State 1
   {
      Call State_1
   }
   Case 2: State 2
   {
      Call State_2
   }
   Case 3: State 3
   {
     Call  State_3
```

```
Function State_1
{
   //State 1 Actions
}
Function State_2
{
   // State 2 Actions
}
Function State_3
{
   // State 3 Actions
}
```

Figure 12. Case Statements Used to Represent FSMs

Case statements can easily be substituted for “IF” “Then” “Else” statements to represent the FSMs, though neither approach offers much scope for further expansion. For more scalable solutions a state transition table (Table 4) can be used in conjunction with one of several approaches including look up Tables, databases or for the most versatile approaches using XML to represent the state transition information.

State	Trigger	Transition to State
Patrol	Enemy Sighted	Guard
Guard	Enemy in Melee Distance	Attack
Attack	Enemy Dead	Patrol

Table 4 – Sample State Transition Table

Examples of FSMs being used in commercial computer games are widespread and include agent behaviour in Quake and PacMan, and are according to Carlisle (Carlisle 2002) usually based on deterministic programming i.e. if-then production rules. The limitations of FSMs for computer games are that they rely on conditional *true* or *false* variables resulting in actions that are predictable and could be perceived as being limited. To enhance FSMs the Boolean variables can be replaced with fuzzy variables as shown later.

2.3.1.1 Emotions and FSMs

Referring back to Section 2.1.8, it can be seen that some emotions have different internal states such as “frustration to anger”, and according to previous work by Slater et al (Slater et al 2008), these can be represented by finite state machines as shown in Figure 13.

Figure 13. Anger transitions represented by an FSM

2.3.2 Fuzzy Logic

It is common in software solutions, to include threshold values for certain variables so that for example

```
IF x = 10 THEN
{
   Do Something
}
```

Or alternatively include ranges such as

```
IF x>0 AND x<50 THEN
{
   Do something
}
Else
IF x>=50 AND x < 100 THEN
{
    Do something else
}
```

The usage of this type of boundary is referred to by Buckland (Buckland 2005) as Crisp Sets and is a method of organizing ranges of variables, which works well for many applications where set boundary conditions are required. The problem is, that when attempting to model variables such as emotional behaviour, a method is required to be able to represent emotional language i.e.

- I am feeling a little unhappy.
- I am really sad, but a little bit angry as well.

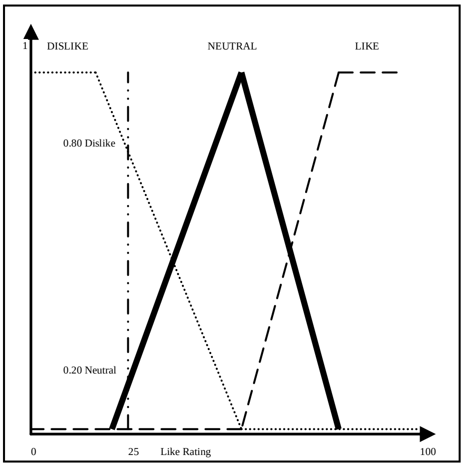
For these situations a more linguistic style of representation is needed and this is addressed by the use of Fuzzy Logic a term proposed by Zadeh (Zadeh 1965). This allows for a more complex set of actions i.e.

"IF player in sensory range AND gun has enough bullets THEN fire weapon ELSE look for ammunition"

which would mean that an agent might not fire the gun if they do not have enough bullets to kill the player, thus they might go instead to retrieve ammunition. This according to Waveren (Waveren 2001) allows developers to expand agent goal options by using linguistic rules to define behaviour in conjunction with tiered goal systems involving primary and sub goals to allow a breaking down of complex tasks. This tiered approach to tasks enhances the behaviour options of agents to offer them choices depending on the primary task set. A difficulty with giving agents sub tasks is that if the agent's option path is highly varied, then a situation may arise where conflicting goals will need to be carefully managed to avoid a gridlocked agent response.

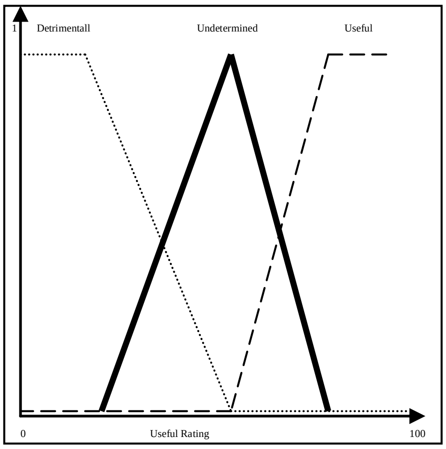
2.3.2.1 Fuzzy Logic and Emotional Appraisal

Referring back to the emotion detection process is Section 2.1.4.1 suggested by Le Doux, the three types of appraisal can be represented by fuzzy logic as shown in Figures 14, 15 and 16.



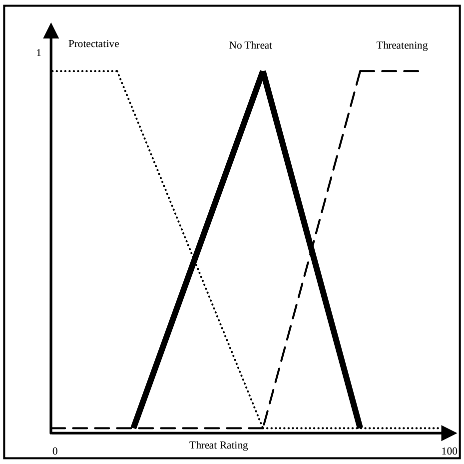
Where a High Like Rating = Liked Stimulus

Figure 14. Fuzzy Logic Emotional Appraisal for Liking.



Where a High Useful Rating = Useful Stimulus

Figure 15. Fuzzy Logic Emotional Appraisal for Useful.



Where a High Threat Rating = Threatening Stimulus

Figure 16. Fuzzy Logic Emotional Appraisal for Threat.

There are several areas that require explanation in order to understand how the graphs should be interpreted.

2.3.2.1.1 Activation Levels

The peaks activation of each condition can be altered as shown in Figure 17, to for example show different personality types as discussed in section 2.1.6. Therefore Figure 17 could be interpreted as a personality type that is easily pleased.

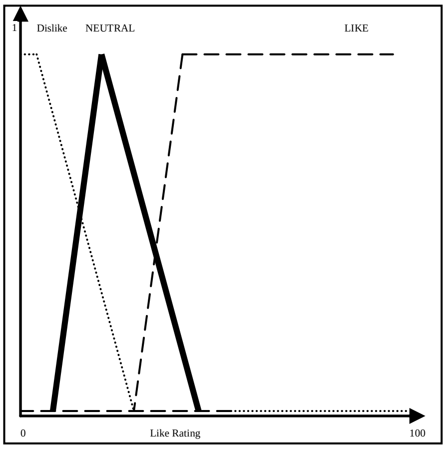


Figure 17. Negative Personality Type for Liking.

2.3.2.1.2 Mixed Feelings

It has been shown that at certain levels, *Like* and *Dislike* are clearly associated with specific stimulus, but what is certainly not clear is *Like* ratings between say 0.2 and 0.8 where there is a blend of "Dislike & Neutral" and "Like and Neutral". For this range, textual descriptions can be applied to describe the level of *Likeness* such that:

$$\textbf{Dislike}_{\textbf{(Agent X)}} = \textbf{F}_{\textbf{(Like)}}\ \textbf{25} = \textbf{0.80}$$

$$\textbf{Neutral}_{\textbf{(Agent X)}} = \textbf{F}_{\textbf{(Neutral)}}\ \textbf{25} = \textbf{0.20}$$

This could correspond to:

- I pretty much dislike Agent X when they are around, but I have some neutral feelings as they might be able to help me.

2.3.2.1.3. Combining Fuzzy Outputs

The three graphs shown for stimulus *Liking, Useful* and *Threat (Figures 14, 15, and 16)* can be used in conjunction with each other to provide an emotional appraisal as shown in the following example of a happy response. Previous work by Slater et al (Slater et al 2008) has shown a similar mapping to anger responses.

1) If Stimuli *Liked* AND Stimuli *Useful* for a Goal AND Stimuli poses *Low Threat* then happy response. (The actual description can be mapped to the emotions presented in section 2.1.)

Liking	**Useful (undecided not shown)**	**Threat**	**Response**
Like	Yes	Beneficial	
Like	Undecided	Beneficial	Happy
Like	No	Beneficial	
Like	Yes	Undetermined	
Like	Undecided	Undetermined	
Like	No	Undetermined	
Like	Yes	Threat	
Like	Undecided	Threat	
Like	No	Threat	
Neutral	Yes	Beneficial	
Neutral	Undecided	Beneficial	
Neutral	No	Beneficial	
Neutral	Yes	Undetermined	
Neutral	Undecided	Undetermined	Cautious maybe
Neutral	No	Undetermined	
Neutral	Yes	Threat	
Neutral	Undecided	Threat	
Neutral	No	Threat	
Dislike	Yes	Beneficial	
Dislike	Undecided	Beneficial	
Dislike	No	Beneficial	
Dislike	Yes	Undetermined	
Dislike	Undecided	Undetermined	
Dislike	No	Undetermined	
Dislike	Yes	Threat	Sad
Dislike	Undecided	Threat	
Dislike	No	Threat	

Table 5 – Partial Stimulus Appraisal Table (Not Ordered)

2.4 Character Believability and the Role of Emotions

2.4.1 What is Believability?

Bates (Bates 1994) proposes that the term believable when applied to characters in virtual environments, means characters with the "illusion of life". This illusion according to Bates, allows the user interacting with or viewing the character to have their belief suspended long enough to believe the character is real within the confines of the application. Ortony (Ortony 2003) extends this description by supporting the notion that believability also concerns the "plausibility" of the characters behaviour, including its consistent behaviour across similar situations. To this end, the following discussion involves a look at this believability (based on Bates and Ortony's definitions) with a focus on games and virtual worlds, and concludes with a look at the role of emotional characters in supporting believability.

2.4.2 A Look Back at the Evolution of Game Characters

During the early 1980s character believability was not incorporated into the arcade style games being developed. Instead developers concentrated on implementing only enough simple behaviour to enhance game play. This behaviour was often driven by simplistic algorithms many of which were implemented to allow simple path planning such as the ghost's movement in the *Pac Man* game or simple finite state machines (FSMs) for controlling agent actions. These were traditionally implemented in very small game environments such as single screen or tile based games and required almost no agent planning of goals but instead used scripted behaviour. Later games utilised more advanced A.I. techniques such as the A* algorithm (Higgins 2002) which was used for agents path planning simply because virtual worlds have become considerably more complex. These techniques were implemented with limited processing resources and without regard for creating agents that were believable through their appearance and behaviours. By the late 1990s games such as 'first person shooter' (FPS) style games were becoming more popular and as a consequence of consumer expectations in graphics and sound, the development became considerably more complex as these additional considerations meant that there was a need for game characters to both look, move and sound more realistic.

Although the allocation of developer resources in areas such as sound and graphics had increased, less development resources were generally attributed to agent A.I. This is potentially because in some genres of games such as FPS games, the agents only live for a short time and with tight budgets and approaching deadlines, additional development in A.I. was not justifiable due to the minimal return in game-play. These agents did not need to exhibit behaviour beyond running into the players' viewing area, but they did need to look as realistic as possible and therefore the visual appearance was a high priority. The relevance of this rationale began to diminish in other game genres such as simulation-style games like the *Sims 2* developed by Maxis and *Guild Wars* developed by ArenaNet that both involved the players' avatar interacting with non-player characters (NPC's) over extended periods. In these games improved A.I. was advantageous because it improved the single player experience; therefore greater resources were invested accordingly.

2.4.3 Visual Believability

Bates discusses in the context of visual appearances, that appropriately timed and clearly visible displays of emotions are a particular cornerstone of believable characters, and as such the rapid evolution of graphic processing technologies has helped to support this requirement. This technology improvement has resulted in higher polygon throughput and incorporation of new technologies such as vertex and pixel shaders, which allow developers to make skin, more human like in appearance.

With an evolving realism in the outward appearance of game characters there has been a growing amount of commercial development in game character physiology such as inverse kinematics (Scarowitz 2004) and "ragdoll" simulation (Leonard 2003). Inverse kinematics includes techniques to allow more realistic limb movements in characters. "Ragdoll" is a term for the growing area of physics application to agent physiology such as allowing agents to fall and move in a realistic human way.

Top selling titles such as *Half Life 2* combined both the advances in graphics, physiology and physics modelling to infuse characters with human like movements and appearances. This advance has provided the gamer with a new level of realism and a higher level of interaction expected with each new generation of game.

2.4.4 Believable Behaviour & Actions

With clear visual improvements of characters, there has also been an increase in allocation of development time for character A.I. such as path-planning. This area of A.I. allows characters to traverse virtual worlds using techniques such as A*(Higgins 2002) and waypoint navigation systems and have been implemented in increasing complexity for many years in some format from *Pac Man* to *Doom 3*. These navigational systems have been implemented with both cognitive modelling and goal-based reasoning, giving the agents the ability to navigate around a virtual world with a purpose, such as the goal of looking for food, as can be demonstrated with the use of the *Renderware AI* tool or the goal of collecting weapons to fight against a human opponent.

What is an interesting development is the number of A.I. researchers developing software solutions to try and beat the Turing test, a test intended to find software solutions that can pass as humans in textual chat conversations. Livingstone (Livingstone 2006) suggests that the A.I. being integrated into solutions intended to beat the Turing test are more related to the "demonstration of intelligence" rather than creating intelligent applications, as such the believability of these solutions is context dependant. Livingstone also suggests that if the user is "fooled" into thinking they are talking to a human being then believability has been achieved in that instance, although its presence is still subjective.

Recent A.I. research has focused in two developing areas, which can be used in conjunction with path planning techniques to create more believable characters. These are sensory input processing and increased agent autonomy through methods such as real-time agent planning (Orkin 2006).

2.4.4.1 Believable Sensory Systems

A growing area of interest in both academia and industry is in the field of agent sensory systems i.e. agents who can both "see" and "hear" items in their environments. This area of interest is causing a dilemma, due to the differing goals of industry and academia, for example industry chooses to implement only enough technology to provide an element of game play due to processing limitations a term coined "emulation and not simulation" by Leonard (Leonard 2003) is termed Academic research on the other hand tends to focus in-depth on areas of interest. Remembering that the vast majority of commercial A.I. implementations use "smoke and mirrors" techniques, there is a definite need to be able to scale down academic research findings so they are applicable within the processing and game play constraints of commercial projects.

Current implementations of agent sight and hearing provide compromises between tweaking virtual worlds so that in some games the scenery broadcasts to the agents as in the *Sims* games (Orkin 2002) and/or the sensory input is driven by either polled or interrupt driven perceptions in order to limit processing load (Kirby 2002). Therefore if an agent needs to eat, then the agent will actively seek out food using some form of planning, which blends navigation and either pre-scripted behaviour or real-time decision making. Whilst navigating, polled perceptions will provide information about the environments to the agent's sensory system on a continuous basis, if the agent is stationary and a player gets within its sensory range then an interrupt drive perception will feed the information to the agent, this gives a much less processor intensive form of implementation. This research has led to a greater scope in game play such as the ability to sneak behind enemies in games such as *Thief*, which added sophisticated auditory and visual senses to agents in the game (Leonard 2003). *Half Life 2* and *Thief* have agents that can "seemingly" see and hear human players as they wander around their virtual world. This has meant that for the first time agents can be made aware of human players based on similar constraints to those of real human hearing or sight, or at the very least the first steps in simulating these sensory systems. The usage of sensory systems in games such as *Far Cry* developed by Crytek Studios, have been used to allow not only elements of stealth, but the ability to distract agents by throwing rocks near them or sneaking past them whilst their backs are turned.

Emerging areas of interest are inter-agent communications as seen in the "walkie talkies" in *Far Cry* or cries for help from agents in *World of Warcraft* by Blizzard Entertainment allowing enemy characters to get support from their allies. Similar techniques have been used in *Call of Duty* developed by Infinity Ward, when bullets are fired near enemy agents this causes a change of behaviour that allows the agent to dive for cover allowing human controlled game characters to advance forward to capture areas or attack.

With the implementation of agent sensory systems has come a greater use of data storage for the sensory input for agents. These storage systems are linked to agent decision making through back-end management systems and have created a new area of research in fast data access and storage mechanisms such as the work by Reynolds (Reynolds 2000) on spatial data structures. These new systems and technologies are crucial to real time considerations in modern computer games.

Implementations of senses such as touch and smell though not presently adding much to the game play are beginning to appear as in the use of smell for agents in *Half Life 2* which allows agents in the game to "sense" a player through an artificial olfactory system.

2.4.4.2 Constraining Characters

As mentioned previously, decision making has focused on mainly goal based reasoning and path planning. This allows agents, such as those seen in *Unreal Tournament 2004* to work co-operatively or adversarial with or against the player. Agents are given goals, such as "kill gamer", supplemented with inter-agent communication frameworks that provides co-operative team play with other agents or the gamer.

Making more adversarial players is not the only way that A.I. has been improved. Games such as *Creatures* blend techniques such as neural networks, and aspects of biochemistry to create agents with unique behaviours that can interact and mutate into new agents with unique behaviours (Higgins 2002) (Stern 1999).

Many developers have serious concerns about agents that could try and move beyond the constraints of the game architecture if they exhibited unpredictable behaviour. Therefore developers rely on a more scripted-behaviour approach to avoid any kind of adverse emergent behaviour. Another concern of games developers is that there are serious concerns with A.I. adversely affecting game play due to both the processor time required and the speed of the response. This may be due to the software waiting for the next agent action or simply overly complex A.I. that interrupts the player's immersion. In some cases this has led to developer's reducing agent capabilities such as in *Ultima Online* (Stern 1999).

2.4.5 Characters with Emotions & Believability

Commercial implementations of interactive characters continue to provide a reasonable challenge to the user, but as discussed in Chapter 1 most virtual environments in games and Virtual Worlds still lack any implementation of emotions in their inhabitants and thus they can appear devoid of emotion and the characters not believable within the context of the application (Bates 1994). Some developer's have responded to this lack of emotions by scripting facial animations to appear on agents' faces at intervals, to give the gamer the illusion of agent emotion i.e. when a player is killed by an enemy the facial emotions might show a smile. Butcher (*Butcher et al 2002)* reveals that the game *Halo* features limited support for the emotions surprise, anger and awe[4] and upon activation of these "emotions" the enemy would flee in terror, go berserk and attack, or retreat into a defensive position, with each action complemented with a suitable facial animation. The developers of the *Virtual Petz* games (Stern et al 1998) implemented some simple "emotional behaviours" including aggression, playful and grumpy into their characters, in the form of scripted behaviours, which were integrated and evaluated purely from the observer's judgments of expected behaviour. The behaviour of these "petz" was not goal based, and merely allows the user to interpret the behaviour and actions of their "pet agents" from a casual observance point of view. The developers clearly discuss the agent interaction as being based predominantly on storytelling, drama and artistic elements rather than computer science or psychology models.

[4] though of course awe is not classified in the context of this work as an emotion

Games such as *World of Warcraft* demonstrate that some developers have begun to tackle the issue of integrating limited emotions into agents. This has mainly been achieved with facial animations that involve the display of rage and fear, supported with scripted behaviours such as running away when the agent has taken considerable damage. This incorporation of limited agent emotions does add to the believability of agents, but does not alter the agent's behaviour in anything other than a scripted and repetitive way.

Reflecting on Ortony's definition of the term believability, it could be said that the repetitive behaviour currently being seen in games featuring emotionally enhanced characters supports his view that believability involves consistent behaviour, but it could be argued that plausibility is affected if the range of emotions is limited and the triggers, actions and subsequent behaviours of these characters does not conform to the varied emotional responses expected by the user.

2.5 Chat Bots

2.5.1 Avatars

Virtual worlds such as *Second Life (SL)* by Linden Lab, usually allow users to create a character (usually referred to as an avatar) that they are able to navigate around a graphically rich 3D virtual environment interacting with other users' avatars or objects. It is common in these environments, as in the practice of many MMORPGs[5] such as the World of Warcraft (WoW) by Blizzard Entertainment, that users are free to customise the visual appearance of these avatars so that they can resemble almost any person, or in fact anything, within the constraints of the available options.

Whilst in these virtual worlds, users typically move their avatars around using a range of methods such as walking, flying or for quick access teleport mechanisms are common in both SL and WoW, which allow users to visit distant locations. When another avatar is encountered, users are free to interact in a variety of ways, such as through voice or textual chat to carry out a conversation as they would with any other real person, or often in the case of MMORPGs, to trade items, or to engage in combat. Upon encountering some objects, including non-player characters in games (NPCs), users are often able to interact with them depending on their in-world purpose, including providing useful information.

[5] Massively Multiplayer On-Line Role Playing Games

2.5.2 Enhancing Avatar Interaction

Text chat can often lack interaction as according to Ekman (Ekman 2009a); human beings also communicate with their eyes, and passively observe faces and postures as part of the communication process. To this effect, many of the aforementioned virtual worlds allow the user to make their avatar appear to be making gestures such as waving, and smiling, a sample of common gestures are shown in Table 6.

Gesture	Trigger in SL	Trigger in WoW
Bow	/bow	/bow
Clap	/clap	/clap
Muscle	/muscle	/flex
Point at You	/pointyou	/point
Stretch	/stretch	/yawn
Whistle	/whistle	/whistle
Dance	/dance1 to /dance8	/dance
Chuckle	/chuckle	/chuckle
Laugh	/laugh	/laugh
Shrug	/shrug	/shrug

Table 6 – A Range of Avatar Gestures.

These gestures, combined with the text and speech options mentioned, provide the user with a more complete communication interface to accompany their virtual presence. For users who may require a more expressive avatar, then SL features the ability to add or customise gestures as shown in Figure 19.

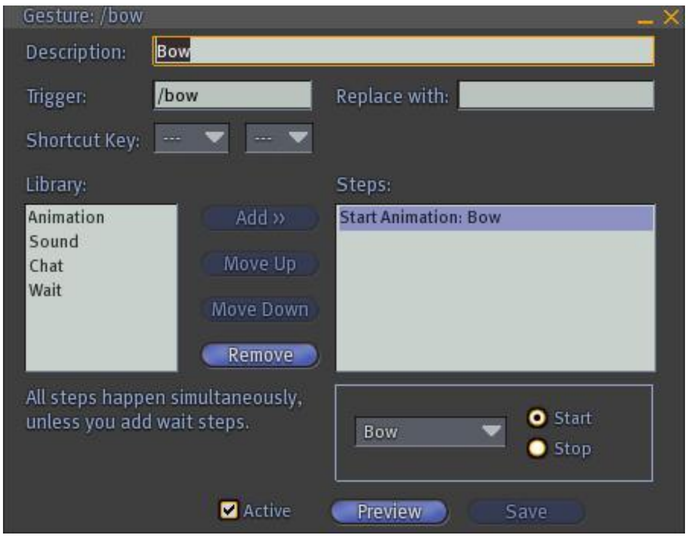


Figure 19. Custom Gesture Creation.

Through this SL interface, users can combine:

- An animation – What their avatar does when prompted, these can be modelled in packages such as *Poser* by Smith Micro Software.
- Sound – A suitable sound that will come from their avatar during the gesture.
- Chat – Text can be displayed when the gesture is activated.
- Wait – Allows different delays to occur between animations, chat or sounds.

Once a new gesture has been created, it can be added to the avatar, and be subsequently activated by pressing a pre-defined key or by typing a shortcut into the text input bar preceded by a forward slash.

2.5.3 Avatars in e-Commerce

One of the uses of virtual worlds such as Second Life has been as a marketing tool for a range of industries leading to its acceptance as a solution for e-commerce as discussed by Freedman (Freedman 2007). This usage allows companies to sell products and advertise services within these virtual spaces, including the linking of in-world resources to real life external sites. This e-commerce involving real world products marketed through virtual worlds, has also been accompanied with a growth in the selling of virtual products for use in-world. In the case of SL, businesses have developed that provide customisation of others users' interactive experiences, which are sold within Second Life, and paid in Linden dollars that can be subsequently converted into real world currencies. These customisations include amongst other things visual enhancements for avatars, like hair and clothes.

To support e-commerce, some companies such as Daden (www.daden.co.uk) have employed staff to control avatars situated at their virtual company location. These staff controlled avatars are able to answer questions when approached by visitors, allowing prospective customers to enquire in much more detail about issues they may have or to gain a better understanding of the services/goods available. The main limitation with these staff controlled avatars is that the virtual worlds are accessible worldwide, unfortunately staff can only be available during employed hours, and as such help is only available for a small portion of the day. To address this issue computer controlled avatars have been developed as discussed next.

2.5.4 An Introduction to Chat Bots

An increasingly growing area of interest in virtual worlds according to Burden et al (Burden et al 2008) is the ability to create an in-world avatar, and control it externally with some type of automated intelligent software often referred to as bots (short for robots), or "chat bots" if they are primarily used to converse either through text or speech. These software solutions can have many forms, but in essence can provide a level of autonomy to the bot so that it can conceivably pass as a human controlled avatar. The advantages of such a facility are numerous including being able to have a 24hr/365 days a year presence that can answer questions and of course does not need paying, an example is shown in Figure 20.

Figure 20. Halo a Daden Chat Bot[6].

2.5.4.1 Interfacing to Avatars to Create Chat Bots

The fact that many virtual worlds such as SL do not natively support chat bots, means that there is a reliance on third party developers to develop their own back end technologies to control the avatars behaviour including movement and chat, and subsequently interface it to *the virtual world application* via a suitable interface such as libsecondlife (www.libsecondlife.org) that remotely connects to Second Life. One example of back end technology is called Altair and was developed by Daden (Burden 2008) as shown in Figure 21.

[6] Image courtesy Daden Ltd .

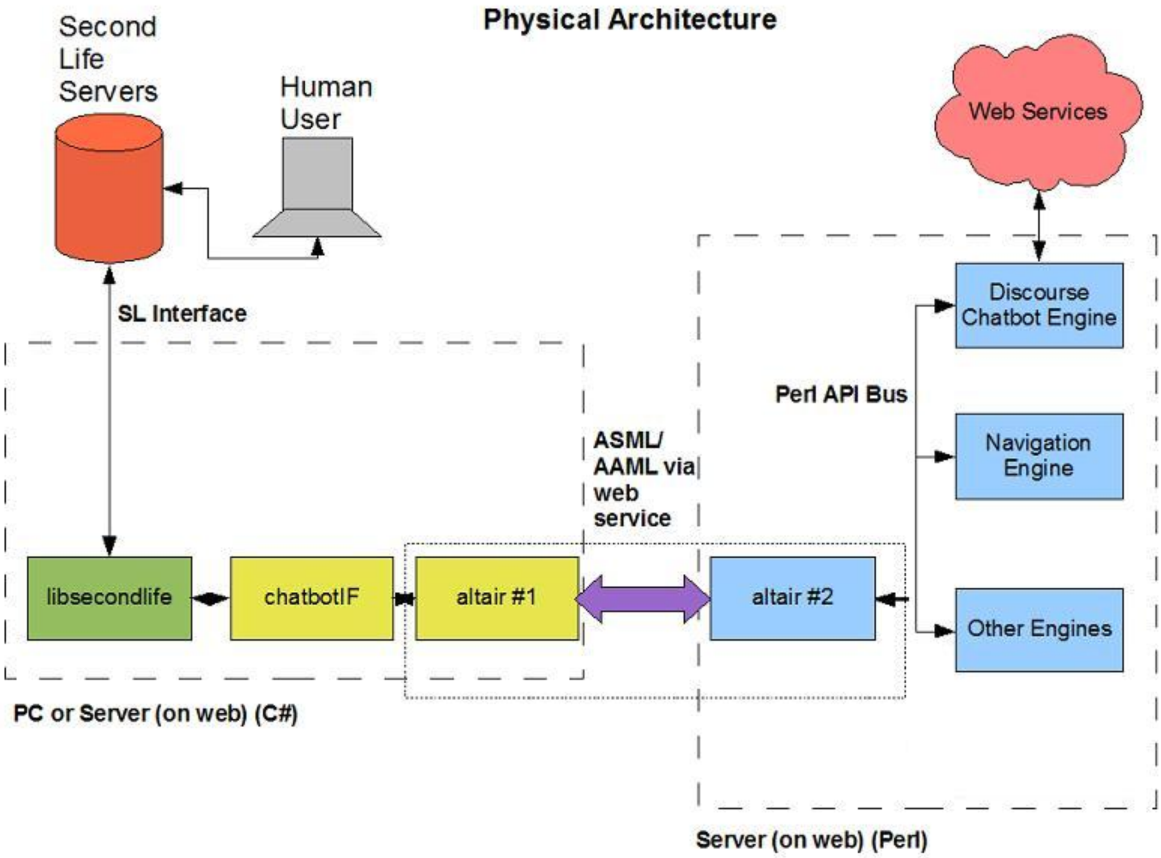


Figure 21. The Altair Chat Bot Architecture[7]

2.5.4.2 Limitations of Chat Bots

Limitations include, the need for a consistent connection to the avatar from the remote PC, the fact the bot can only deal with known questions that have been pre-programmed, and the risk that some users may be offended if they engage in conversation with a bot thinking it is a real human user. This lack of recognition of a chat bot, rather than human controlled avatar, usually occurs after a short conversation featuring the same repeated pre-programmed responses, or questioning outside of the chat bots range of questions. Understandably e-commerce isn't about recreating a perfect mimic of a human being, but instead is focused on meeting the user's needs and as such the limited facilities in many chat bots makes them fit for commercial purposes as discussed next.

2.5.5 Commercial Chat Bots

The commercial use of chat bots can typically be found on sites such as Scottish Power (www.scottishpower.co.uk). In the example shown, users can ask a range of questions from a range of categories, and if a sentence match is found, a pre-programmed response is displayed. If the chat parser does not understand the sentence i.e. it is not in the database, then a typical

[7] Image provided by Daden Ltd (www.daden.co.uk)

apology like *"Sorry, I didn't understand your question"* is usually displayed. This response will be continually repeated and could easily lead to the user becoming frustrated or irritated (Slater et al 2008a). Understandably if the user feels frustrated they may simply navigate away from the site and as such commerce is affected through user dissatisfaction.

2.5.5.1 Chat Bot Similarities

Figure 23 shows examples of chat bots used for e-commerce across a range of companies featuring similar layouts and functionality.

2.5.5.2 Common Traits

In these and many other examples, commonalities include:

- Typically chat bots have images of people, typically female and a name.
- Images are usually waist up photo image (most common), or some are cartoon style images.
- Few chat bot images are animated, some chat bots have changeable images depending if the question is answered.
- Users typically ask questions in plain English by typing their question into a text box.
- Some chat bots have prompts to further guide users.
- Some chat bots ask the user their name and then address the user accordingly.
- If spelling errors are made in sentences most chat bots cannot understand the question.

2.5.5.4 Expressive Chat bots

It is extremely uncommon to find chat bots that are animated or seem to respond visually to the user. What is common is for the actual image to change dependant on the outcome of the question.

2.5.6 NPCs

Currently many games such as the World of Warcraft feature instances when gamers need to approach characters in the game that give them information or tasks to do. These characters are called non-player characters (NPCs) and usually used as a user information retrieval system. In the World of Warcraft they form an integral part of the game, the user experience and as a way of telling a story within the game. Many of these characters cannot be killed, but are themselves part of the story, giving tasks to the user to enable them to progress further into the game.

With games-type technologies now being used for non-gaming purposes, such as the virtual world of Second Life developed by Linden Lab, there is a noticeable similarity between non-user controlled characters in these worlds (the already mentioned chat bots) and the aforementioned in-game NPCs. This similarity means that in principle the infrastructures and back-end systems of both NPCs in games and non-controlled avatars[8] could essentially be the same, and developments such as emotion architectures could apply equally to both types of characters.

2.5.7 Final Words on Chat Bots

Chat bots are becoming a popular option for companies looking for more interactive mediums for a question and answer facility located on their web sites. The down side of these chat bots is really down to their automated, pre-programmed responses, compounded with a difficulty understanding questions not stored in their back-end database. This lack of being able to answer questions in a rather blunt, and non-emotional way might well have an effect on the end-user, and it is certainly a recommendation that further work or investigation should occur on the expectation by the user of such systems.

2.6 Conclusions

This chapter began by presenting a range of theories and research into the psychology of emotions. This review drew together what is formally known about the psychology of emotions, and highlighted and resolved, within the scope of the project some conflicting ideas and theories. The review also clarified terminology to remove confusion on word usage when referring to emotions, including the specifying of a glossary of terms as shown in Appendix 2. With the review completed, a solid foundation of theory is considered available for any subsequent work. Following the section on the psychology of emotions, was a review of computer models of emotions, highlighting previous research including three prominent models each one differing in its capabilities and features. When compared to the underlying basis of formal emotion psychology previously conducted, it was considered that the models discussed were not actually based on very much formal psychology, at best some projects adopted the OCC model of emotions (Ortony et al 1988), which represents only one aspect of emotions. The outcome of this section revealed that at present there is not an architecture that could be both easily scaled and easily understood by a typical developer without a background in psychology to understand which aspects of each proposal are firmly based in formal theory.

Though there was a general concern on terminology usage and basis in formal psychology, the use of “like” and “dislike” as part of the OCC implementations would seem to support aspects of emotion appraisal as discussed in section one and would be seemingly beneficial in future architectures. Following the computational models review, an investigation was conducted into how aspects of emotions discussed in section one, could be represented using Finite State Machines (FSMs) and Fuzzy Logic. This review included examples of emotional aspects suited for both techniques in order to help build upon the foundation proposed in the first section.

The review continued with a discussion on the current state of emotions in characters in games and virtual worlds, with an emphasis being placed on the role of believability in these applications and the role of emotions in believability. Though it is not the intention of this work to prove emotions add believability to characters as discussed in the introduction, there were some interesting points raised. These points included the theory by Livingstone (Livingstone 2006) of believability in the context of the application, i.e. only enough modelling to give the illusion required. This approach would certainly be better supported with a more modular architecture which might appeal to a range of developers with different requirement levels of emotional responsiveness in their characters.

The review was rounded off with a discussion on chat bots and non-player characters (NPCs) to add context to the work as a whole.

Chapter 3: Research Method

This chapter begins with an overview of the approach being taken for the development of an emotion architecture suitable for answering the research question. This is followed by a discussion of the methodology being followed to validate aspects of the architecture through developer focused implementations. Finally a validation approach is proposed, that is based on an investigation and synthesis of suitable evaluation techniques.

3.1 An Approach to Developing an Emotion Architecture

With a literature review completed in Chapter 2, it would seem that there is some background research available to begin developing an emotion architecture (called E-AI) applicable to characters in virtual environments. This proposed architecture should be based first and foremost on the underpinning psychology background shown in section one of the literature review in order to keep the work in the context of the research question. This background provides enough formal theory to allow both a hierarchical and descriptive view of emotions to be specified, that is suitable for in-world characters. The next stage is to supplement this specification with relevant aspects that emerged from the computational models of emotions in section two of the literature review. Next, techniques suggested in section three which discussed suitable A.I. techniques for modelling aspects of emotions, need to be integrated to formalise an architecture suitable for meeting the research objectives. Finally it was suggested in Section four of the literature review, that only enough implementation in applications is needed to support believability. With this view in mind, wherever possible, a modular approach will be followed to allow as much or as little of the architecture to be integrated into characters, to meet the needs of the application. This proposed architecture is shown in Chapter 4.

3.2 Proposed Implementations of the Architecture

With a modular architecture specified, the next step involves implementing aspects of the architecture in software solutions in order to begin validating the architecture. While deciding on possible implementation options, three commercial projects became available and as such a developer based implementation was chosen (as shown in chapter 5). These projects were:

1) The integrating of emotions into bots (computer controlled characters in Quake 3) in the *Quake 3* game engine to see how it affected their combat performance. This was

supported by a case study to begin looking at how the user experience is affected by the inclusion of emotions into combat bots.

2) The addition of emotions to chat bots (computer controlled characters in Second Life) in Linden Labs' Second Life to enhance their human like appeal. This was supported by a case study where users were able to interact with both a standard chat bot and emotional chat bot and report on which chat bot they preferred.
3) The addition of emotional characteristics into a web character used for e-commerce.

3.3 Development of an Evaluation Methodology

Whether the pursuit in applications is characters with human like emotions (response & behaviour including visuals), or alternatively characters who can only exhibit the visual appearance of emotions, both routes need some method of evaluating the effectiveness of the implementations in order to validate the implementation. Furthermore, if a requirement of adding emotions to characters is to add to their believability and realism, then some evaluation of the believability within the context of the application needs to be conducted. To meet this latter requirement, Gratch and Marsella (Gratch et al 2004a) evaluated their success based on the believability of the agents they created using human observers to comment on the characters behaviours against a set of criteria to ensure that the behaviour and expressions they observed, reflected what a real human might do in similar circumstances.

With a need to provide evaluation techniques for emotionally enhanced agent implementations, with potentially different outcomes an investigation was conducted into:

- Currently used evaluation techniques for emotionally enhanced characters (see section 3.3.1).
- How software agents are evaluated against usability and HCI criteria (see section 3.3.2).

This investigative research was intended to provide information that could be used to guide the development of an evaluation methodology for agents with emotions. This could then be used with the proposed architecture to provide some degree of confidence to developers that agents developed, were fit for purpose.

3.3.1 Evaluation Techniques Used for Emotionally Enhanced Characters

As previously mentioned, Gratch and Marsella (Gratch et al 2004a) evaluated their Mission Rehearsal Evaluation project (MRE) by comparing the behaviour of agents within MRE, against what is known about real human behaviour in similar circumstances. By having reference data produced by Gratch et al (Gratch et al 2001), they were able to compare the performance of the agents against the expected behaviour (baseline data), rather than having to involve a range of participants to comment subjectively on what emotions they were actually witnessing within the virtual world. The actual data was derived from the Stress and Coping Process Questionnaire (SCPQ) which is used to measure a subject's response to coping against a baseline of what is expected of "normal" human behaviour. Gratch et al (Gratch et al 2004a) highlight potential flaws in the agents that may have been missed from observations without their baseline of data. Furthermore, Gratch et al conclude that there is a need for more evaluation of their work in order to enable others to make an informed decision on the effectiveness of the emotion implementation in the system. This evaluation would therefore need to involve more end-user interaction.

Alternatively Reilly used the Em System (Reilly 1996) to develop seven agents who were programmed with a level of emotions and autonomous behaviour. These agents were then presented to seventeen users for around twenty minutes, who observed the agents within the same simulation, with and without the emotional aspect activated. The order of interaction with the agents was changed to avoid repetitious behaviour, and after the experiment was finished, each participant completed a questionnaire, part of which asked them about what emotions they may have observed. The participants were not scientifically screened or selected for their knowledge of emotion observation skills. Users were asked to rate agents on a scale from 1 (unemotional) to 7 (emotional), after which a statistical t-test (a method used to assess statistical significance of data) was used to analyse the data. This data was gathered via questions related to believability including:

- Did the behaviours basically work?
- Did the characters have distinctive personalities, even when they were engaging in social behaviours?
- How often did the characters break the users' suspension of disbelief?
- Were the characters good characters?

In research by Selvarajah et al (Selvarajah et al 2005), the use of questionnaires has been used to evaluate the interaction of a player controlled avatar in a virtual world, where for much of the time the player's avatar is ignored, commonly called the "cocktail effect". This type of simulated social situation is useful for evaluating an individual's emotional response to social disclusion, and typical questions included:

- Do you think this room contained guests controlled by actual humans?

In this research two simulations were developed, the first used scripted agents (i.e. they could simply show seven facial expressions only, without concern for the emotions of others around them), the second simulation featured agents with more autonomous behaviour. The two simulations featuring the agents were given to a group of participants to evaluate on believability. In the simulation only the six emotions proposed by Ekman (Ekman et al 1975) were included in the game agents expressions and behaviour. These six emotions were anger, surprise, fear, disgust, happiness and sadness and additionally neutral was added for no emotion.

The experimental details included a group of forty nine participants, whose responses were gathered via a series of questionnaires. Question areas included:

- Identify agent facial expressions - the purpose of which was to evaluate whether the participant can differentiate between the facial expressions suggested by Ekman.
- Complete questionnaires on believability in both simulations, to provide comparative data for the investigators.

According to Selvarajah et al (Selvarajah et al 2005), the experimental approach used during the research was intended to discover the answer to "whether the addition of AI agents displaying emotions increases the realism of the agents, which in turn increases the realism of the virtual environment?", and according to the conclusions, the results did support the hypothesis based on the fact that the participants could in general identify the different facial emotions and that the results also showed that the agent based simulation was better than the scripted approach for believability and interaction.

A similar approach was used by Bates (Bates 1992b) with the emotionally developed agent Lyotard, where the validity of the emotion model was evaluated by observers commenting on the agents' observable behaviour.

3.3.2 Evaluating Agents from a Usability Perspective

Assuming agents in games applications can be categorized as software, and furthermore a type of software interface, then applying formal usability evaluation techniques to them, would seemingly be central in order to ensure they meet end-user requirements. This usability evaluation could conceivably be used to ensure that emotionally endowed agents are a benefit to users, adding depth, realism and an increased level of interaction, rather than irrelevant and obstructive to the experience and thus affecting user satisfaction.

According to Torres (Torres 2002), there is wide support for the notion that one of the biggest factors contributing towards user satisfaction, concerns the user interface. Assuming that the interface is the medium in which a user interacts with a piece of software, then if developers expect users to interact with emotionally endowed agents, then these same agents need to be evaluated as software interfaces, including traditional techniques and metrics that provide feedback from end-users in the areas of:

1) Features
    a. Including are there enough?
    b. Are there too many?
    c. Are they what the user expects?
2) User Interaction
    a. Is it intuitive to interact with agents?
    b. If not users can become dissatisfied, therefore how responsive is the interface as slow tedious software affects usability.
3) Reliability
    a. Overall quality of interface
    b. Does it crash, does it lock up?
4) User Assistance
    - Is there some method included to help the user when they are confused or get stuck?

Torres proposes that these four aspects are fundamental for evaluating user satisfaction with software solutions and could be evaluated using:

- Conventional usability tests – Participants are selected based on their similarity to typical end-users. These participants are presented with typical usage scenarios, after which they complete questionnaires to ascertain if they actually like the interface.
- Comparative usability tests – Users are given variations of the interface and then choose the interface they prefer. This approach removes a potential pitfall of developers delivering an interface that they envisage, but not necessarily suitable for end-users, referred to by Torres as “ego-driven design”.

The evaluation is typically broken into three stages a screening questionnaire, modular evaluation of the system under test, and finally an overall evaluation of the users' experience of using the system. A small number of users can be used to highlight some usability issues, but Torres recommends ten to twelve subjects to provide better statistical analysis.

3.3.2.1 Screening Questionnaire

Users should be typically screened prior to participation in the main usability assessment. This process can highlight the relevance of their core skills, some of which may have a bearing on the outcomes of the evaluation, and their similarity to typical end-users. This style of questionnaire typically should take no more than ten minutes and should include:

- Their previous usage of similar software.
- Their background in using the type of software.
- Anything else relevant.

3.3.2.2 Modular Evaluation

The modular evaluation is intended to evaluate aspects of the system by asking the users around five to seven questions on the aspect under investigation to gauge their feedback. These questions should be easy to follow, specific, unambiguous, and normally not to exceed one page per aspect. These questions should focus on the five areas of usability identified earlier and be collated together once the usability study is completed to look for trends that could confirm assumptions, or even may highlight unexpected problems.

3.3.2.3 Final Evaluation

Once specific aspects of the system have been evaluated, the user will normally be expected to complete a final questionnaire. This final evaluation is intended to focus the user on what they thought of the system as a whole and their satisfaction with it. This is typically no more than two pages and is intended to sit alongside the modular evaluation to provide a better understanding of the users' experience of using the interface.

3.3.3 HCI Considerations

There are several well known HCI heuristics such as Nielsen's Heuristic (Heim 2008) which provide clear pointers on what aspects systems developers should focus on when trying to assess end-user HCI including:

- *Is the system status clear and obvious to user?* – I.e. does the software keep the user informed of what is going on?
- *Is there a match between the system under evaluation and real world systems?* – I.e. does the system allow the user to interact with it in a way they would normally expect?
- *Does the user have some degree of control and freedom?* – Does the system let the user know when something is wrong? Can the user correct problems themselves?
- Is the interface consistent and following an expected layout? – Does the system follow conventions expected by the users?
- *Has the system been thoroughly tested by the developer to reduce errors?* – Are there errors in the system? How does this affect the users' experience?
- *Does the system rely on recognition not recall?* – Does the system behave in an intuitive way? Or does the system require the user to remember complicated steps to achieve tasks?
- *Does the interface offer any flexibility on interaction for the user?* – Are there shortcuts that users can learn or use to speed up common tasks?
- *Is the interface aesthetic and minimal*? – Does the system have irrelevant data that detracts from the system?
- *Does the interface help users to recognize and recover from errors?* – If users make errors does the system allow them to go back and correct their error?
- *Is there help and documentation provided?* – Is there some method of users learning how to use the system before usage?

3.4 Bringing Evaluation Techniques Together

The research presented up to now, highlights a range of techniques in several disciplines that could be used to evaluate different aspects of software agents. These techniques can be summarised as:

- Evaluation of software agents featuring aspects of emotion (Table7).
- Evaluation of playability with improved software agents (Table 8).
- Usability of software interfaces (Table 9).

Who is Assessing?	Assessing What?	What is the Goal?	How Do They Do It?
Researcher trying to create emotionally responsive agents.	Whether the emotions added to the agent, function the way they intended.	Creating agents with human like emotions and evaluating the agents on their emotional behaviour and/ or appearance.	Human participants (may or may not be trained) commenting on the emotions they see from the agents. This may take the form of a Table detailing expected human behaviour given certain circumstances as used by Gratch et al (Gratch et al 2004)
Developers and researchers creating agents with an emphasis on believability.	Whether software and modelling additions to agents, make them more believable.	Assessing how agents can be made more believable.	Human participants commenting subjectively on whether the agents are believable.

Table 7 – Methods Used to Evaluate Agents Incorporating Emotional Aspects.

Who is Assessing?	Assessing What?	What is the Goal?	How Do They Do It?
Games Developer	Whether additions (features added) to agents improve interaction for the end-user.	Deciding if the software features added to agents, add to game play for the end-user.	Utilise games testers and beta testers.
Games Tester	If the agent breaks the game.	Playing the game repetitively, to try and identify flaws in interaction.	Ensuring that agents' behaviour doesn't break games.
Beta Tester (Play Tester) These testers typically represent end-users.	If the game is fun and playable. Can identify bugs that have been overlooked during in-house testing.	To ensure that the game developed, and features it contains, will be received well by end-users prior to release.	Feedback on the agents in respect of playability and interest from a typical end-user point of view.

Table 8 – Evaluation Methods Used by Commercial Game Testers

Who is Assessing?	Assessing What?	What is the Goal?	How Do They Do It?
Software Developer	Usability of software interface.	Deciding if the interface meets end-user requirements.	Compare the final interface to the initial specification to ensure that the interface meets the end-user's initial requirements. Ensuring interface meets HCI guidelines.

Usability/HCI specialist utilizing end-user interaction	The usability of the interface from an end-user point of view.	To ensure the interface suits the typical end-user.	Typical end-users interact with the interface and comment on it, via questionnaires. They may also be observed using it.

Table 9 – Methods Used to Assess the Usability of Software Interfaces

3.4.1 A Three Way Evaluation of Agents with Emotion

It is proposed that these categories could be combined as shown in Figure 25 to formally evaluate several aspects of agents with emotions (or without fundamentally) to ensure that they are not only suitable for the application, but received well by end-users, immersive in use and actually exhibit the level of human-like features (emotions) the developer intended. This combination also includes the ability of agents to self report based on their current emotional states.

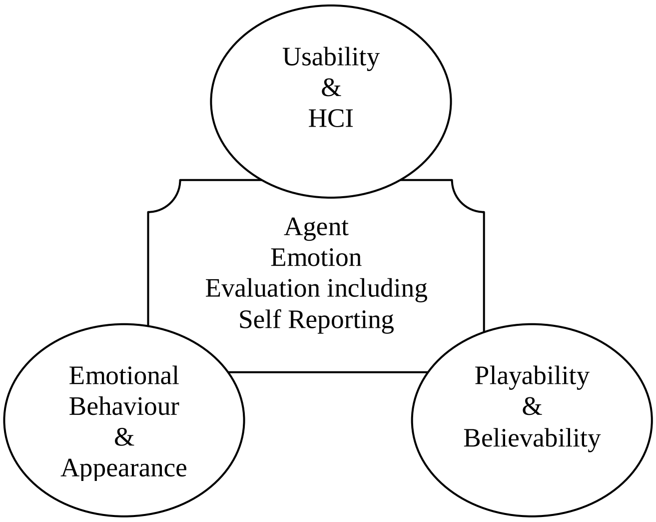


Figure 25. Three-way Approach to Evaluating Agent Emotion.

The proposed three-way evaluation relies on the notion that extensive system testing has occurred before the end-user evaluates the system. This prevents the users' experience being affected by bugs and crashes that should have been removed (or at least minimized) by the developer. This approach allows the end-user to report on their subjective experience of the interface rather than being annoyed or fixated on the stability of the system.

Managing the users' expectations is important, and thus it should be clear to developers and users alike, whether the user is expecting:

- An agent with emotions, interacting within its virtual world.
- An agent that appears to behave as though it is being controlled by a human player and thus reflecting real human emotions independent of the virtual world.

3.4.1.1 Usability and HCI – Agents as Software Interfaces

There is a clear need to ensure that the designs for emotionally enhanced agents are both well implemented and not over laden with features that might adversely affect a user's experience. To fulfil this requirement, an evaluation is required that can encompass HCI and usability evaluation techniques, to ensure these enhanced agents meet the needs of the target application and subsequent user expectations. This evaluation will minimize ego driven design, and instead focus efforts on producing a suitable end-user experience. Developers should ensure that the agent's emotion capabilities fit the target application to avoid over engineering. Evaluation should allow for scenarios with and without the agent emotions activated and possibly evaluations of the agents, in and out of the target application. This dual testing allows a more objective assessment of the contribution the emotional enhancement makes to the overall usability of the application. Evaluation should focus on:

1. **Features**
    - Do the emotional enhancements function as the user expects them to?
    - Do the various agent emotional enhancements get in the way of a user interacting with the software?
    - Do the emotional enhancements add to the overall experience for the user?
2. **User Interaction**
    - Are the agents behaving as the user expects?
    - Are the visual signs of agent emotion as the user expects?
    - Is it easy to see what effect the emotions have on the agent?
    - Is there consequently a user emotional response to the agents' display of emotions, i.e. a level of empathy or noticeable user emotional interaction? Maybe a system like Desmett's PrEmo (Desmett 2003) could be used to evaluate whether the user is experiencing an emotional response from the agent, or to identify what emotion they think the agent is experiencing. Alternatively questionnaires could be used as in the work by Plutchik (Plutchik 1980).

3. **Response Time/Performance**
    - Commercial game developers limit the amount of CPU and memory allocated to AI within a game, to around 10%. This limitation means that any additions to AI such as emotions, ideally need to fall within this constraint and should not adversely affect the time it takes for the agents' decision making process (response time) to complete.
4. **Reliability**
    - Is the agent consistent in its emotional behaviour?
    - Does the agent consistently behave as the user expects?
    - Is the agent implementation buggy, making errors, or the application crashing?
5. **User Assistance**
    - Can the user ascertain what emotion an agent is experiencing, and understand how they are expected to interact with it?

3.4.1.2 Playability and Believability – Agents as Interesting and Immersive Elements

It is not surprising that commercial game developers favour playability over believability within the games they produce. Terms such as "smoke and mirrors" are used to identify aspect of games that have been implemented to reduce development and processing time, but give the illusion to the user of more sophisticated features, such as using 2D images to represent 3D objects as in the practice of bill boarding. Playability is also highlighted with the common practice of job adverts favouring programmers, testers and designers who play games, so that the software is developed by typical end-users.

Commercial games testing using typical end-users to evaluate games prior to release to not only find bugs in the game, but to comment on the playability and fun aspect of the game is an approach that is not so distant from the view by Ritter (Ritter 2004), that "testing and validation has to be done with the purpose of the model in mind".

A question that must be investigated if developers intend to incorporate emotions into their in-game agents is:

- Does the emotion in the agents make the game more playable/enjoyable for the end-user?

This question will be difficult to not only ask because of the danger of getting a biased answer, but how will playability and fun be ultimately assessed?

As already mentioned, believability is also a difficult issue to resolve as games and most simulations are in virtual worlds that are fantasy environments after all. Therefore the question to ask is whether the emotional agent in the game or simulation is believable within the world the user is viewing (Livingstone 2006).

3.4.1.3 Emotional Behaviour and Appearance – Agents that Appear Human

When the desired level of agent emotion has been identified and subsequently implemented, then a scientific approach to evaluating the implementation can be undertaken. This evaluation should involve an in-depth evaluation of each emotional aspect, and how they interact to produce more complex behaviours. This evaluation will require the formulation of specific questions that evaluate each component part, how it operates, and the expected outcome. It is suggested that this conforms to the typical formulation of a hypothesis and the usage of independent and dependant variables to ensure that variations in users and situations can be later analysed as part of the final results. This data can be subsequently cross checked against the agent self reporting to evaluate whether or not an observer has correctly identified the specific response of the agent.

Further work in this area suggests the need for reference data that could be used to provide expected outcomes from emotional behaviour and interactions, some work has already been conducted in this area by Gratch et al (Gratch et al 2004a). This data could provide a baseline of data for future experimentation and development in emotionally endowed agents.

3.4.1.4 Agent Self Reporting – Agents That Can Interact and Respond

According to Knapp (Knapp 1963), emotions have three aspects, physiological, i.e. observable body changes that happen unconsciously to the individual, expression, i.e. facial changes that appear and can be read in social context and private experience, what the individual feels as a consequence of the emotion. Therefore we can only observe what we can see and the private reflection can only be ascertained from a subjective response by the individual. Couple this with evidence to show that observable agent states beyond the basic six emotions of anger, sadness, surprise, fear, disgust and happiness have been shown to be difficult to ascertain as well, then ideally agent self reporting needs to be integrated into software solutions. This self reporting should rely on in-game that is subsequently mapped to what is known of typical emotional states and responses such as emotions and moods.

The self reporting data can then be statistically analyzed in conjunction with a human observer to evaluate the agents' emotional states using traditional psychology techniques as has been demonstrated by Schachter (Schachter et al 1962) and remove the need for trained observers to evaluate the agents' emotional behaviour.

3.4.1.5 Use of Questionnaires

Typically it is common to see evaluations of software being conducted via user interaction and subsequent questionnaires. Much work has been conducted in the area of questionnaire design, but typically numeric scales similar to the Likert Scale shown below are common (Likert 1932).

Unfamiliar			Limited Use			Frequent use
1	2	3	4	5	6	7

Very Dissatisfied			Neutral			Satisfied
1	2	3	4	5	6	7

Nielsen (Nielsen 2004) suggests that to reduce the problems with users reporting what the interface was like to use earlier, to instead rely on smaller question sets throughout usage, so users rely less on recollection.

3.5 Conclusions

It is intended that the evaluation methodology discussed will be used where appropriate by developers to assess the suitability of characters based on the proposed architecture. Aspects of the evaluation methodology will be applied to the case studies discussed in Chapter 5.

Chapter 4: The Development of the Emotion Architecture

4.1 Introduction

The following chapter is the culmination of the research presented so far, and involves the development of the proposed E-AI architecture. This is mainly based on the foundation of psychology research presented in Section 2.1. Which is further built upon by the inclusion of aspects of the computational models of emotions presented in Section 2.2 and suggested software development techniques where applicable.

4.2 The Flow of an Agent Emotion Architecture

Figure 26 shows the proposed architecture structure that is based on Scherer's 6 stage emotional appraisal model as discussed in Section 2.1. This structure offers a modular approach to help both understand the architecture, and to also enable it to be more easily implemented.

The remainder of this chapter will present details to fill in each of the modules proposed, and how they should link together for the purposes of this work.

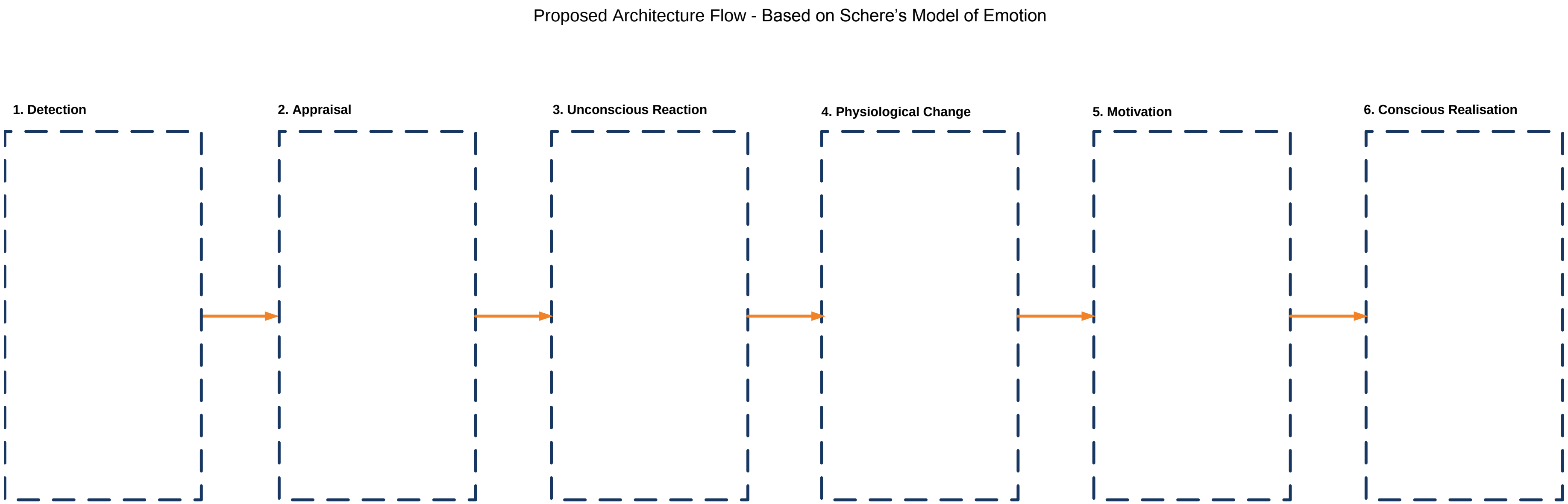


Figure 26. Proposed Architecture Overview

4.3 Detection of Stimulus

It iscommon in some genres of games that characters can detect the following:

1. Static/moving objects (such as weapons and ammo)
2. Other characters (usually enemies)
3. Players' avatar (player character)
4. Changes to the environment (such as changes to lighting)

These detected categories (or as we will refer to them as *stimulus types*) do correspond exactly to the three categories of stimulus identified through the OCC Model of emotions as shown in Section 2.1.5.1, which were objects, agents (includes any other encountered entity) and events.

4.3.1 Stimulus Type & Unique Identifiers

Because there are fundamentally only four stimulus types, then these can be assigned a notional numeric label that can be used when encoding information later, as shown in Table 10.

Stimulus Type	Reference Value
Object	0
Agent	1
Player Avatar	2
Environmental Change	3

Table 10 – Stimulus Type

Most applications will also feature multiple instances of the types listed in Table 10 i.e. multiple objects including ammo, weapons, plants and food. These will usually need to be tracked individually and as such each item type will usually be given a unique identifier for its type, which is being called *Stimulus ID*.

4.3.2 Detectable Emotions

Detected stimulus may or may not broadcast a stimulus depending if the main behaviour system currently employed uses a broadcast style system (as discussed in Section 2.4.4.1) or if agents have fuller sensory systems (also discussed in Section 2.4.4.1). Either way the stimulus should be attributed an emotion. Referring back to Section 2.1.3 it was discussed that there are five category one emotions (anger, disgust, fear, happiness and sadness) and a transitional state called surprise, and these are shown in Table 11 supplemented with a no emotion state.

Emotion Visible	Value
No Emotion	0
Angry	1
Disgusted	2
Fear	3
Happy	4
Sad	5
Surprise	6

Table 11 – Detectable Emotions

Note: For the presentation of this architecture it is suggested that only the basic emotions will be specified (as shown above), though it has already been discussed in Section 2.1.3.1 that secondary and tertiary emotions will emerge as a consequence of blends of the basic emotions.

4.3.3 Detectable Sounds

Stimulus could broadcast a sound or in the case of agents or avatars, can talk via speech or text. These could include:

- Speech (audible and text).
- Non-Speech sounds such as grunts.
- No Sound.

4.3.4 Agent Detection Module Overview

Drawing together the elements of the module so far, has suggested the following:

1 Stimulus Type

2 Unique identifier for the Stimulus Type i.e. Stimulus ID

3 A related emotion, or no emotion

4 A sound or no sound

These are shown in diagrammatic form in Figure 27.

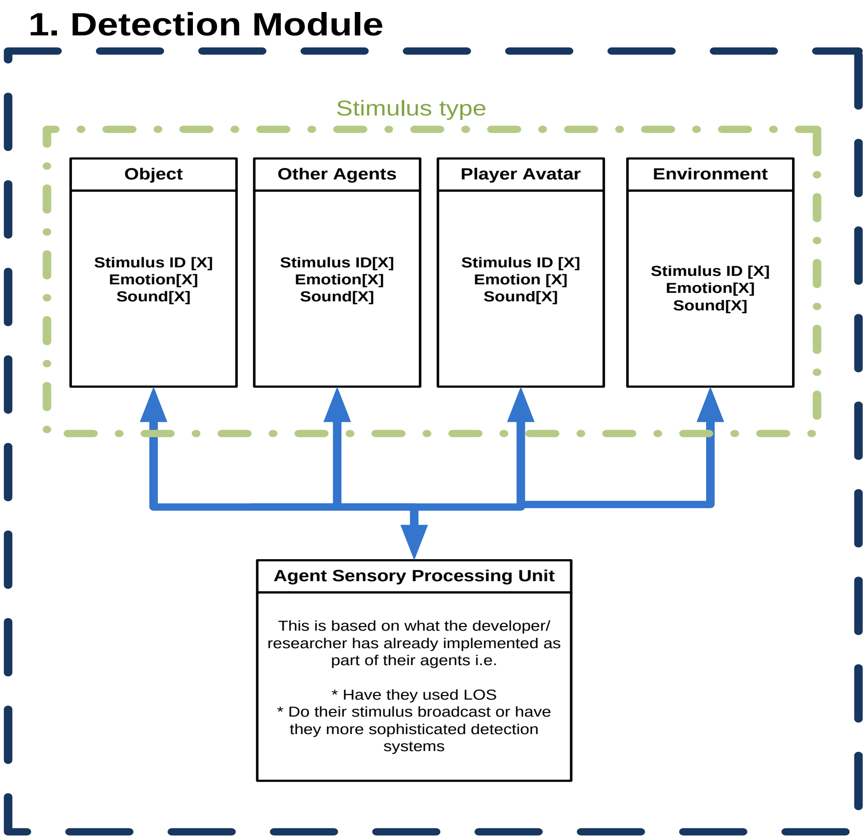


Figure 27: Detection Module Overview

4.3.5 Post Stimuli Detection

The four stimulus aspects will need to be passed to the appraisal module for post detection processing.

4.3.6 Detection Module Example

The following is an example of how the detection module could operate based on a fictitious scenario.

4.3.6.1 Stimulus Identifier Examples

In this example there are a number of different stimuli in the virtual world as shown in Table 12.

	Stimulus Type			
Stimulus ID	**Object**	**Agent**	**Avatar**	**Environmental**
0	Ammo	Fury	Stuart	Dark
1	Ants	User Defined	David	Dusk
2	Book	User Defined	Catherine	Hot Sun
3	Snake	User Defined	Jimmy	Light
4	Giant Spider	User Defined	Omega	Low Sun
5	Tree	User Defined	User Defined	Medium Sun
6	Weapon	User Defined	User Defined	Raining

	Stimulus Type			
Stimulus ID	Object	Agent	Avatar	Environmental
7	Rifle	User Defined	User Defined	Windy

Table 12 – Examples Stimulus

4.3.6.2 Stimulus Detection Type

In this example, the developers have chosen to implement a system where stimuli broadcast within the virtual world to simplify processing. When advised how best to deal with the four parameters related to detection, it was suggested in this example to package them into a 16-bit variable called *Stimulus Description*, plus a separate variable to hold the sound information as shown in Figure 28. This could of course be done many other ways for example a separate class to hold the details with member variables specified that contain the four separate variables.

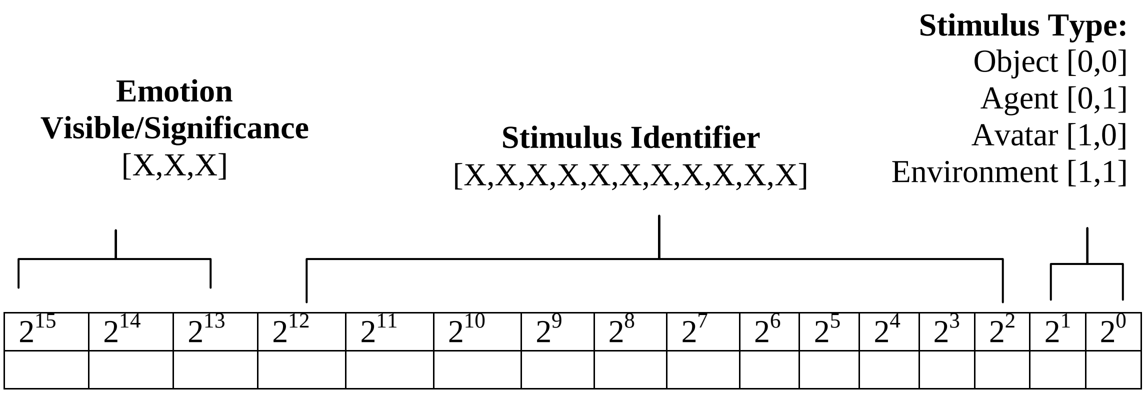


Figure 28. Possible Stimuli Encoding

Worked example

1 Object Detected with ID of 16

2 Broken down into binary number i.e.
0000000000010000
[000] [00000000000] [00]
Emotion ID Type

3 This is encoded as
Type – An object
ID – Giant Spider
Emotion – No Emotion

4 Stimulus significance: I see a *giant spider* and it is *has no obvious emotion*

4.3.6.3 Post Stimuli Detection

The final *Stimulus Description* and *Sound String* are passed to the appraisal module for post detection processing.

4.4 Appraisal of Stimulus

Having been passed both the *stimulus description* (*stimulus type, stimulus ID, visible emotion*) and *sound*, it is now the turn of the appraisal module to decide what, if any emotional response is generated. To enable this module to formulate an appropriate response to the detected stimuli, the emotional significance of the stimuli needs to be ascertained. Referring back to Section 2.1 there has been the proposal by Ekman (Ekman 2004) that part of the appraisal involves an emotion alert database.

4.4.1 Development of an Emotional Alert Database (EAD)

According to Ekman the EAD includes the triggers, thresholds and intensities of the emotions related to the stimuli, in this case the stimuli identified in Section 4.3 (objects, agents avatars, and environmental events). These details are shown in Table 13 for clarity.

Possible Emotional Alert Database Elements	Notes
Stimulus Type	These are elements that are available to the *EAD* from the *Detection Module*
Stimulus ID	
Sound	
Visible Emotion	
Emotion Linked	Need to Be Defined/Added
Trigger	
Activation Threshold	
Emotion Intensity	

Table 13 – Possible Elements of the Emotional Alert Database

For a basic emotional response, the above eight elements would be enough for a basic response, and are based on the psychology underpinning discussed in Section 2.9. The problem is that these elements alone would not be enough to take into account the context of the encounter. In order to make a more thorough appraisal of the situation, additional data is needed such as what the stimulus is doing, and whether the stimulus was seen recently, along with how its behaviour may have changed. For this comparison to be made, not only are additional values such as what the stimulus is doing (its activity), and its position (including its movement), but last seen values for these will be required as well, implying the need for additionally stored values in the database as discussed next.

4.4.1.1 Stimulus Activity & Movement

As mentioned, there is a requirement to better evaluate the situation, by considering:

- What the stimulus is doing? Which will be referred to as *Current Activity*.

- What the stimulus was doing last time it was detected? Which will be referred to as *Previous Activity*.
- How the stimulus is moving i.e. is it approaching? Which will be referred to as *Current Movement*.
- How was the stimulus moving last time it was detected? Which will be referred to as *Previous Movement*.
- Examples of both Movement and Activity types can be seen in Tables 14 & 15.

Activity	#
Attacking Agent	0
Attacking Other	1
Crawling	2
Dead	3
Doing Nothing	4
Dying	5
Falling	6
Innate	7
Jumping	8
Rolling	9
Slithering	10
Picking Something Up	11
Crouching	12

Table 14 – Examples of Agent Activities

Movement	#
Stationary	0
Approaching Slowly	1
Approaching Quickly	2
Moving Away Slowly	3
Moving Away Quickly	4
Behind Agent	8

Table 15 – Examples of Agent Movements

It is feasible that *Current Activity* and *Current Movement* can be ascertained from inspecting the current stimulus, but *Previous Activity* and *Previous Movement* are proposed as being best stored in the EAD.

If the appraisal of stimulus is dependant on what movement and activity the stimulus was last seen doing, then this will need to have a *time stamp* associated with it, adding an additional variable to the database. Next the *stimulus's last location* may have some bearing especially for position and so this will need to be stored as well. Finally it was suggested in Section 2.1 that stimulus could be attributed a *like rating* as used in the OCC model of emotions discussed in Section 2.1.5.1.

Table 16 shows the properties identified as being essential for the EAD.

Emotional Alert Database Properties	Notes
Stimulus Type	These are elements that are available to the *EAD* from the *Detection Module*
Stimulus ID	
Sound	
Visible Emotion	
Emotion Linked	Need to Be Defined/Added
Trigger	
Activation Threshold	
Emotion Intensity	
Previous Movement	Supplemental Values that may be required
Previous Activity	
Previous Emotion Seen	
Time Last Seen	
Stimulus Location Last Seen	
Stimulus Like Rating	

Table 16 – EAD Variable Requirements

Now that the EAD is specified, it is possible to begin describing what form emotional appraisal should take. Referring back to Section 2.1.5 it is suggested that emotional appraisal actually takes the form of:

- An initial fast response called the fight or flight appraisal, that checks to see if the stimulus is an immediate threat.
- The second is a longer, more thorough appraisal if the stimulus is not considered an immediate threat.

4.4.2 Fight or Flight Evaluation Stage (Low Road)

According to Le Doux (Le Doux 1998) this stage is indicative of a fast response mechanism for emotional appraisal; this provides a low computational, fast response to threats, defined in this instance as thing that we are afraid of, i.e. stimulus with related fear responses. According to Scherer (Scherer 2005), the low road produces some response as soon as 80ms after stimulus is registered where the high road is the 80ms (low road) + 50-100ms. The flow of the fight or flight mechanism is shown in Figure 29.

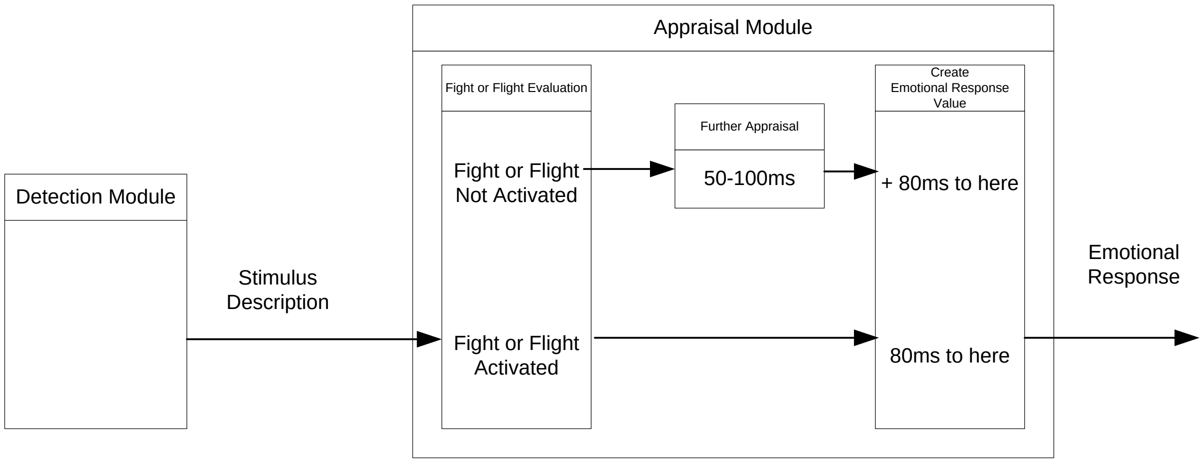


Figure 29. Fight or Flight Overview

The first stage of the *fight or flight appraisal* process is to ascertain if the stimulus activates the fear response, thus triggering a *fight or flight response*:

1. The appraisal module receives the s*timulus description* (*stimulus type*, *stimulus ID, and visible emotion*) and *sound*.
2. The stimulus should be checked for a fear response in the emotional alert database. In effect this means checking that both the stimulus type and stimulus ID to get a match.
3. If a fear emotion is matched then this needs evaluating to see if the emotion threshold value (for fear in this instance) has been reached. If the emotion is not triggered, a fight or flight response is not activated and thus further emotional appraisal is carried out.
4. If fight or flight is activated, then a fight or flight emotional response is automatically generated and the rest of the appraisal processing is bypassed.

An example Fight and Flight walkthrough is shown in Figure 30.

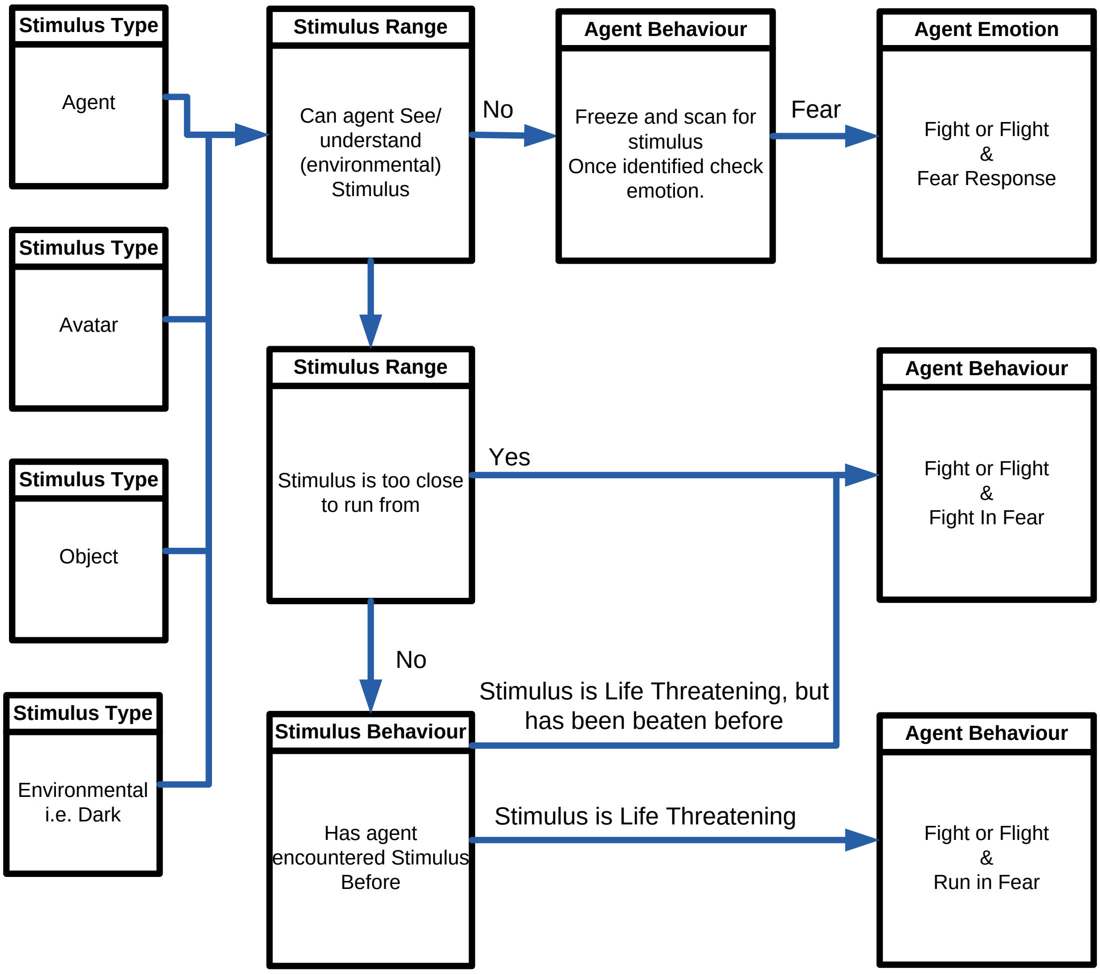


Figure 30. Example Fight or Flight Walkthrough

4.4.3 Main Emotional Appraisal (High Road)

The high road according to Le Doux is indicative of a much more processor, time intensive path that requires the gathering/processing of information before making a full appraisal of the situation including what the stimulus is doing in both actions and movement.

4.4.3.1 Stimulus Activity Stage

The stimulus activity stage forms part of the main appraisal module, and is intended to assess the actions of the detected stimulus i.e. what activity is the stimulus engaged in at the moment such as loading a gun or picking something up, this should ideally be mapped to a descriptive text label such as those in Table 13 so that they can be subsequently stored in the EAD as *previous activity*.

4.4.3.2 Stimulus Moving Stage

The purpose of this stage is to identify what kind of movement the stimulus is engaged in as such as moving towards, moving away, or stationary. This will invariably need to be based on the in-world coordinate system that can account for both the agent and stimulus' position and speed. It is suggested that this is mapped to some descriptive text as shown in Table 14 so that it can be subsequently stored in the EAD as previous movement.

4.4.3.3 Appraising Behaviour

With both the stimulus activity and movement ascertained i.e. the stimulus's behaviour, it is possible to check the EAD to see if a previous entry has been made and as such evaluate whether the stimulus had been seen recently i.e. has it been tracked.

With further information gathered on the stimulus, and the fight and flight appraisal concluded, appraisals of the four stages of surprise (discussed in section 2.1.9.6), and the five basic emotions (discussed in section 2.1.9) are discussed next.

4.4.4 Four Types of Surprise Appraisal

Referring back to section 2.1.9.6 it has been suggested that when an unexpected stimulus is encountered, or an unexpected encounter with a stimulus occurs, that a surprise response is possible. It was also suggested that this surprise response, is not actually an emotion, but one of four responses startle, surprise, shock or interest based on the context of the encounter as shown in Figure 31.

If one of the four surprise states becomes active, a subsequent further emotional appraisal will occur to determine what, if any emotion response is required.

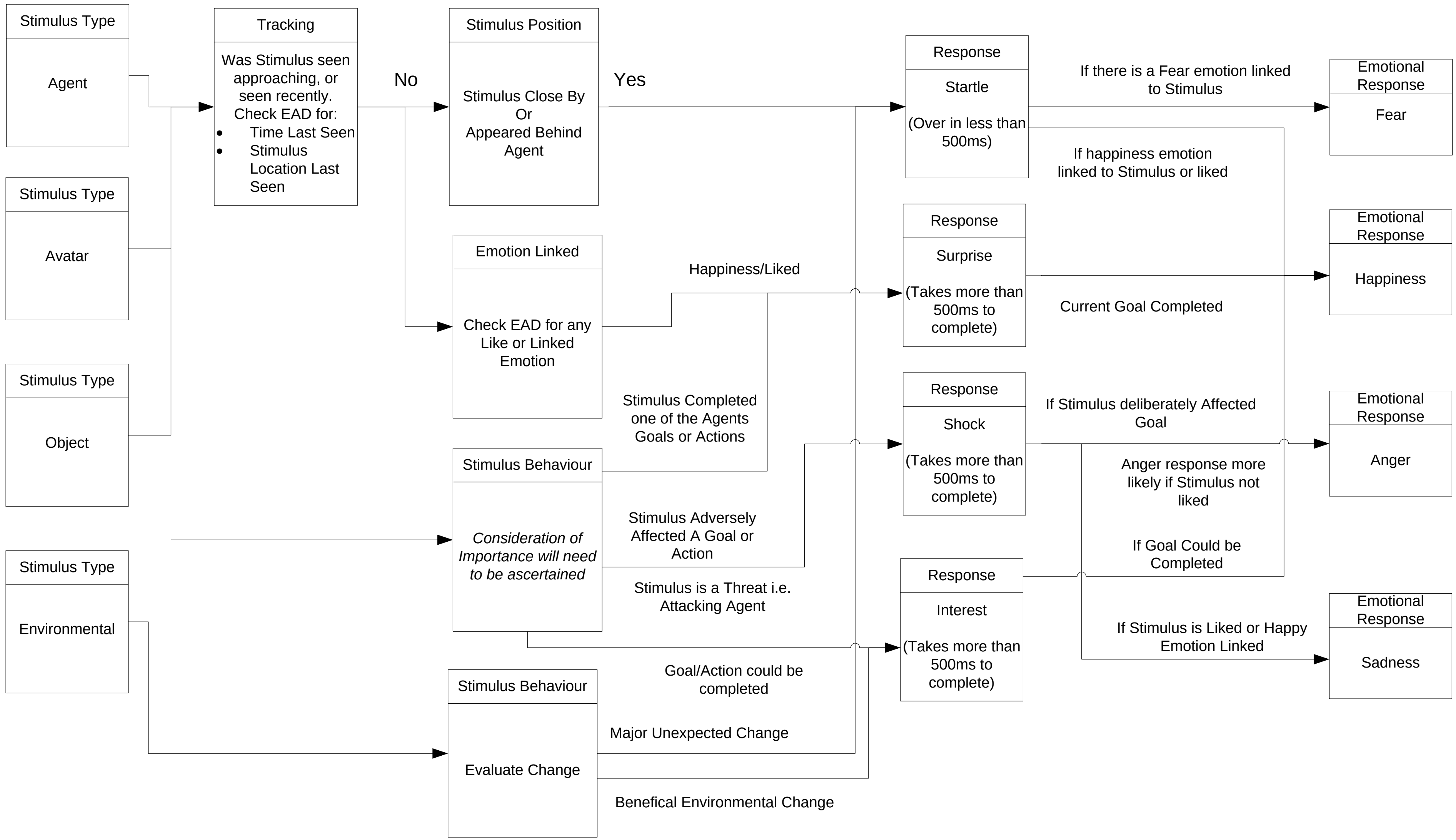


Figure 31. Surprise Appraisal

4.4.5 Final Stage Emotional Appraisal

The final stage is the emotional appraisal of the encounter, to check if any of the five category one emotions (anger, disgust, fear, happiness, and sadness) are activated.

4.4.5.1 Anger Appraisal

Based on the description of anger in section 2.1.9.1, a possible appraisal of anger that could be followed is shown in Figure 32.

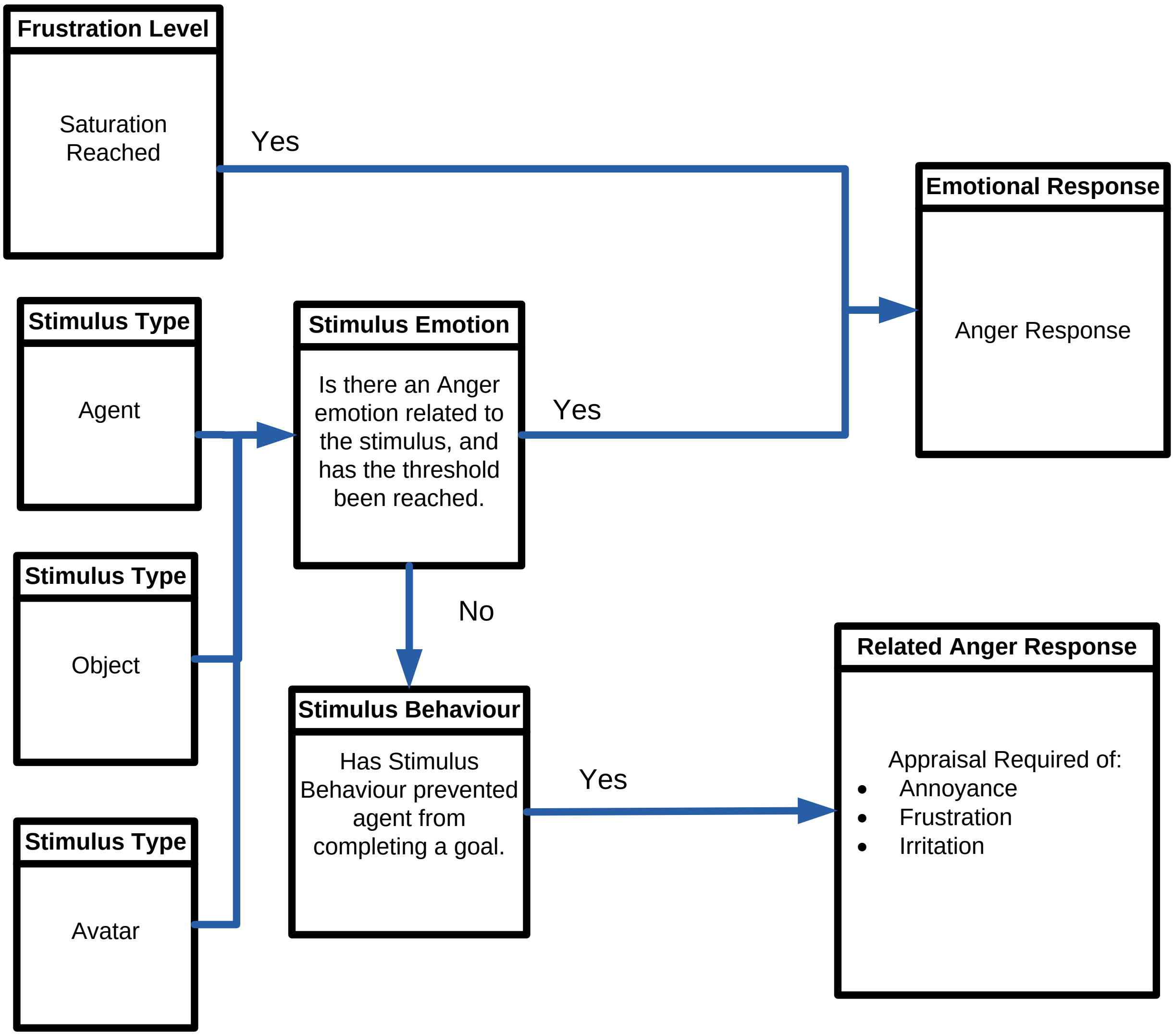


Figure 32. The Anger Appraisal Process

4.4.5.2 Disgust Appraisal

Based on the description of disgust in section 2.1.9.2, a possible appraisal of disgust that could be followed is shown in Figure 33.

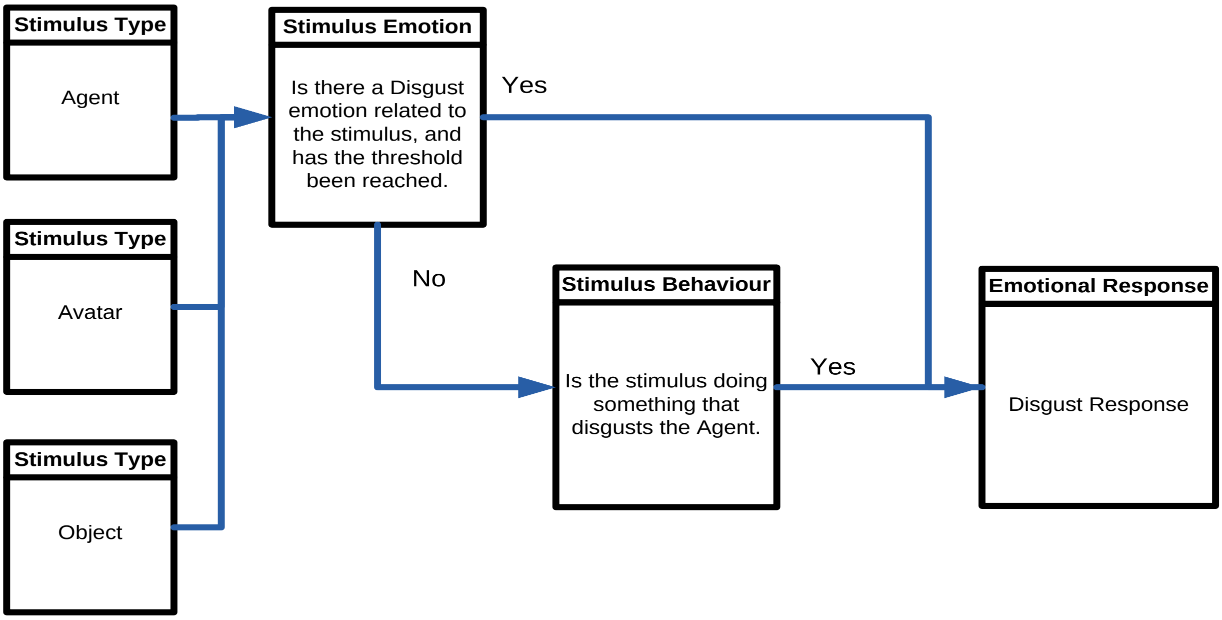


Figure 33. The Disgust Appraisal Process

4.4.5.3 Fear Appraisal

Based on the description of fear in section 2.1.9.3, a possible appraisal of fear that could be followed is shown in Figure 34. As discussed in Section 2.1.9.3.5 anxiety is similar to fear, but involves a future threat, as such the fear response can be used for anxiety as well.

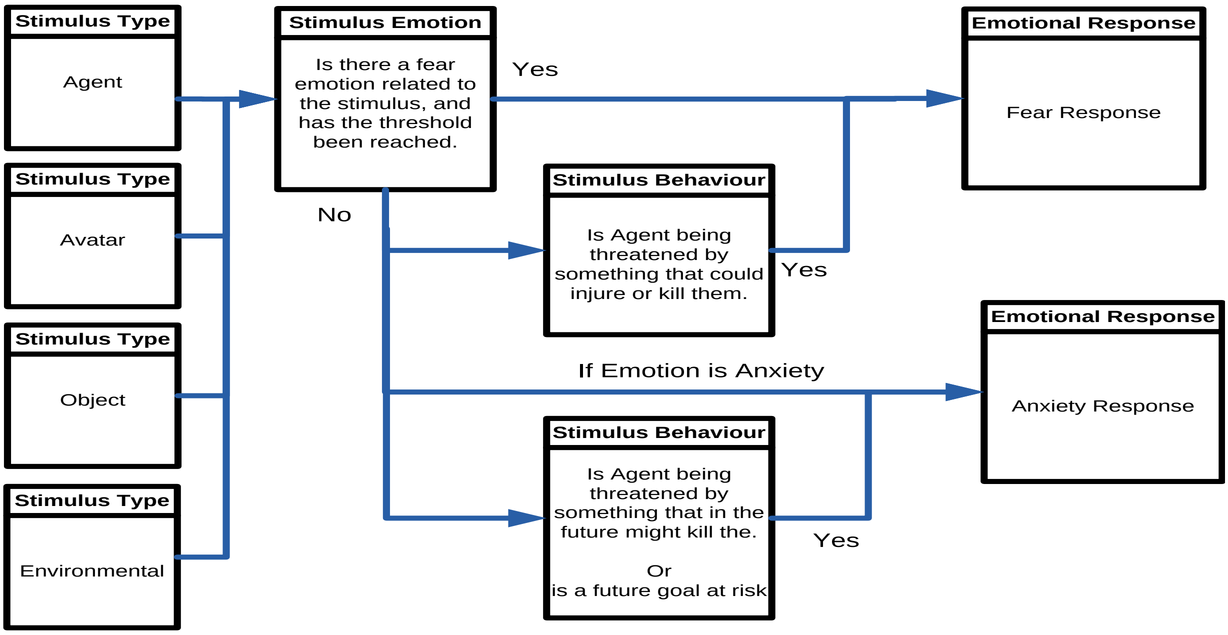


Figure 34. The Fear Appraisal Process

4.4.5.4 Happiness Appraisal

Based on the description of happiness in section 2.1.9.4, a possible appraisal of happiness that could be followed is shown in Figure 35.

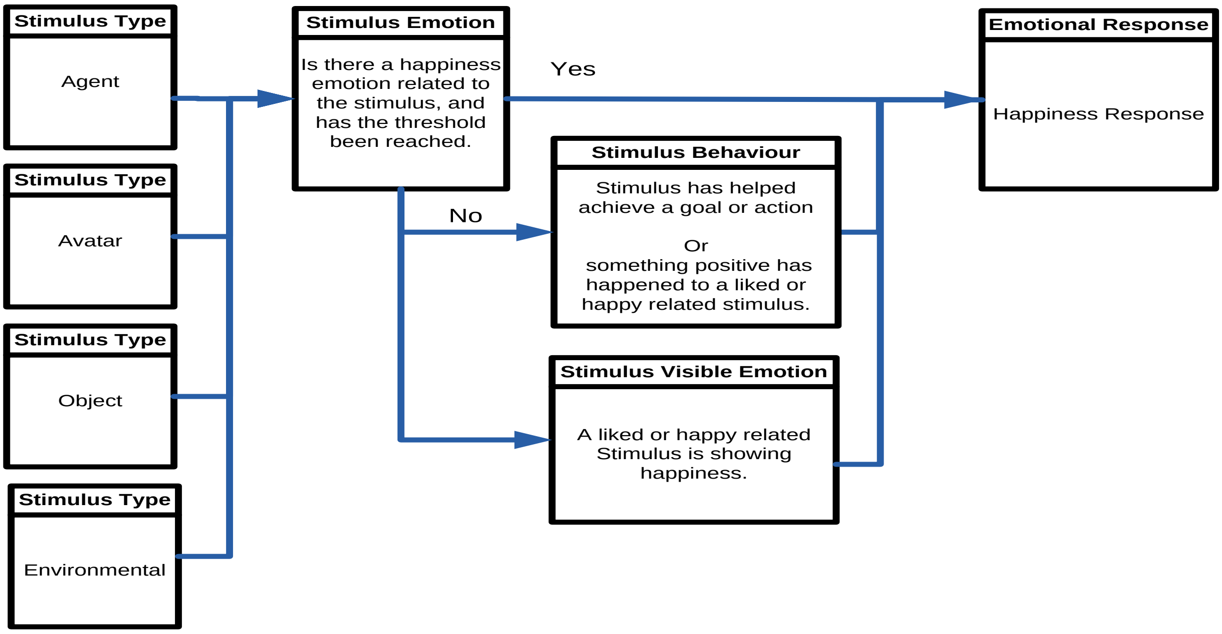


Figure 35. The Happiness Appraisal Process

4.4.5.5 Sadness Appraisal

Based on the description of sadness in section 2.1.9.5, a possible appraisal of sadness that could be followed is shown in Figure 36.

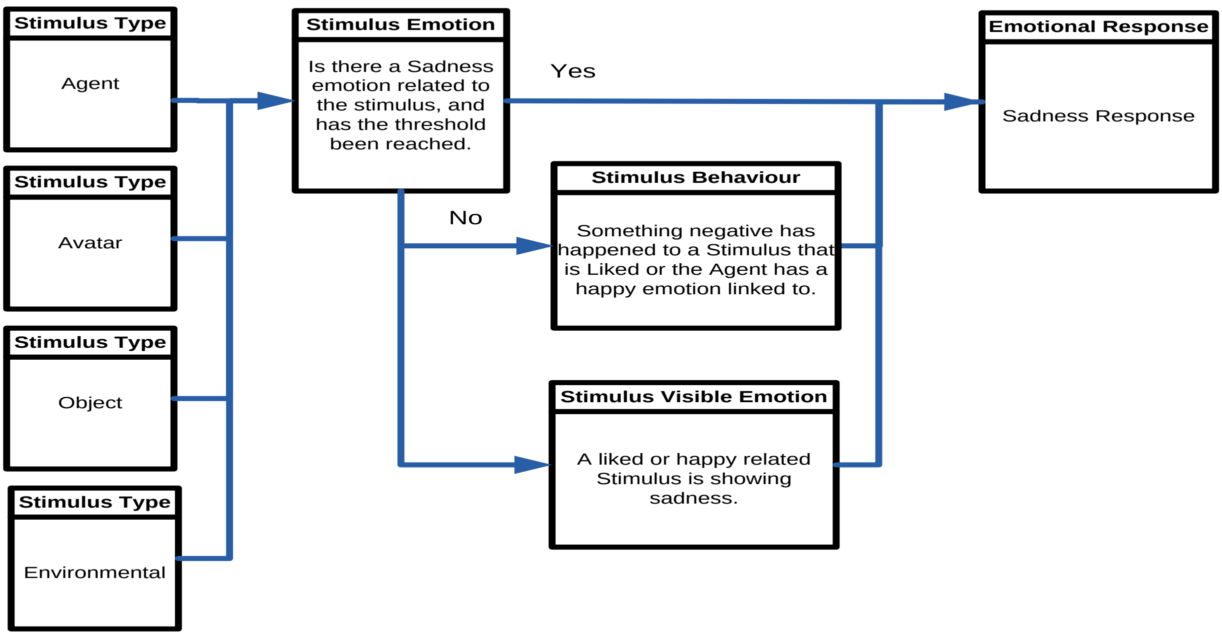


Figure 36. The Sadness Appraisal Process

4.4.6 Textual Chat Appraisal

According to Plutchik (Plutchik 1980), words can have an emotional significance for individuals, and this significance can be used to ascertain possible emotional states. Based on this theory, a process is proposed for appraising textual chat, that can attribute weighting of the five category one emotions to a word (stored in a suitable schema such as XML), before summing them across a sentence to gauge a probable emotional meaning. An example is shown below with notional values attributed to each emotion:

```
word name="hello" anger="0" happiness="10" fear="0" sadness="0" surprise="0"
word name="boo" anger="0" happiness="0" fear="50" sadness="10" surprise="30"
```

This summing of emotions mean that the presence of a predominant emotion beyond a threshold value (set during development) will indicate that the agent had detected some emotional significance to a conversation, and allow it to respond accordingly, depending on its own current emotional state.

If the bot is unable to answer a question it begins raising a frustration flag for the user, when this value reaches a threshold, an apology is made to the user and alternative answers or prompts are made. This threshold level is currently set as:

- Two consecutive “could not find answers” to the same question – the bot raises the frustration flag and asks if the “user meant xxx”, where xxx is a match to another question with a lower number of word matches.
- Three consecutive “could not find answers” to different questions – the bot apologises and suggests a few possible choices based on a lower word match to the user question.

Again the exact number of frustration flags can be fine tuned with consequent matches, to enable the bot to detect frustration more accurately.

4.4.6.1 Frustration

It is proposed that frustration should be triggered when an agent repeatedly does not know the correct answer to a question, when a threshold is reached the agent could transition into anger.

4.4.6.2 Happiness

If the agent is able to answer a question successfully then it is suggested happiness should increase, and frustration reduce.

4.4.6.3 Sadness

If the agent does not know the answer to a question from a stimulus they like, then it is suggested that sadness increases.

Note: This proposal for an emotional appraisal of textual chat for agent's, requires further work especially in what weightings for words need to be made, and how reliably this might detect emotions in both the agent and the user the agent is speaking to.

4.4.7 Stimulus Response Over Time

According to Gray (Gray 1971), exposure to emotionally significant stimulus can change the way an individual (agent in this instance) responds to it over time including:

1. **Stimulus Adaptation** – Repeated exposure to emotionally significant stimulus will reduce the response to the stimulus. This may not affect the triggering of the emotion, but will affect the subsequent behaviour.
2. **Stimulus Extinction** – It is possible that with enough exposure (frequency of exposure) to a stimulus, that an agent can have no behavioural response to a previously emotional stimulus.
3. **Stimulus Habituation** – Repeated exposure to unexpected stimulus can potentially reduce the response i.e. the agent gets used to stimulus.
4. **Stimulus Generalisation** – It is possible that an agent can have a similar emotional response to stimuli that are similar to a previously detected stimulus with a related emotional response, i.e. if an agent has a fear of dogs, and then potentially they might have an emotional response to wolves as they are similar in appearance to dogs.

4.4.8 Final Appraisal of Stimulus Module Overview

Figure 37 shows each stage of the appraisal process.

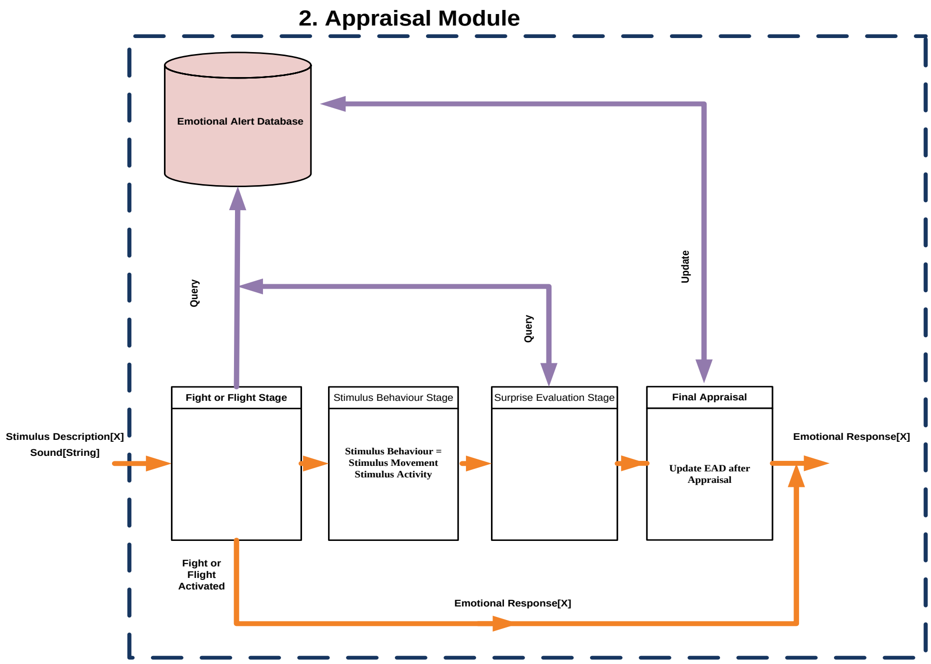


Figure 37. Appraisal Module Overview

4.5 *Unconscious Reaction*

According to Damasio (Damasio 2000), the unconscious reaction aspect of emotions is a change to the endocrine, blood and hormone levels in the body. These changes occur without conscious realisation, and according to Damasio they prepare the individual for a particular emotional response mentally and physically. As a consequence of these changes there are somatic markers (bodily signs), including the ones shown in Table 17.

Physical Signs of an Unconscious Reaction	
Somatic Marker	**Anger (Summarised from Section 2.1.9.1)**
Heart Beat Change	Faster
Breathing Changes	Breath faster
Skin Colour Change	Reddening of face
Skin Texture Change	Sweaty hands from clenching
Body Temperature Changes	Increased
Somatic Marker	**Disgust (Summarised from Section 2.1.9.2)**
Heart Beat Change	None
Breathing Changes	None
Skin Colour Change	None
Skin Texture Change	None
Body Temperature Changes	None
Somatic Marker	**Fear (Summarised from Section 2.1.9.3)**
Heart Beat Change	Very fast
Breathing Changes	Breath much faster
Skin Colour Change	Face washes out and can appear pale

Physical Signs of an Unconscious Reaction	
Somatic Marker	**Anger (Summarised from Section 2.1.9.1)**
Skin Texture Change	Goosebumps and skin contractions
Body Temperature Changes	None
Somatic Marker	**Happiness (Summarised from Section 2.1.9.4)**
Heart Beat Change	A Little Faster
Breathing Changes	Face may show glowing cheeks
Skin Colour Change	A Little faster
Skin Texture Change	None
Body Temperature Changes	A little increased
Somatic Marker	**Sadness (Summarised from Section 2.1.9.5)**
Heart Beat Change	Slower
Breathing Changes	Slower
Skin Colour Change	Skin colour paler
Skin Texture Change	None
Body Temperature Changes	Cooler

Table 17 – Somatic Markers Related to Unconscious Reactions to Emotions

For computer games in general, game characters will have the unconscious processing merged into the main emotional state animations, and thus this stage (unconscious realisation) does not have to be implemented separately from the *Physiological Change Module*. This is because "realistic" bodily system modelling is not usually a part of games.

For simulations within virtual worlds, such as medical scenarios, this stage can be combined with micro expressions (Ekman 2000) to create a more believable character which could potentially increase the immersion of the user in the training application. This could for example, include seeing heart beat changes and skin colour changes while working with virtual patients.

4.6 Physiological Change

4.6.1 Background

As discussed in Section 2.1 the physiology of emotions can be split between facial signs, body posture changes, and vocal queues.

Facial Emotions

As discussed in Section 2.1, Ekman's (Ekman et al 2003) work on facial expressions offers a comprehensive description of the basic emotions that can be used by developers looking to model more accurate facial expressions.

Body Posture

When experiencing many emotions, the brain seeks information from the senses, and as such the head is often tilted towards the stimuli to allow the eyes and ears to focus more fully (Ekman et al 2003). The exception to this according to Ekman is disgust, where the head is actually turned away from the stimuli. Other posture changes specific to each emotion are discussed in Sections 2.1.9.

Vocal Emotions

Ekman (Ekman et al 2003) states, that during emotional activation, the voice provides three indicators of the emotion:

- The choice of words used i.e. increased use of metaphors and an increasing usage as the emotion intensifies (Ortony et al 1987). The use of metaphors during some emotional activation is thought to occur because the individual believes that they cannot convey information otherwise.
- The tone of the voice.
- Speed of dialogue i.e. pauses, hurried speech.

Ekman also says that the longer an emotion lasts, the more typical it is to observe vocal sounds such as crying and laughing.

4.6.2 Format

Typical aspects of physiological emotion can be seen in Table 18 below. Sample Table entries for each emotion can be found in Appendix 4, and are based on descriptions by Parrott (Parrott 2001) for body and audio changes, and Ekman (2004) for facial changes.

Location	Actual Change	Description
Physiology	Facial Changes (Facial Modelling)	Which facial animation to display
	Posture changes (Body Modelling)	How does the agent’s posture change?
	Audio (Speech synthesis) Or Textual	Is the agent’s voice changed in pitch, speed tone and loudness? Does agent use of metaphor’s change.

Table 18 – Physiological Effects of Emotion

4.7 Motivation to Act

This stage of the architecture (module) has one specific purpose, to affect current agent behaviour after the appraisal of an emotionally significant stimulus, where behaviour changes in this context are based on Scherer's (Scherer 2001) description, which is a mix of:

- Changing *goals* including re-prioritising of goals.
- Changing *actions* i.e. action selection, which according to Gray (Gray 1971) involves the re-choosing of appropriate actions to fulfil a goal, based on a new motivation.

According to Gray (though where human was referred to, agent has been substituted), this motivation can have the following effects:

- Current goals will be changed by an agents life being threatened, causing a life preservation goal to take priority, as a consequence current actions will change. An example is if an agent is injured then if their current goal is the collection of plants, they will change and seek a goal and actions to heal themselves.
- If goals are overridden, the agent may not automatically pursue them after the new goal has completed.
- Some motivation behaviours include increased alertness, and preparing the agent to do something, such as in the fight and flight response discussed in Section 2.1.
- Based on section 2.1.9.3, if the emotional appraisal is to enter a state of readiness, then a subsequent evaluation needs to be made. This decides if it is possible to run away, hide or to attack the stimulus. If the outcome from readiness is flight, then the agent will prioritise a self preservation goal with an action selection based on running away. If the outcome is fight, they will prioritise a goal of self preservation through aggression.
- Some motivating behaviour could allow agents to choose particular goals and actions that could serve their interests long term.

Individual emotion activation will have the following effects:

- Anger: Based on Section 2.1.9.1 the agents goals and actions will be biased towards some form of aggressive behaviour towards the stimulus, which may be imagined (towards), verbal or physical depending on the appraisal. This will also include any actions that would gain a response to the show of anger such as taunting or use of sarcasm.

- Annoyance and Irritation: Based on Section 2.1.9.1.3 the agent's goals and actions may be affected if they choose to ignore the stimulus, becoming counter-productive if the stimulus is required for a goal or action. Alternatively the agent may simply choose to respond verbally with sarcasm.
- Frustration: Based on Section 2.1.9.1.3 the agent's goals and actions may be affected as they take a focus off their current goals and actions to blame and shame the stimulus. This may quickly escalate into anger both physical and verbal, ultimately being counterproductive to any goals and actions that may involve the stimulus.
- Disgust: Based on Section 2.1.9.2 the agent's goals and actions will be changed to avoid the source of the disgust. Nausea may occur which may affect any goals related to eating or the seeking of food. The agent may also move away from any stimulus immediately in their vicinity, even if a goal or action is failed.
- Fear: Based on Section 2.1.9.3 and the discussion based on Gray above, fear when activated will normally stop all immediate actions while the agent freezes. This is followed by the replacement of all current goals and actions due to the processing of the fight or flight response. Subsequently the agent's actions will be to either run away or stand and fight. As discussed in section 2.1.9.3.5 the agent may enter a state of anxiousness and as such, may choose goals and actions based on self preservation as they perceive that they are still in danger.
- Happiness: Based on Section 2.1.9.4 the agent has become happy based on either seeing a stimulus that makes them happy, or something beneficial has happened as a consequence of the stimulus, such as an unexpected goal becoming completed. Therefore the agent is more likely to participate in goals and actions that may have a more negative effect such as attempting a challenging or previously failed goal or action.
- Sadness: Based on section 2.1.9.5 the agent will be less likely to choose actions and goals that require much effort as they become withdrawn. The agent may also avoid actions and goals involving other people.

The flow of the motivation module can be seen in Figure 38, and the module is based on the assumption that the agent already has a goal and action behaviour system which can be adapted to allow emotions to change the selection of goals and actions.

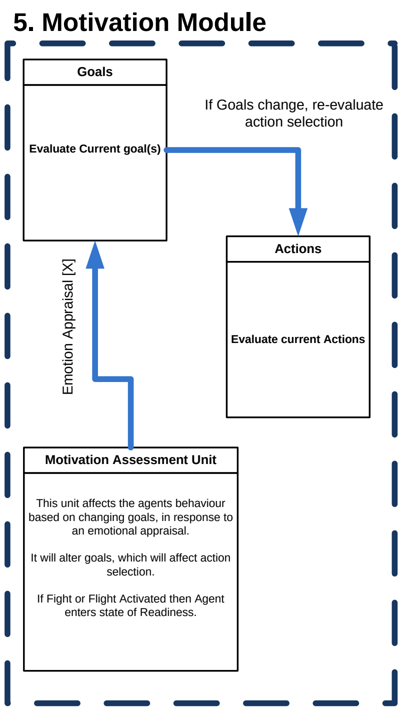


Figure 38. Motivation Module

4.8 Conscious Realisation

This module is intended to provide a feedback mechanism within the virtual world, so that the emotionally enhanced agents can be queried on behaviours and emotions. This is achieved by formulating a textual response from the agent, which could be based on the parameters shown in the first column of Table 19.

	Example 1	Example 2	Example 3	Example 4
***Stimulus Type* (From Detection Module)**	Agent	Object	Agent	Agent
***Stimulus ID* (From Detection Module)**	Barry	Snake	John	Chalky
***Visible Emotion from Stimulus* (From Detection Module)**	Happy	None	Anger	Sad
***Appraisal* (From Appraisal Module)**	Sees Barry Approaching. Happy emotion linked to Barry.	See snake while walking. Fear emotion linked to Snake.	See John running towards me. Anger emotion linked to John.	Chalky walks over to me. Happy emotion linked to Chalky.

Table 19 – Conscious Realisation: Sample Entries

4.8.1 Example Textual Response Mechanism

In this example, when the words "How are you?" are typed into the chat system aimed at the emotionally enhanced agent, the flow shown in Figure 39 could be followed. This can be applied to each of the examples shown in Table 15, to provide the responses shown below:

1. I am happy because I can see Barry and he looks happy to see me.
2. I am afraid because I encountered a snake.
3. I am angry because I can see John and he looks angry.
4. I am sad because I can see Chalky and he looks sad.

This can be extended or revised according to requirements, for example to offer more detailed feedback such as:

> "I am happy because I can see Barry and I like him, he also looks happy to see me"

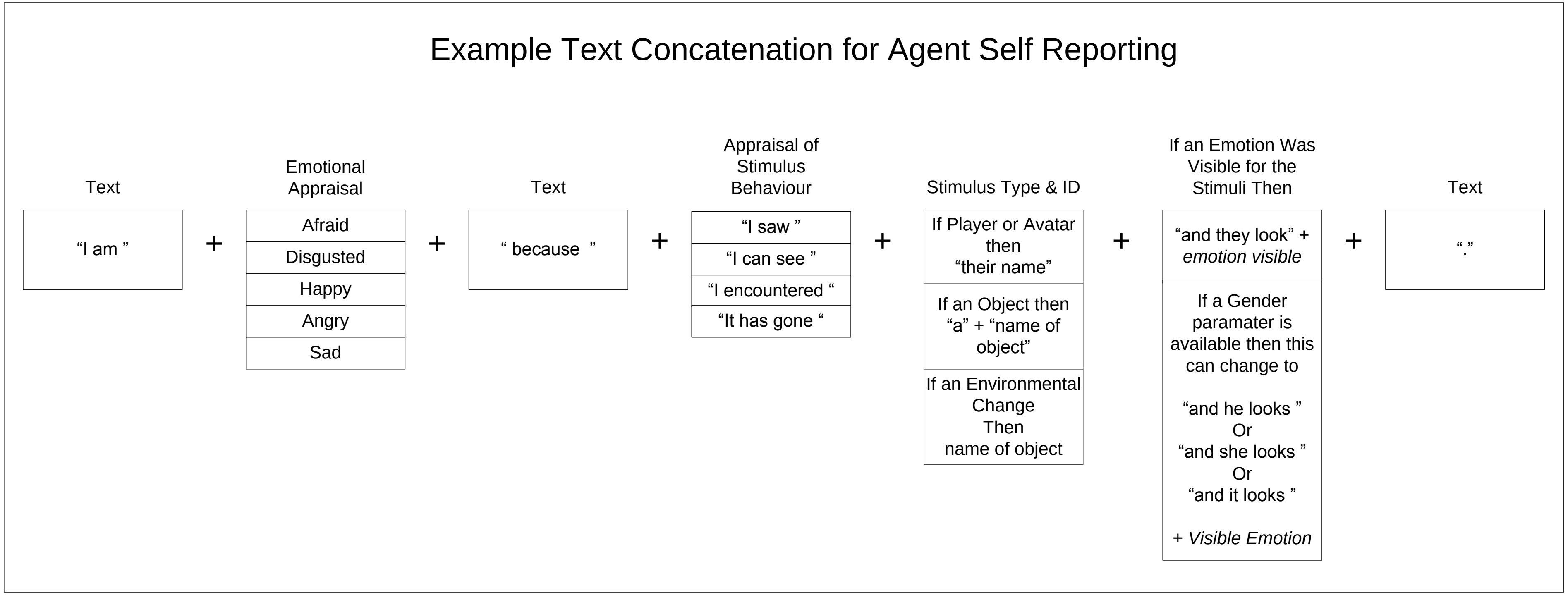


Figure 39. Example Textual Response Mechanism

4.9 Emotion Duration & Moods

As discussed in Section 2.1.6, most emotions last as long as the stimulus is present or until the individual manages to rectify the situation themselves to change the emotionally significant stimulus so that it no longer affects them. If the emotion is not resolved, then the individual will enter a particular mood, increasing the likelihood of activating related emotions.

The consequences of being in a mood, is that decision making is also affected, and thus goals and actions will be more likely to be related to the mood. Moods can last up to a few days or until another emotion becomes active, naturally moods decay over time.

With the above points in mind:

- Agents will enter a mood if an emotion is not resolved.
- Agents will try to rectify the following emotions:
    - Anger through aggression as discussed in Section 2.1.9.1.
    - Disgust by moving away from the stimuli as discussed in Section 2.1.9.2.
    - Fear by running away or fighting (fight or flight response) as discussed in Section 2.1.9.3.
- Emotions decay over time, which can be dependent on the individual.
- Moods decay over time or are replaced with emotions through new appraisals.
- Whilst in a mood, behaviours and actions can become focused on the underlying emotion.

4.10 Summary

The purpose of this Chapter was to provide guidance to developers on what each of the modules suggested by Scherer's model (Scherer 2005) should contain. It is based upon the background research conducted in Chapter 2 along with suitable examples, and is intended to provide the researcher with an architecture ready for integration into their pre-existing agent A.I. system. Utilising a modular approach as shown in Figure 40, the development of agents with "broad" and/or "deep" levels of emotions should be feasible. To avoid limiting the application of the architecture, specific software recommendations were avoided as the architecture should be applicable to a range of platforms, technologies and usages.

The next stage is to apply the architecture to software solutions, and review the outcomes.

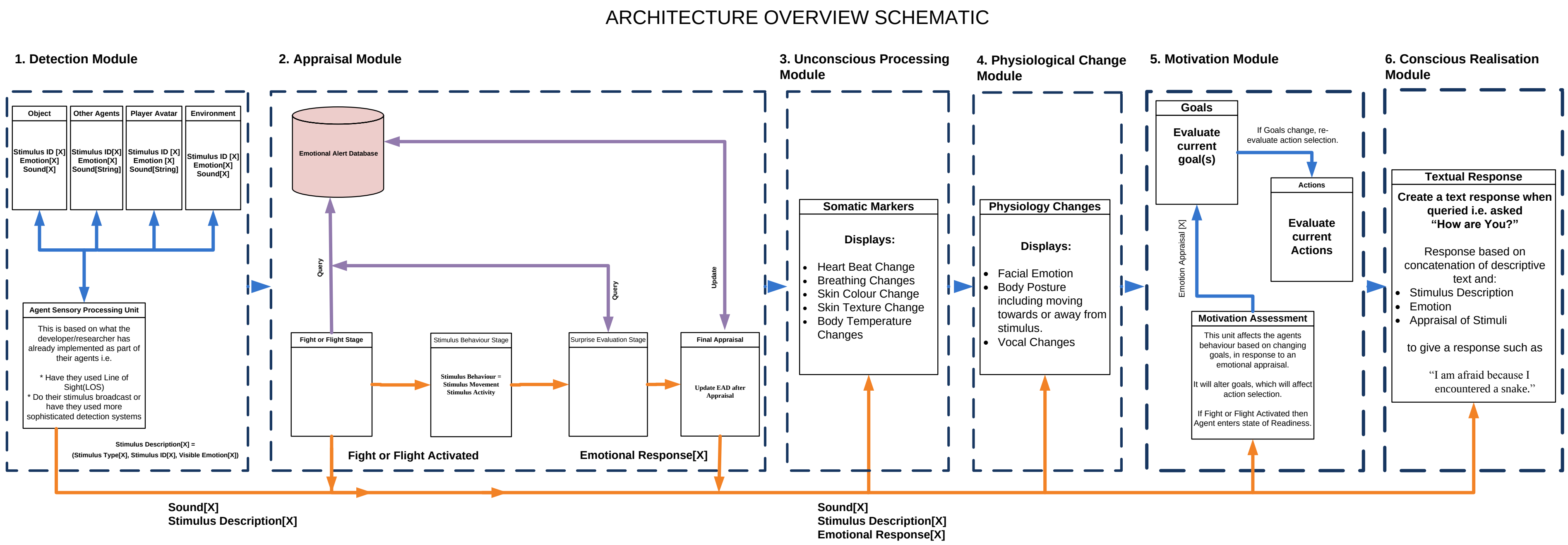


Figure 40. Final Architecture Overview

Chapter 5: Implementation Case Studies

5.1 Overview

In order to validate the effectiveness and suitability of the architecture, three implementations were made into software solutions that support different types of agents. Each of the solutions selected - Quake 3(a game), Second Life (a virtual world), and the Web Chat Bot fitted in with the scope of this research and each arose from the requirement by a developer to add emotions to the agents in their applications. The evaluation techniques chosen were based predominantly on user interaction, because the approach being taken is that if a developer is able to implement the architecture and subsequently a user can interact with the emotionally enhanced characters and report on their experience, then this could be used as partial validation of the framework.

The first involved the application of the E-AI architecture to a bot in the *Quake 3* game to provide it with a limited set of emotions and evaluate the bots combat performance within a typical combat game environment. This was supported with a separate evaluation by end users. The initial implementation was carried out with a skilled C++/Quake 3 developer Adam Westwood.

The second project was a request by a developer David Burden for an emotion architecture that could be applied to chat bots in Second Life, which could also interface to the pre-existing back-end technologies. The project was implemented by the developer David Burden, and was followed by a pilot evaluation involving postgraduate end users.

The third implementation involved the addition of emotions to a commercial web chat bot to add to its interest for users. This was implemented in the Macromedia Flash CS3 platform by a skilled Flash developer Jason Scarfe, and was followed by some testing to ensure the emotional states were activated as expected.

The remainder of this chapter is concerned with both a discussion of each implementation, followed by a discussion of the evaluation techniques used.

5.2 Adding Emotions to Bots in Quake 3

Quake 3 by Id Software, was a popular first person shooter (FPS) game during its initial release of December 1999.

The game was consequently followed by a range of tools created by independent developers to provide the ability to customize the playing experience. In 2005, most of the source code (in the C programming language) for the game was released under a GNU public licence. This source code and previously mentioned tools, provided amongst other things, the opportunity to alter the behaviour of the combat bots within the game, principally through two key files:

1. **AI_dmq3.c**– This file contains the functions related to bots abilities and actions in death matches. Information such as bot position and current actions can be ascertained from this file.
2. **AI_dmnet.c** – This file contains the actual finite state machines for the bots encoded as a series of switch statements.

With a well documented and easily adaptable game engine, examples of previous implementations in the preceding Quake 2 engine available for reference (as discussed in the next section), and a developer available with experience in programming the engine, when a FPS game engine was sought for this research, Quake 3 seemed a suitable choice.

In order to add emotions to the bots in Quake 3, a mapping was required of the E-AI architecture specified in Chapter 4 (overview shown again in Figure 42) to the combat bots behaviour systems in Quake 3. This mapping is what forms the remainder of this section.

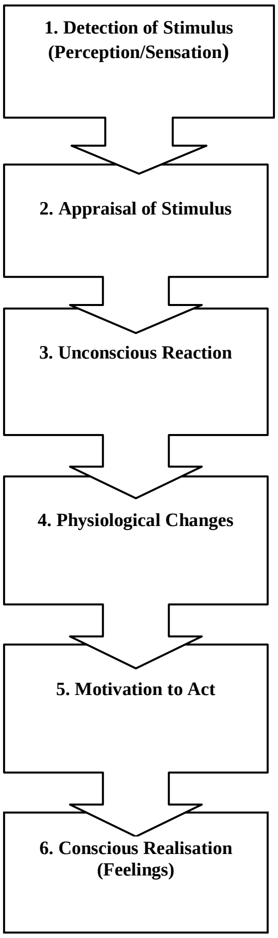


Figure 42. E-AI Six Stage Emotion Process

5.2.1 Detection Module

Quake 3 bots feature an area awareness system (AAS) for representing and processing their cognitive domain knowledge. This AAS can be used to ascertain objects, bots and user character location, along with an identification number for each type. *Quake 3* already features line of sight, and a special variable called "vis" which can be used to represent partial sight through mediums such as fog, and as such, these variables can be used for representing obscured visibility.

Mapping to the E-AI architecture, the variables in the AAS i.e. identification number and type, can be mapped to S*timulus Description (i.e. Stimulus Type and Stimulus ID). Note: Visible emotion and sound will not be integrated at this point, as the intention is not to alter the bots appearance, just the behaviour, and the sound and chat systems in Quake would need substantial work in order to implement the sound/text aspect of the E-AI detection module.*

5.2.2 Appraisal Module

5.2.2.1 Emotional Alert Database

Referring back to section 4.4.1, an essential aspect of the E-AI architecture is the creation of an Emotional Alert Database, which maps where possible to the Quake 3 engine as shown in Table 20.

Emotional Alert Database Properties	Mapping
Stimulus Type	Identification Number & Type in Quake 3 = Stimulus Description in E-AI
Stimulus ID	
Sound	Not Implemented at this time, as Quake 3 has little support for chat and bots simply shout pre-scripted responses.
Visible Emotion	Not Implemented at this time
Emotion Linked	Anger, Fear, Happiness, Sadness
Trigger	Fuzzy Value
Activation Threshold	
Emotion Intensity	
Previous Movement	From AAS
Previous Activity	From previous Appraisal
Previous Emotion Seen	Not Implemented
Time Last Seen	From AAS
Stimulus Location Last Seen	From AAS
Stimulus Like Rating	Like, Neutral and Dislike Implemented

Table 20 – EAD Mapping to Quake 3

Additionally as Quake 3 is a game based purely on combat statistics, it seemed appropriate to include *number of times successfully* killed (by an enemy) and *number of times bot has been killed (self by other), to add some reflective history to combat encounters.*

5.2.2.2 Emotions

Four of the five emotions identified in Chapter 4 were selected for inclusion, anger, fear, happiness and sadness. Disgust was not included at this time, as it was not part of the normal game flow to have objects that might cause disgust, but of course such an inclusion could be added in a subsequent development. The selected four emotions were implemented using finite state machines, examples are shown in Figure 43 (note: other actions exist, that trigger some state changes that are not shown).

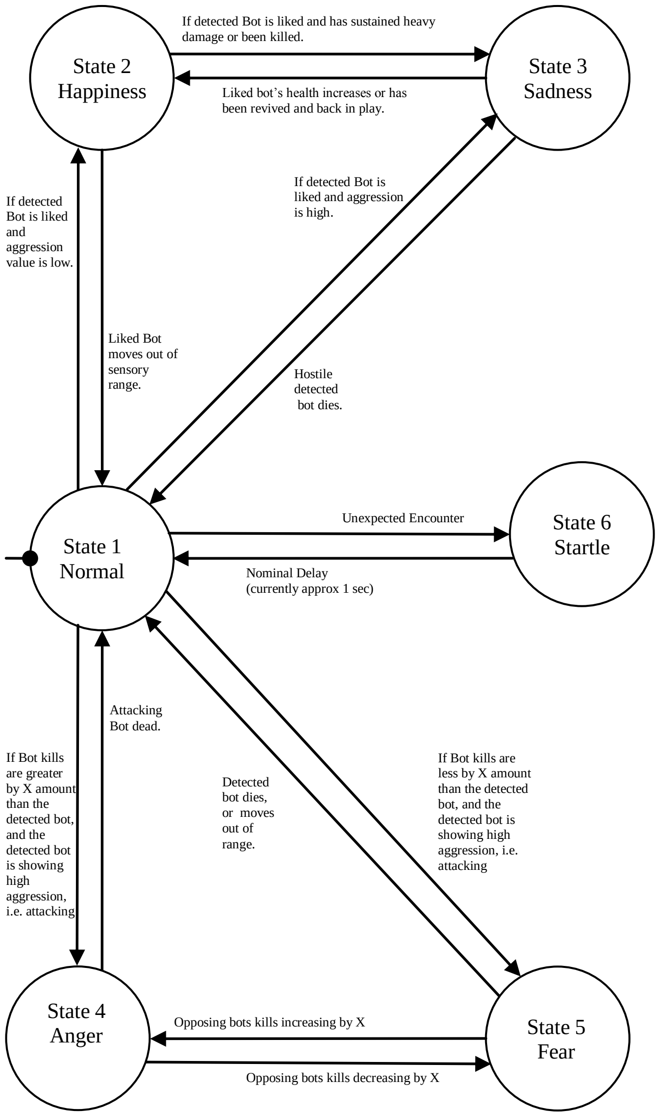


Figure 43. Sample FSM from Quake 3 Emotional Combat Bot

This state transition is supplemented by:

- Anger occurring when frustration reoccurs.
    - Frustration occurring if irritation reoccurs.
    - Irritation occurring when the bots winning streak is affected by another bot or user.
- Fear response if agent is injured badly when an enemy agent approaches.
- Aggression being defined as a fuzzy logic value covering:
    - Attacking – Bot is being attacked and taking damage.

- Potentially Aggressive – Bot is being approached by an armed bot.
- No Aggression – Detected bot is liked.

When bots encounter each other, an object, or the user avatar, an appraisal is made and a fuzzy value is returned that in part, is used to determine the emotional response. The appraisal is based on a combination of whether the bot has any history with the encountered stimulus, and if the detected stimulus is showing aggressive behaviour. If no previous history is recorded for the encountered stimulus, then a fuzzy value is stored based on details of the encounter, i.e. if the bot is aggressive or not. Either way, the fuzzy value represents an aggression trait (mainly because this is prebuilt into *Quake 3* and can be used for altering behaviour), that is used with the previously mentioned FSMs to activate one of the following emotions fear, anger, sadness, happiness, startle or additionally no emotion (normal).

Figures 44, 45 and 46 show the key fuzzy logic variables that are used for some of the emotional appraisals shown in Table 21. This Table simplifies the deffuzification process normally required with using fuzzy values, which for a fast combat game where processing of decisions affects performance, is considered a good trade off.

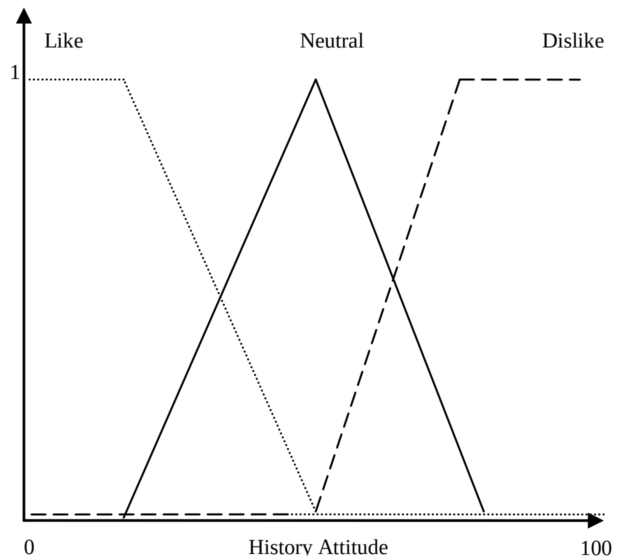


Figure 44. Fuzzy Logic Assignment of Like and Dislike.

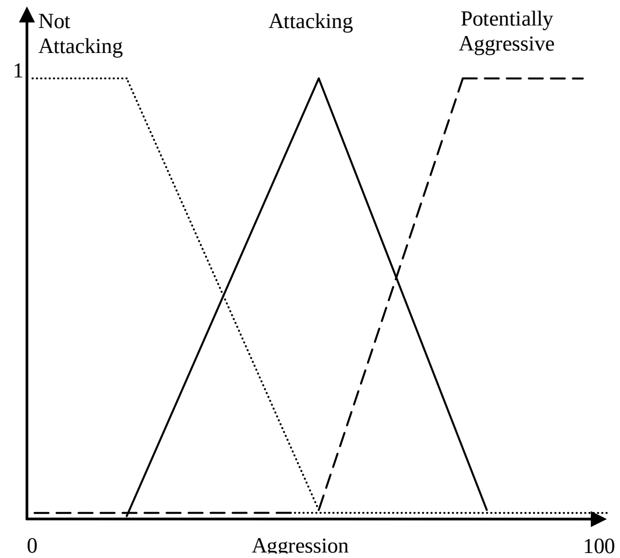


Figure 45. Fuzzy Logic Assignment for Aggressive Behaviour.

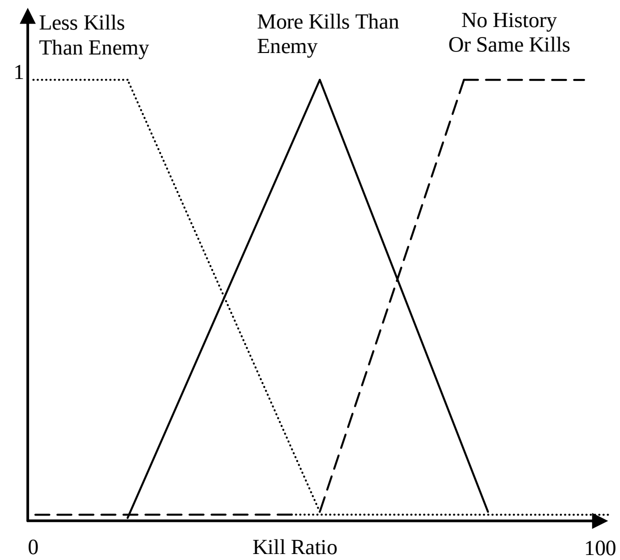


Figure 46. Fuzzy Logic Assignment of Kill Ratios

Liking	Aggression from Enemy	Kill Ratio (Threat)	Possible Emotions
Like	Very Aggressive	> Kills than Target No History <Kills that Target	I am being attacked by someone I like, therefore that might make me feel: *Angry* *Sad* *Afraid* Depending on their threat level to me.
Dislike		> Kills than Target No History <Kills that Target	I am being attacked by someone I Dislike, therefore that might make me feel: *Angry(More Angry)* *No Emotion* *Afraid* Depending on their threat level to me.
Neutral		> Kills than Target No History <Kills that Target	I am being attacked by someone I feel neutral about, therefore that might make me feel: *Angry* *No Emotion* *Afraid* Depending on their threat level to me.
Like	Potential Aggression	> Kills than Target No History <Kills that Target	I might be under threat from someone I Like, therefore that might make feel: *Angry* *Sad* *Afraid* Depending on their threat level to me.
Dislike		> Kills than Target No History <Kills that Target	I might be under threat from someone I Dislike, therefore that might make me feel: *Angry(More Angry)* *No Emotion* *Afraid* Depending on their threat level to me.
Neutral		> Kills than Target No History <Kills that Target	I might be under threat from someone I feel neutral about, therefore that might make me feel: *Angry(Less Angry)* *No Emotion* *Afraid* Depending on their threat level to me.
Like	No Aggression	> Kills than Target No History <Kills that Target	I have encountered someone I Like and they are not attacking me, therefore that might make me feel: *Happy* *Happy* *Fear* Depending on their threat level to me.
Dislike		> Kills than Target No History <Kills that Target	I have encountered someone I Dislike and they are not attacking me, therefore that might make me feel: *Happy* *Happy* *Slightly Fearful* Depending on their threat level to me.
Neutral		> Kills than Target No History <Kills that Target	I have encountered someone I feel Neutral about and they are not attacking me, therefore that might make me feel: *Happy* *Happy* *Slightly Fearful* Depending on their threat level to me.

Table 21 – Look up Table Intended to Reduce Computational Processing.

5.2.2.3 Startle Response

A function was added to the AI_dmnet.c file that is used when the bot encounters an enemy who was not seen coming. This function takes distance and visibility variables from the AAS and compares them to the entry in the EAD for *previous movement*, *time last seen*, *location last seen.* Referring back to Figure 23 in Section 4.4.4 it can be observed that the startle[9] response is the most suitable surprise reaction that uses these variables. Regardless if startle is activated, if a bot encounters something it has not seen before then the *movement*, *time last seen*, *location last seen* are written to the EAD.

5.2.2.4 Final Response

The fuzzy emotional state represented by aggression, liking, combat evaluation, and whether an emotion is related to this stimulus, are used together to form the emotional appraisal the outcome of which, is an emotionally motivated behaviour change (discussed later).

5.2.3 Unconscious Processing Module

Not implemented at this time.

5.2.4 Physiological Change Module

Quake 3 features a range of prebuilt animations for each bot, stored in the MD3 format. These animations allow a bot to display a range of behaviours through the fact that the bot is broken into three sections, a head animation, body animation, and legs animation. For this project modelling and animation were not a focus, thus physical signs of emotions that can typically be revealed through the face or body postures have not been implemented. Behaviours that have been implemented are focused on the positioning and movement of bots thus for example, when a bot experiences fear, it freezes.

5.2.5 Motivation Module

Bots in *Quake 3* currently use a combination of fuzzy logic and finite state machines to meet certain goals such as find player, find ammo, attack player etc. These behaviours can be altered by either adding additional functionality to the engine, or manipulating the fuzzy values associated with agent choices, the effect of behaviour change is invariably a forced state change.

[9] Though only startle was implemented at this time, the intention is that surprise, interest and shock can be added in subsequent implementations.

This use of fuzzy logic includes selecting how much a bot wants to do a particular action (to meet their goals) or how much they want a particular weapon. The fuzzy logic is used in combination with finite state machines to achieve objectives such as attack player, retreat when injured and chase enemy.

The changes to behaviour include:

- If *Startle* is activated then either:
    - Increased aggression if agent is irritated, frustrated or angry.
    - Agent freezes if startled and fear active.
    - Else no response.
- If *Fear* is activated, then bot will run away from the fear stimulus, its aggression value will be reduced to a nominal value causing the bot to avoid combat for the time being, until its aggression value increases.
- If *Anger* is activated, its aggression value is increased.
- *Happiness* and *Sadness* in this implementation merely have a textual display in the console; the agent's behaviour remains unchanged. This is intended to be expanded in subsequent implementations.

5.2.6 Conscious Realisation

Quake 3 features a pull down console (Tab key) and on screen text facility that was used to display particular emotional states, and their causes through textual information. These output methods were used to display the relevant emotions for the agents, but a facility to actually query a particular bots emotional state or bot feelings, was not added at this point.

Once the agents were coded, some software testing was conducted to ensure that the correct emotions activated when certain trigger events occurred (using the *Quake 3* pull down console for emotion output), before conducting two experiments based on both the user experience and the effect on bot combat effectiveness.

5.3 An Investigation to Examine if the User Experience is Affected by the Addition of Emotionally Enhanced Bots in Quake 3

5.3.1 Abstract

The purpose of this experiment was to investigate the effect on the user experience when interacting with both an emotionally enhanced and non-enhanced combat bot in Quake 3. This was achieved by allowing participants to interact with one of two conditions after which they completed a questionnaire. The first involved interacting with a non-emotionally enhanced combat bot (standard Quake 3 bot). The second was a similar scenario and combat situation, but this time the combat bots were emotionally enhanced. The results produced as part of this pilot study, offer some support to notion that users could see little difference between the two types of bot and thus their user experience in this instance is unchanged or at a stretch negligibly affected.

5.3.2 Introduction

Prior to the release of the Quake 3 engine and tools, the Quake 2 (called Quake II as well) was a common tool used by A.I. researchers such as Laird et al (Laird et al 2000) who applied the SOAR[10] (Laird 2000) architecture to the Quake II engine, in order to create more human like behaviour in combat bots. This was achieved in part by limiting a bots knowledge about the game to that of a human player, while allowing an experienced human player to interact with the enhanced bot. The final evaluation of the enhanced bot was based on video recordings of the bots and the human players to see if observers could identify which onscreen character was being controlled by a human or computer, i.e. a variation of the Turing Test. In this work the results gave some support that the humanness of the computer controlled bots was improved, but the observers were in general able to differentiate the computer controlled players from human opponents. Later work by Hooley et al (Hooley et al 2004), built on this work by adding fear to a Quake II bot through Fuzzy Logic and if-then statements. The results for this work were inconclusive, except to state some difference to the observable bots behaviour.

Reflecting on both of these pieces of research highlights two attempts that have been made to add human like behaviour to combat bots, but neither experiment really investigated whether the time and effort taken to implement these behaviours was worth the development time, i.e. did users actually notice a difference in the bots they were killing? To this end this experiment

[10] Soar is an engine for decision making in agents, based on if-then rules.

is intended to look at exactly this issue by allowing participants to interact with emotionally enhanced combat bots and attempt to answers two questions:

1. Do users notice changes to game-play when playing against emotionally enhanced combat bots?
2. Do users notice the added emotional characteristics?

It was intended, that the answers to these questions could be used to both provide an indication of the end-user experience of emotionally enhanced characters, and an indication to developers as to whether the time and resources required to implement emotions into combat bots, is a worthwhile investment. With these points in mind, a research and null hypothesis were specified to focus the investigation:

- Research hypothesis - “That the user experience is affected by the addition of emotions to combat bots.”
- Null hypothesis - “That the user experience is not affected by the addition of emotions to combat bots.”

5.3.3 Method

5.3.3.1 Design

The independent variable was:

- Condition 1: Participants played against non-enhanced combat bots.
- Condition 2: Participants played against emotionally enhanced combat bots.

The dependant variable was the exact same set up of scenario, including the same number of kills required to win, the same game level and the same number of combat bots. A between-participant design was chosen.

5.3.3.2 Participants

Fourteen participants took part in the study, all of whom were studying a Games Development course at the University of Wolverhampton. Participants were randomly allocated to one of two conditions meaning that there were seven participants in each condition. All participants were briefed and gave their consent to participate in this experiment, and were debriefed afterwards.

No ethical issues could be identified for this study either physically or psychologically, including both the nature of the study, and the environment used for the study.

5.3.4 Procedure

The first stage of the evaluation was to provide a pre-evaluation questionnaire to each participant; this is shown in Appendix 3.1.1. The Quake 3 game was started by the observer, and set to whichever condition the participant was allocated to, then each participant was then sat individually in front of the game in a lab. They were not told the exact nature of the study, but instead were told that they were interacting with a new type of combat bot and could they try and beat it. The rules were stated, which was a deathmatch set for a first to 15 kills wins. Once the game had ended, each participant was asked to fill in a post-game questionnaire (Appendix 3.1.3), after which they were debriefed as to the purpose of the participation.

The data gathered was then entered into SPSS version 14.0 based on the variable definitions shown in Appendix 3.1.4, Appendix 3.1.5 shows the raw data. Finally the data entered was analysed as discussed in the following section.

5.3.5 Results

This report began with the hypothesis that:

> “the user experience is affected by the addition of emotions to combat bots.”

To test this hypothesis the experiment was conducted as shown in the methods section, including the compilation of answers from a questionnaire shown in Appendix 3.1.3, which was completed by each participant after participating in one of two conditions, as discussed in the design. These results were processed in SPSS to gain the mean and standard deviation (SD) values, as shown in Appendix 3.1.6. A statistical analysis using an independent samples t-test was also conducted as shown in Appendix 3.1.7. The statistical results for each question are discussed next.

1. Did you enjoy playing Quake 3?

The mean score of 6.14 (out of 7) with SD values of 0.9 for condition 1 and 0.69 for condition 2 seems to indicate that in this small study that the participants did enjoy playing, and an analysis of the independent t-test results ($t(12) = 0.00$; $p = 1.000$; $d = 0.000$) show no statistical significance between the groups. This is indicative in this small pilot study that both groups equally enjoyed playing, furthermore it is being assumed that if users are engaged and enjoying the game that they are more likely to notice unusual behaviour, as they won’t be distracted.

2. Did you find the bots challenging?

The mean score of 4.57 (out of 7) with SD values of 1.134 for condition 1 and 0.976 for condition 2 seems to indicate that in this small study, that the participants did find the bots challenging, but not significantly so. An analysis of the independent t-test results (t (12) =0.00; p = 1.000; d = 0.000) show no statistical significance between the groups. With no significant difference between the two groups it could be assumed that the emotionally enhanced combat bots (slower performance and less combat effectiveness) did not have a significant detrimental effect on the participants' experience; otherwise it would have been expected to see less satisfaction with participants interacting with these bots. When considering why gamers did not particularly find either bot particularly challenging, it could possibly be because combat bots have improved since *Quake 3* and thus the participants may have interacted with more challenging bots before.

3. Did you win many games?

The slight difference in mean values of 5.25 (out of 7) for condition one (SD of 1.496) and 5.71 for condition two (SD of 0.756), could indicate that the e-bot is easier to beat than a standard Quake 3 bot. An analysis of the independent t-test results (t(12) =0.00 ; p = 0.512 ; d = 0.373) shows no real statistical significance between the groups, though it is suggested that there is a need for further studies in order to explore this question and to ascertain in larger studies whether there is any significant difference.

4. Compared to previous first person shooters did you notice anything different about these bots?

The difference in mean values of 2.00 (out of 7) for condition one (SD of 0.816) and 4.14 for condition two (SD of 0.900) indicates a difference between the two groups on what they noticed. An analysis of the independent t-test results (t (12) =0.00; p = 0.01; d = 2.49) confirms the statistical difference between the groups. From these results and in the context of this small pilot group the participants interacting with a standard Quake 3 combat bot understandably noticed little difference. The differences they reported may have been because they were asked the question, and felt they had to circle something. The participants who interacted with the emotionally enhanced combat bot did notice a difference in the bots they were interacting with compared to their experience of bots in FPS games, but these were not significantly noticeable differences as supported by a mean of 4.14 (out of 7). The actual differences are noted next.

4.1 What did you notice?

- Feedback from condition 2 included:
- 3 users noticed that the bots seemed to freeze occasionally.
- 1 user noticed the bots running away more often.
- 2 users said they thought the enemies seemed to be acting very aggressively.

5. Would a slower game with more human behaving enemies provide a challenge for you?

The mean score of 6.57 (out of 7) with SD values of 0.535 for condition 1 and 0.787 for condition 2, and an analysis of the independent t-test results (t (12) =0.00; p = 1.000; d = 0.000) show no statistical significance between the groups. The high mean value, is indicative in this small pilot study that both groups equally share the view of liking the idea of playing against more human combat bots even if the game pace was slower. The main area of further work suggested, is to try and ascertain what the participants idea of a more human combat bot is.

5.3.5.1 Overview

According to the results for participant enjoyment (Q1) and challenge (Q2), which in this study showed no difference in either mean values, or statistical significance, it can be stated that the addition of emotions did not alter the participants experience in these areas. The mean and t-test for whether participants noticed anything different about the bots (Q4) does show variations, including statistical significance of the data, indicating that when prompted, participants could describe differences between the conditions. The main issue is that participants had to be prompted and asked about this aspect, after which they did report as expected, the problem is it did not seem to affect their enjoyment of the game.

On the basis of these results the research hypothesis is rejected and therefore in this study, there is little support that the user experience is affected by the addition of emotions to combat bots in Quake 3.

5.3.6 Discussion

Overall conclusions are that the participants did not relate the observable bot behaviour such as freezing and running away to the programmed emotional response (but of course they were not expecting emotional behaviour), nor did the additions seem to affect their experience of playing the game. That is not to say that participants did not observe unusual behaviour, as evidence from this pilot group shows that several participants did notice bots behaving in an unusual way. When the participants were asked if they would like to see more emotional bots, the replies were a resounding yes, but certainly in this study the contradictory evidence indicating a largely unchanged experience does not support the extra development time required to implement emotions in this type of application. Therefore based on this outcome, further work in other application areas or genre of games is suggested in order to ascertain which ones might benefit from the inclusion of emotions.

The results presented and conclusions should not be taken verbatim for several reasons:

1) The pilot study was small, with a total of fourteen participants split into two groups.
2) A between-participant approach was taken, meaning that participants only got to experience one condition.
3) Participants were not told that the enhancement to the bot was emotional enhancement, and therefore feedback on emotional aspects of the bots could not be made.

5.4 An Investigation to Examine the Effect on Combat Effectiveness of Emotionally Enhanced Bots in Quake 3

5.4.1 Abstract

The purpose of this experiment was to investigate the effect on combat performance of a combat bot in Quake 3, compared to the emotionally enhanced combat bot discussed in section 5.2 and 5.3. The results show that the emotionally enhanced combat bots perform around 20% less well in combat than standard *Quake 3* bots. This was attributed to a blend of increased processing and the result of the emotional behaviour activations such as running away when afraid, freezing when surprised, and pursuing enemies when near death due to the activation of an anger state. It was concluded that reduced combat effectiveness alone should not be the only factor considered by developers looking at implementing emotionally enhanced combat bots, but the effect on user interaction is also important.

5.4.2 Introduction

This experiment follows on from the experiment discussed in section 5.3 concerning the effect on the user experience when interacting with emotionally enhanced combat bots in Quake 3. In the previous experiment, it was shown that the user experience was largely unaffected by the additions of emotions to combat bots, though when prompted, users who interacted with combat bots seemed to notice unusual behaviour. In this second experiment the emphasis is on how the emotionally enhanced combat bots perform in combat against standard Quake 3 bots. This evaluation was intended to observe how the emotionally enhanced bots performance is affected by the addition of emotions such as fear, which will cause it to run away in some types of situations.

With these points in mind, a research and null hypothesis were specified to focus the investigation:

- Research hypothesis - “That bot combat effectiveness is adversely affected by the addition of emotions.”
- Null hypothesis - “That bot combat effectiveness is not adversely affected by the addition of emotions.”

5.4.3 Method

The method followed involved pitting the emotionally enhanced combat bot against two other combat competitive bots[11] within a standard arena in *Quake 3*. To ensure enough statistical data was gathered, it was decided to allow the bots to repeatedly fight in twenty games and the bot who reached fifteen kills first, would win that game. These matches, provided over 698 combat encounters resulting in the death of a bot.

5.4.4 Results

For each of the matches the results were written to a text file and the results for the number of kills collated into tabular form as shown in Table 22. These results provide details of how many successful kills each bot made, how many games they won, and their total kills.

Game	Emotionally Enhanced Bot	Bot2	Bot3	Total Game Kills
1	12	15	7	34
2	15	5	4	24
3	2	7	15	24
4	12	15	13	40
5	5	12	15	32
6	6	15	6	27
7	15	12	14	41
8	3	15	12	30
9	11	11	15	37
10	15	14	12	41
11	12	14	15	41
12	13	15	12	40
13	11	12	15	38
14	15	14	14	43
15	11	14	15	40
16	14	11	15	40
17	12	14	15	41
18	8	15	7	30
19	7	6	15	28
20	8	15	4	27
avg	**10.35**	**12.55**	**12**	**34.9**
Games won	**4**	**7**	**9**	
Total Kills	**207**	**251**	**240**	**698**
As % of total kills	**29.7%**	**36%**	**34.3%**	

Table 22 – Results from The Quake 3 Combat Encounters

From the table it can be observed that the e-bot only won 4 of the 20 games, and only a total of 207 games compared to 251 and 240 for the standard combat bot. This would seem to support the research hypothesis, so to give a greater confidence a *statistical t-test was conducted which provided* (t (58) =1.997; p = 0.0604; d = 1.102) based on the results in Appendix 3.1.7. On the basis of this statistical t-test the, results are not quite statistically significant, and as such the research hypothesis is rejected as there is not enough statistical evidence to support the fact that

[11] The other two bots were instances of a standard bot in Quake 3 called Bones, the emotionally enhanced bot was a modified Bones bot.

emotionally enhanced agents in this pilot study perform less well in combat than standard Quake 3 bots, though from observing the number of kills and games won, there is a need to conduct further experiments.

5.4.5 Discussion

The purpose of this experiment was to investigate whether the addition of emotional characteristics to a combat bot adversely affected its combat performance. The implementation and evaluation chosen, were based on a bots combat effectiveness simply because the purpose of *Quake 3* is to find and kill other players or bots. Referring back to the results shown in Table 22, it can be observed that the emotionally enhanced bot in over 300 combat situations involving the death of another bot are getting around 20% less kills, and won only 4 games out of 20, against an expected 6.66 (average) games. That means the emotionally enhanced combat bot was approximately 2.7 games below the average, and the other two bots were 0.3 and 2.3 above average indicating some significance. Because the hypothesis involved combat performance i.e. number of kills, and not number of games won, the actual number of kills for each game were analysed using a statistical t-test. Surprisingly it was found that the number of kills was not quite statistically significant indicating that the emotionally enhanced combat bots, though running away and freezing due to the activation of emotions, do not seem to be performing as adversely as expected. Therefore based on this pilot study, and the previous pilot study involving user interaction with the same bots, it can be suggested that the user experience and bot effectiveness are seemingly unchanged when emotions are added to this type of agent. Of course these pilot studies need further development, especially in larger studies involving increased sample sizes to ascertain if the statistical significance is unchanged, and whether a bots ability to win games rather than kill is something that should also be tested for statistical significance.

5.5 Adding Emotions to Computer Controlled Avatars in Second Life

As discussed in Section 2.5, Second Life supports chat bots through a combination of a third party interface such as libsecondlife, and a back-end expert system such as the one mentioned in section 2.5.4.1, called Altair. The intention of this implementation is to add emotions to the chat bots in Second Life through adding an emotional component (shown as Emotion Engine) to Altair as shown in Figure 47. Altair was chosen for this implementation, as the developer of Altair was looking to add an emotional aspect to the architecture including a software implementation (that they were happy to do); as such it seemed a logical choice.

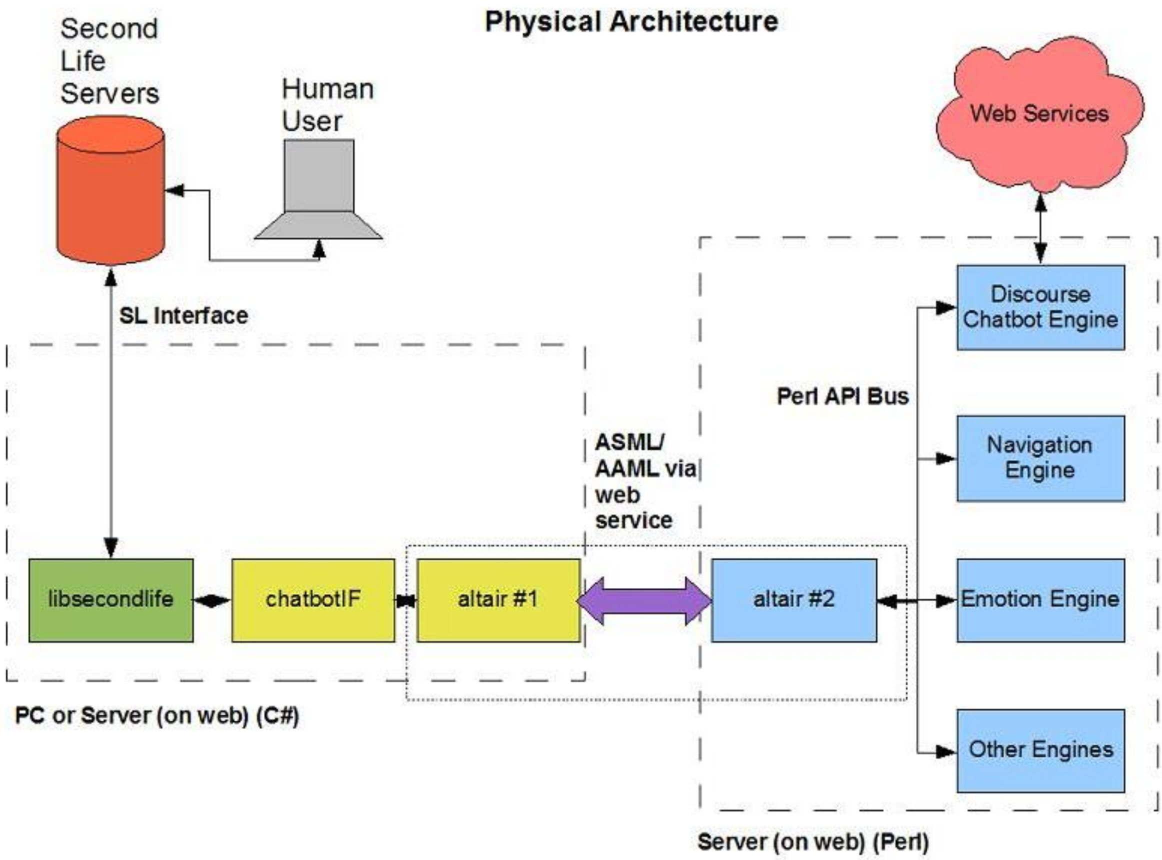


Figure 47. Revised Altair Architecture Showing Emotional Engine

The general method for this implementation was to add emotional enhancements based on the E-AI architecture to the chat bots decision process which will ultimately affect the avatars movement, speech (textual), and gestures. This integration could potentially create a more human-like chat bot.

In order to integrate emotions into the chat bots in Second Life, a mapping was required of the E-AI architecture specified in Chapter 4, to the chat bot functionality in Second Life, via Altair. This mapping is what forms the remainder of this section.

5.5.1 Detection Aspect

World data is passed from Second Life through *libsecondlife* to a back-end program called *ChatBotIF*. This data includes details about:

- the local environment
- other avatars location, behaviour, speech
- objects, locations, behaviours

This data is via an ID assigned to avatars and integer for objects that can then be used to represent *Stimulus Description* in the E-AI architecture.

5.5.2 Appraisal Aspect

An emotional alert database (EAD) as proposed in the E-AI architecture, was added, that supports the five category one emotions of anger, disgust, fear, happiness and sadness, as well as startle and surprise. The developer chose to weight each stimulus with an emotional value for each emotion, and to then take the emotional values for each of the five emotions and uses fuzzy logic to derive the new emotional state. The underlying process employed was to balance the dominant emotion against other currently experienced emotions, to always have one overriding emotion. Surprise and startle were incorporated based on information from *libsecondlife*, and the entry in the EAD as specified in the E-AI architecture.

5.5.2.1 Chat Appraisal

Emotional chat appraisal was implemented using an XML schema called ASML (Burden 2008). ASML (Avatar Sensory Markup Language) in essence, allows emotions to be tagged to detected input text i.e.

> "I don't like you" heard by bot, then an emotion linked could be anger or sadness.

5.5.2.2 Moods

Referring back to Section 2.1, emotional responses were defined in terms of a very short duration event, moods as longer term persistent emotions. When incorporating the E-AI architecture into Altair, the developer decided to represent the current mood state with fuzzy logic, and combine the current emotional response with this fuzzy value, in order to provide a starting point for including a mood aspect to the chat bot. To simulate mood decay, the developer applied a "half-life" factor to the current mood, so that the mood will decay over time, unless a subsequent emotion is activated.

5.5.3 Unconscious Processing Aspect

Unconscious physiological reactions are not easily implemented due to the granular nature of the reactions such as elevated blood pressure and galvanic skin responses. However after discussions within the development team, it is considered feasible that in future projects, subtle physical skin changes such as blushing (embarrassment), pale skin (sadness), and hairs standing on edge due to skin contractions (fear) could be processed away from the physiological change to provide a new aspect to emotional visibility where bots in the virtual world could have the ability to show small physiological changes.

5.5.4 Physiological Change Aspect

Depending on the emotional response, a call was sent to the *Agent Manager Class* in *libsecondlife* to update the chat bots appearance. This was specifically through the *Animate* and *Animation* methods. In this implementation, this simply activates one of the readily available responses in Second Life such as displaying an angry gesture when angry. It is expected that this will change in future implementations to provide a more subtle response.

5.5.5 Motivation Aspect

When an emotional response such as anger is activated, then this is processed via an XML schema called AAML (Avatar Action Markup Language) (Burden 2008) which is designed to control the bots behaviour such as its movement to run away or to freeze. This is then sent to *libsecondlife* for activation by the chat bot in Second Life. Additionally the developer implemented a habituation aspect to the emotions so that repeated exposure to the same emotional stimulus would reduce its effects.

5.5.6 Conscious Realisation Aspect

Recent emotional changes and subsequent moods are stored in the chat bots database and thus can be queried i.e.

Query – "Why are you happy?"

Replay – "I am happy because " + **whyhappy** from database.

5.5.7 Initial Testing

Once the five basic emotions, plus startle and surprise were integrated into the Halo Bot, it was decided that some emotionally challenging situations would need to be implemented in order to observe the bots behaviour. With the developer's expertise in *Second Life*, he chose to place objects in the bots vicinity that she would encounter whilst travelling, and these objects would have an associated emotional significance, examples included a snake, which was given an association of fear (as shown in Figure 48).

Figure 48. Scenario Featuring a Snake in the Second Life World.

Another example was a rabbit that had an associated happy emotion.
Both entries are shown in Table 23 as part of the EAD incorporated into the Emotion Engine in Altair.

Stimulus	**Emotion**	**Value**	**Habituation**
		0-100	*Multiplicative factor*
Snake	Fear	100	0.95
Rabbit	Happy	50	0.4

Table 23 – Sample EAD Entries

Over several repeated runs of the simulation by the developer, it was noted that when Halo encountered the snake, a fear response was registered in the output file as well as Halo stepping back, an action that has been programmed to occur during a fear response. During repeated experiments, additional snakes were placed together, and due to the habituation modifier Halo's response reduced as she became habituated to the snake-fear stimulation. Additional experiments included placing a rabbit near Halo, and this was shown to produce a happy response. As a second and third rabbit were added, the response diminished until it becomes extinct.

5.6 An Investigation to Discover If Users Prefer Interacting With Emotionally Enhanced Chat Bots in Second Life

5.6.1 Abstract

The purpose of the experiment was to investigate the effect on the user experience when interacting with both an emotionally enhanced and non-enhanced chat bot in Second Life. This investigation was primarily concerned with whether users preferred interacting with emotionally enhanced chat bots in Second Life. This was achieved by allowing participants to interact with two conditions after which they completed a questionnaire. The first involved questioning a non-emotionally enhanced chat bot on a range of questions provided by the observer. The second was a repeat of the session, but this time the user interacted with an emotionally enhanced chat bot after which, participants were asked to complete a questionnaire on the session. The results produced as part of this pilot study, offer some support to notion that users noticed the differences between two identical looking chat bots, and do in fact prefer interacting with the emotionally enhanced chat bot.

5.6.2 Introduction

The purpose of the experiment was to investigate the end-user’s response when interacting with an emotionally enhanced chat bot. The evaluation involved a range of users, some of whom may have encountered chat bots previously and others who may have played games or used virtual worlds. This range of users was deemed necessary because the chat bots under test, exist in the virtual world *Second Life*, and future uses are intended for similar virtual worlds including games. The participants interacted with both an emotionally enhanced chat bot and a non enhanced chat bot and reported:

- on any observations they made
- which chat bot they preferred?

It was intended, that the answers to these questions could be used to both provide an indication of the end-user experience of emotionally enhanced characters, and an indication to developers as to whether the time and resources required to implement emotions into chat bots, is a worthwhile investment. With these points in mind, a research and null hypothesis were specified to focus the investigation:

- Research hypothesis - users prefer interacting with the emotionally enhanced chat bot
- Null hypothesis - users do not prefer interacting with the emotionally enhanced chat bot

5.6.3 Method

5.6.3.1 Design

The independent variable was:

- Condition 1: Participants questioned normal chat bots.
- Condition 2: Participants questioned emotionally enhanced chat bots.

The dependant variable was the exact same set up of scenario, including the same physical appearance for both chat bots, and the same questions. A within-participant design was chosen.

5.6.3.2 Participants

All twenty five participants for the evaluation were postgraduate students studying human computer interaction (HCI) and usability at the University of Wolverhampton. These participants were expected to have a range of diverse backgrounds related to the use of software interfaces, in this context chat bots were being classed as software interfaces. The participants are a mix of age groups, genders and nationalities. All participants were briefed and gave their consent to participate in this experiment, and were debriefed afterwards.

No ethical issues could be identified for this study either physically or psychologically, including both the nature of the study, and the environment used for the study.

5.6.4 Procedure

The first stage of the experiment was to provide a pre-evaluation questionnaire to each participant; this is shown in Appendix 3.2.1 with a matching justification report. Each participant was then sat individually in front of a PC in a lab. The Second Life application was started by the observer, and the avatar the user was assigned to question, was placed in front of them, which was either a normal chat bot (condition 1) or emotionally enhanced chat bot (condition 2). Participants were not told the exact nature of the study, but instead were read out instructions as shown in Appendix 3.2.3, in short they were told that they were supposed to try and find information from a chat bot based on a list of questions they were supposed to ask, as shown in Appendix 3.2.4. Once they had completed the first task, they were asked to repeat the experiment with the alternative condition before filling in a post-evaluation questionnaire. Finally they were debriefed as to the purpose of their participation (Appendix 3.2.5).

5.6.5 Results

This report began with the hypothesis that:

users prefer interacting with the emotionally enhanced chat bot

To test this hypothesis the experiment was conducted as shown in the methods section, including the compilation of answers from a questionnaire, which was completed by each person after participating in both conditions. These results are discussed next.

Question 1: Did You Complete All of The Tasks?

Though the question does not have an obvious bearing on whether or not users noticed the emotional characteristics, it could indicate whether users were able to use the interface, and as such whether they spent sufficient time observing the bots responses and behaviour. In the results obtained the mean value was 5.36 (out of 7), with a Standard Deviation (SD) of 1.58 which is indicative that on average users completed most, but not all of the tasks.

Question 2: Did You Find The Information Required?

Following on from Question 1, it can be seen that the mean of 5.36 (out of 7) with a SD of 1.69, is not surprising as it would be expected that users who completed the task were likely to report finding the information requested. *Note: maybe in future runs this question should be integrated into Question 1.*

Question 3: Did You Notice Any Difference Between the Chat Bots?

The mean of 3.52 (out of 7) with a SD of 1.50 reflects the fact that users sometimes noticed differences between the chat bots, but not significant differences from their perspective. Looking at the individual results, only two from the 25 participants actually noticed a clear difference, though 17/25 (68%) users noticed some differences, giving a total of 19/25 users (76%) noticing something different. The indication from this result is that the difference between the bots may have been subtle which could be explored further in subsequent studies, and its significance further examined.

Question 4: Did you notice Any Human Like Traits in the Chat Bots?

Not surprising here, is that the mean of 4.24 (out of 7) with a SD of 1.71 indicating users sometimes noticed human like traits is probably because both chat bots look human, and as such the question is probably flawed in that it is unclear from the users perspective what human like traits they are reporting on. *Note: This should probably be removed as a question in future runs.*

Question 5: Would You Use a Chat Bot Interface if a Human Operator was Not Available?

This question was asked at the request of Daden Ltd, the commissioning company and for this experiment has no bearing in the present context.

Question 6: Which Chat Bot Would You Prefer to Chat to in a Virtual World?

The mean of 4.76 (out of 7) with a SD of 2.20 is indicative that users were leaning towards the emotionally enhanced chat bot (HALO B), so a closer look at the actual results was carried out. This revealed that 56% of participants preferred the emotionally enhanced chat bot compared to 20% of participants who preferred the standard chat bot. The remaining 24% of participants did not mind which chat bot they interacted with. Therefore a statistical one sample t-test was conducted as shown in Appendix 3.2.6 where ($t = 10.283$; $df = 24$ and the significance = 0.000) which means that the outcome is a statistically significant result. On the basis of this result, the research hypothesis is accepted and therefore in this small pilot study, there is some support to the notion that users do prefer interacting with an emotionally enhanced chat bots.

5.6.6 Discussion

So in this small pilot study, participants noticed subtle differences between two identical looking chat bots where one was emotionally enhanced. These observations were made while observing the chat bots behavioural and textual responses over a period of around 10 minutes during which time, the participants were engaged in a question and answer session with the chat bots. Once users had interacted with both chat bots they reported on a range of areas including which chat bot they would prefer to engage with, and as already stated there was a significant preference towards the emotional chat bot.

The results presented and conclusions should not be taken verbatim for two reasons:

1) The pilot study was small, with a total of twenty five participants, as such further studies need to be undertaken to strengthen the results.

5.7 Adding Emotions to Web Based Chat Bots

The following implementation, builds upon the background research conducted in Section 2.5, and involves the addition of emotional characteristics to a prototype chat bot for an online technology specialist. The chat bot is intended to interface to the currently existing customers' web site and offer visitors a complementary help facility to help guide them to the products and services available from the company. Once active, the pre-programmed responses from the back-end expert system will mean that the chat bot should be active as long as the underlying web site is on-line, giving the company a virtual online Q & A (questions and answers) facility. The addition of emotions to the visualisation and conversation systems is intended to provide an additional interactive feedback dimension. The general method for this implementation was to add emotional enhancements based on the E-AI architecture to the chat bots text-parser mechanism which ultimately affects the bots on screen appearance and answers to questions. Because this research is not concerned with developing chat bot back-end and client technologies, but instead is concerned with how the E-AI architecture could be applied to currently existing platforms, detailed discussions on chat bot design are not included, although a background is covered in Section 2.5. Instead, it is suffice to say that the back-end chat bot software used in this implementation, is extremely similar to the one employed in the previous Second Life implementation as discussed in Section 5.5. Therefore for the remainder of this section concerns the mapping of the E-AI architecture to the chat bot under discussion.

5.7.1 Detection

Only chat information is available. Therefore the chat bot detects emotions through a chat interface using text, linked to an XML schema similar to ASML discussed in the Second Life implementation in Section 5.5.2.1.

5.7.2 Appraisal

Because the chat bot back-end technology in this implementation is based on the previous Second Life chat system, the intention is to discuss the major difference which is the inclusion of a frustration mechanism based on Section 4.4.6.

5.7.2.1 Frustration

If the chat bot is unable to answer a question it begins raising a frustration flag, and produces a response of:

“Sorry I do not know what you mean”

It is suggested that:

- Two consecutive “could not find answers” to the same question – the bot raises the frustration flag and asks if the “user meant xxx”, where xxx is a match to another question with a lower number of word matches.
- Three consecutive “could not find answers” to different questions – the bot apologises and suggests a few possible choices based on an even lower word match to the user question.

The exact number of frustration flags can be fine tuned with consequent matches, to enable the bot to detect frustration more accurately.

Example

When the chat bot is unable to find the correct answer, i.e. a match is not found in the XML schema the bots frustration level is raised:

- If the frustration level is 0, it is raised to 1, the bot shows a surprised animation, and then says it doesn't know what the user means.
- If the frustration level is 1, it is raised to 2, a frustrated animation is shown and it apologises to the user. It then tries an 80% word match to see if it can find matches.
- If the frustration level is 2, it is raised to 3, a frustrated animation is shown and it apologises to the user. It then tries a 60% word match to see if it can find matches.
- If the frustration level is 3, it is raised to 4 the threshold for anger, therefore an angry animation is shown and the bot says it simply doesn't know the answer and can it help with anything else.
- If a correct answer (100% match) is found the bots frustration level is set to zero, else if a lesser match is found frustration is reduced by 1 level.

5.7.3 Unconscious Processing

Not incorporated

5.7.4 Physiological Change

Physiological change involves both arm movements and facial changes involving the eyes, lips and arm movement. The facial aspects of each were based on Premo (Desmet 2003) which is a visual tool that is used to identify user emotions.

5.7.5 Motivation to Act

As only a text response and animation are available for the chat bot, these have already been discussed in the preceding sections where they differ to the Second Life implementation.

5.7.6 Conscious Realisation

Chat bots emotional states, and triggers are stored so that the chat bot can be queried on its current emotional behaviour as in the Second Life implementation.

5.7.7 Web Chat Bot Testing

As the chat bot was controlled by a back-end expert system, testing was broken into two stages:

- *Basic emotion testing* was conducted with repeated runs of the chat bot to see how the bots emotions changed with blunt emotion change via hard wired changes such as "act_sad" and "act_angry".
- *Frustration testing* from repeated runs with varying levels of frustration allowed to sometimes saturate into anger, and other times reduce to a neutral emotional state.

For both stages, the chat bot was modified to give a visual display of data onscreen.

Initially repeated runs of the chat bot were performed using blunt emotional changes to ensure that emotion activation performed as expected, this was achieved by providing key words in the XML schema, linked to saturated emotional states. The purpose of the testing was to be able to observe changes to emotions of the chat bot.

Hardwired keywords were:

1. Act_neutral
2. Act_frustrated
3. Act_surprised
4. Act_angry
5. Act_sad
6. Act_happy
7. Act_scared

Over twenty repeated runs, it was found that activation of the emotions performed as expected. Randomisation of emotionally significant and standard questions was performed using a random number generator, thirty questions were asked during each run, giving a total of 600 questions.

The testing was repeated to test frustration, by deliberately asking questions the bot did not know. Similar testing parameters were used, with around twenty repeated runs with random variations of correct and incorrect answers to see the effect of frustration escalation and reduction.

It was noted that some future work could be conducted to allow a transition between emotion visualisations, and the need for a variation in each visualisation to allow degrees of emotion i.e. angry, getting angrier, furious. Additionally, some further work is required to tweak frustration levels to more closely match human behaviour, i.e. should the bot become irritated if the user simply asks the same question over and over again, but the bot provides the correct answer?

5.9 *The First Revision of the Architecture*

The first implementation of the E-AI architecture into a software solution involved integration into the Quake 3 engine as discussed in section 5.2. This was based on the first draft of the architecture as shown in Figure 51. Over the course of the implementation and during final discussions, feedback from the developer included:

- Uncertainty as to how to break certain emotions down such as anger i.e. frustration and irritation.
- The overall architecture was thought to be difficult to follow in places.
- Some aspects such as surprise were deemed too complicated to implement and needed simplifying.

5.9.1 The Second Revision of the Architecture

Based on feedback from the first draft of the architecture several revisions were made including:

1. More detail was added to both emotional appraisal and behaviours in Sections 4.4, 4.6 and 4.7.
2. Further evaluation was deemed appropriate and so a range of techniques were investigated as shown in Section 3.3.
3. The appraisal of stimulus was revisited and changes made to reduce complexity, as reflected in Section 4.4.
4. The E-AI architecture was revisited to simplify aspects such as appraisal.
5. The notes from the *Quake 3* implementation were provided to the developer working on the Second Life implementation.

With a refined architecture and notes available on the first implementation, considerably less time was spent with the developer on the Second Life implementation than on Quake 3.

5.9.2 The Third Revision of the Architecture

During the *Second Life* development discussions it was suggested that the module conscious realisation could be implemented to include graphical skin changes and stored variable details such as heart rate. Based on these discussions, recommendations were added to the proposed architecture, and are discussed in Section 4.8. Other additions included slight changes to the architecture overall to now include recommendations on including chat systems to enhance games, virtual world and web based characters. The final feedback on the architecture from the developer can be seen in Appendix 5.

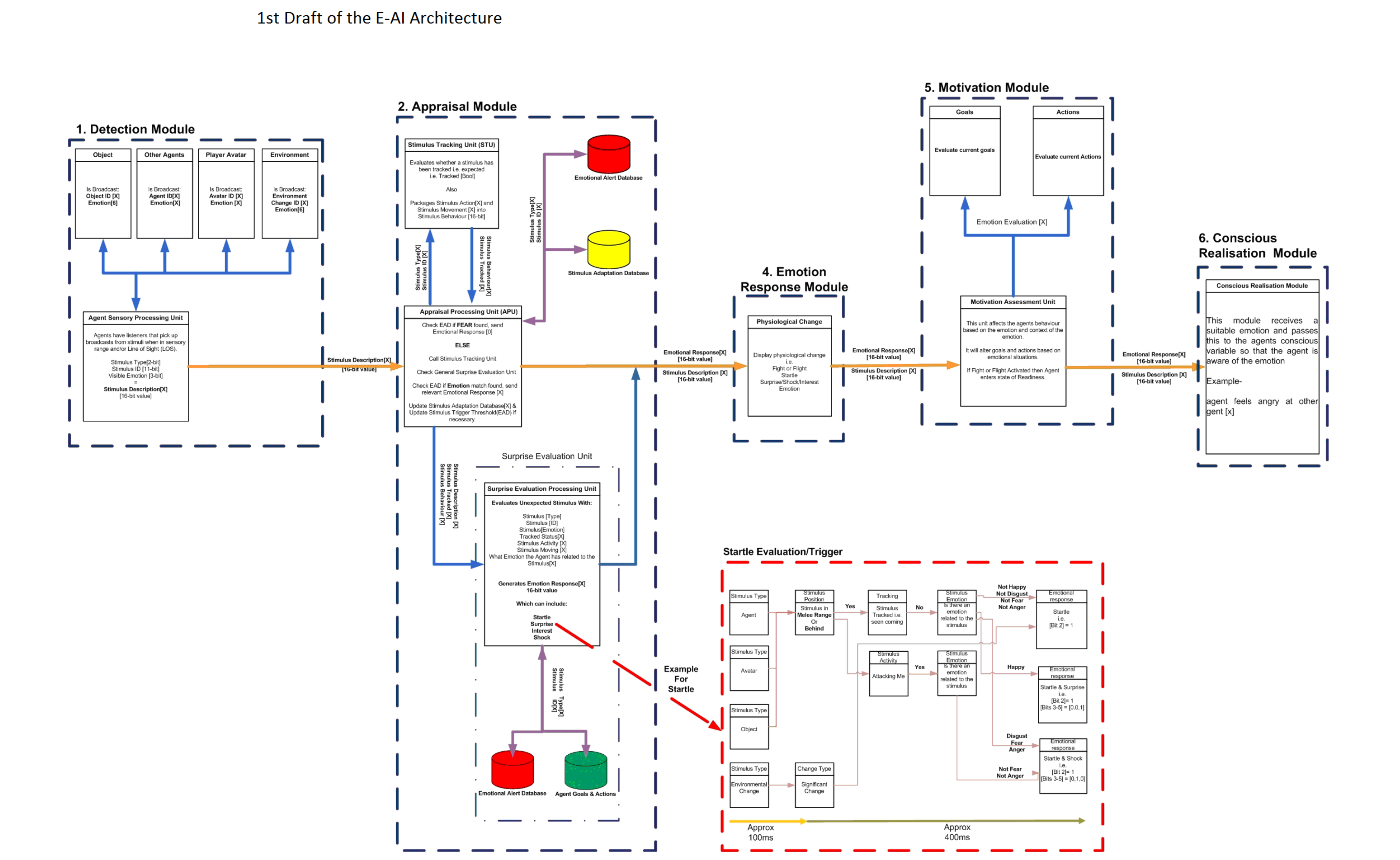


Figure 51. First Draft of the Architecture.

5.10 Implementation Summary

5.10.1 Quake 3 Summary

The implementation of emotions into combat bots in *Quake 3* revealed a concern with spending developer time and resources implementing emotions into agents that do not seem to affect the user experience in a positive way. This lack of affect of the user experience may have been because the combat bots in this genre of game are:

1 constantly moving – so difficult to see

2 often moving away from the player - so not always predominant on the screen

3 killed quite quickly, thus their life expectancy was extremely short (as low as a few seconds in some instances)

With these three points in mind, emotionally enhanced agents in this genre of game may not always be cost effective for developers when considering playability against software development costs. Further discussions with developers, and user-focused research clearly needs to be undertaken at a future stage to highlight which genres of games might best utilise emotionally enhanced characters.

5.10.2 Second Life Summary

Adding emotions to a computer controlled avatar in *Second Life* (chat bot), produced interesting results in so much as *Second Life* predominantly features player controlled characters that can only emotionally respond if the user chooses to do so through keyboard shortcuts, and does not as standard reflect the users' emotional state. By adding emotions to the chat bot in *Second Life,* it became possible to see automatic emotional behaviours based on pre-defined stimulus that was presented to the chat bot, and textual queues while involved in interactive chat. These emotional behaviours mean that users could potentially see emotional responses from chat bots and thus their role within virtual worlds such as *Second Life* needs careful consideration especially if the purpose is to create the illusion of a user controlled entity. Alternatively, if the purpose is to create a more autonomous and emotionally enhanced character then the applications of more human-like chat bots could include, simulations and e-drama applications, where the addition of emotions could make the chat bot more engaging and believable.

5.10.3 Web Avatar Summary

Web chat bots such as the one developed as part of this research, can interact with the user and provide expert system answers to common questions, without the need for a real human call centre operative.

In this case study, five category one emotions, and frustration were added to the chat bot through an XML schema similar to the one used in Second Life. The main difference is that users interacting with the Second Life chat bot might expect emotions in the virtual characters, but more work needs to be undertaken in web chat bots to ascertain the expectations of a typical end-user when interacting with an e-commerce chat bot i.e. will a chat bot that can become frustrated, angry or disgusted have an adverse effect on business. Also, what is clear from observation is that further work needs to be conducted to examine how words and sentences should be processed to provide a more accurate emotional response.

5.10.4 Final Comments on Implementations

The original direction of this research involved investigating whether psychological emotion-research could be presented in such a way that developers/researchers could integrate the foundation of knowledge into their pre-existing agent behaviour and visualisation systems. Initial discussions and background research, support the idea that a range of emotion research, including some conflicting theories can be synthesised into an emotion architecture that could be applied to a range of applications including games, web avatars and chat bots in virtual worlds. The range of target platforms did raise some issues with the original architecture, and as such it was revised based on feedback from commercial developers. This revision process resulted in a final architecture that is non-platform, non-programming language specific but focused on deploying solutions based on a foundation of formal psychology. This architecture was successfully implemented by external developers into the three target platforms and subsequently user interaction occurred after two of the implementations. In the fast paced combat scenario (Quake 3), data gathered from participants did not show a statistically significant change to the user experience, though users did notice the bots emotional behaviour such as running away and freezing. In a second experiment in Quake 3 which was designed to see if combat effectiveness was changed, from the data gathered it did seem that the emotional bots were performing less well in combat, but upon further analysis it was discovered that this was not quite statistically significant. With the Second Life implementation users spent approximately ten minutes with each chat bot and as such when they were asked in a blind test to identify which chat bot they preferred, a statistically significant number did choose the emotional chat bot. The resultant architecture can be applied to many types of "agent", in a diverse range of application areas, but has a boundary that it would appear from the small pilot studies that it is better suited to more interactive applications where the user spends a longer period with the emotionally enhanced character. The fact that developers were able to implement the architecture which was based on a foundation of formal psychology does begin addressing the initial research question.

Chapter 6: Conclusion

6.1 Meeting the Research Objectives

The research started with the question:

"*Can an emotional architecture be developed for commercial games and virtual worlds, that is built upon a foundation of formal psychology?"*

which was considered to be best answered by the identification of five research objectives, each of which has been explored as part of this research, and the extent to which each objective has been met is discussed below:

(Objective 1): Research needed to be undertaken in order to gain a better understanding of the psychology of human emotions.

Section 2.1 was included to meet this objective through a discussion involving the psychology of emotions. This discussion was an attempt to present a cohesive explanation of much of the terminology associated with emotions such as moods, feelings and the stages of emotion. This presentation of emotional research included the development of a supplemental glossary of terms (Appendix 2) to aid clarification especially in the vernacular use of emotion terminology. With the review complete, the reader should have a good grasp of "emotions", from a psychology viewpoint, and be able to apply this to developing their own computational model of emotions, or to be able to understand aspects of an adopted model. This bringing together of emotional psychology aimed at virtual characters is an original contribution to the work.

(Objective 2): Existing computational models of emotions need to be investigated specifically on their underpinning psychology theory.

Section 2.2 was included to meet this objective through an investigation into computational models of emotion and their underlying basis in psychology. Through this review, it was shown that from the models reviewed, most were not based on very much formal psychology, or at least evidence of their basis was lacking. Some models were shown to be based on the OCC model of emotion (Ortony et al 1988), which itself is only based on one aspect of emotion, the appraisal of a stimulus. Because appraisal of a stimulus is central to the mechanism of emotions, *like* and *dislike* featured in the OCC model were considered to be useful inclusions for the architecture being proposed.

> *(Objective 3): The findings from the psychology of emotions needs to be integrated in order to present an emotion architecture suitable for characters in games and virtual worlds. This would need to include suitable A.I. and machine learning techniques that could be used to model aspects of the emotions.*

The proposed E-AI architecture (shown in Chapter 4) is based on Scherer's six stage emotional process model (as discussed in Section 2.1), which has been adapted by combining it with several related areas including a categorical approach to emotions, to include the five emotions anger, fear, disgust, happiness, sadness and the transient condition surprise. The synthesis of this foundation of psychology of emotions is a core part of the research and contributes to the originality of the work presented here. Section 2.3 details A.I. techniques suitable for modelling aspects of emotion such as finite state machines and fuzzy logic to model anger transitions.

> *(Objective 4): Evaluation techniques would need to be identified that are suitable for any subsequent implementation.*

Section 3.3 and 3.4 revealed a wide range of evaluation techniques suitable for evaluating agents in virtual environments. Through these sections, a methodology was described that combines several of these areas to more fully evaluate a range of emotionally enhanced agents (whether they are based on the proposed architecture or not). Aspects of this evaluation methodology related to user interaction were applied to the implementations of the architecture as discussed in Chapter 5, in order to partially validate the proposed architecture. The inclusion of a methodology for evaluating agents with emotions also contributes to the originality of this research by drawing together techniques from commercial game developers, psychology and usability to provide a range of applicable techniques to more fully evaluate the end-user experience when interacting with emotional agents. The recommendation to include a feedback mechanism in agents so that they can be queried about their emotional state is advantageous to developers who may prefer an evaluation tool that closer mimics human self reporting.

(Objective 5): Finally aspects of the architecture would need to be integrated into software solutions to support validation of the architecture.

Three implementations occurred as part of this research as detailed in Chapter 5. These three developer focused implementations meant that developers were given the specification for the architecture, and were able to integrate aspects of this into their virtual agents. The revision process that occurred after each implementation meant that the architecture was fine tuned in order to widen its applicability. It should be noted that this was done without affecting its formal psychology basis and thus its applicability as an emotion architecture.

6.2 Answering the Research Question

The meeting of the research objectives, and the publication of several research publications based on the work as shown in Appendix 1, provides a solid foundation of research that underpins the proposed architecture. The resultant E-AI architecture and subsequent implementations, provides some support that the architecture is applicable across games, virtual worlds and web chat bots. These implementations each applied aspects of the architecture to meet the needs of the project and the feedback from each, allowed further refinements to be made, without affecting its fundamental structure. The evaluation of each implementation, provided a partial validation of the architecture so that the question originally presented in Chapter 1:

"*Can an emotional architecture be developed for characters in games and virtual worlds, that is built upon a foundation of formal psychology?"*

could be answered within the scope of this work. This answering of the research question does of courses come with some limitations as discussed next.

6.3 Limitations of the Research

The architecture presented potentially provides the basis for adding emotions to characters with at least the following aspects possible:

- A six stage emotion process of *detection*, a*ppraisal*, *unconscious reaction*, *physiological change*, *motivation* and *conscious realisation*.
- Six basic emotions including anger, disgust, fear, happiness, sadness and surprise. Each emotion includes:
  - Descriptions of triggers
  - Details on visible changes required by modellers.
  - Changes to behaviour for integration into current A.I. systems.
  - The surprise aspect can be separated into startle, interest, shock and surprise.
  - Each emotion has an intensity level, and some such as anger have stages of escalation.
- Support for secondary and tertiary emotions, though not described in detail (see section 6.4).
- Details about emotional duration including decay and moods (persistent emotions).
- Example A.I. techniques for modelling aspects such as the stages of Anger.
- Details of evaluation techniques applicable to emotionally enhanced agents, including applied examples that partially validate the proposed architecture.

The architecture has also been applied by developers to a range of application areas including a computer game (Quake 3), a virtual world (Second Life) and a web interface (web chat bot). From the Quake 3 implementation, there is some indication from the evaluation that the effort to put emotions into the non-player characters may not have been a wise investment of time, as the users experience in the pilot evaluation was not significantly changed. This differed in the Second Life implementation; where users preferred interacting with the emotionally enhanced chat bot. It is of course accepted that the small scale evaluations do need some further exploration to provide stronger evidence, but it would seem from the results obtained, that there is some support for the notion that the architecture is better suited for applications where more interaction occurs between characters and the users, and not applications where this interaction is based on brief encounters such as in many first person shooter games.

6.4 Further Work

The research presented focuses on the five basic emotions (plus surprise) suggested by Ekman (Ekman et al 2003). These emotions have been clearly described in section 2.1, and implemented in three applications as discussed in Chapter 5. Due to the usage of basic emotions rather than valenced emotions (Plutchik 1980), it is possible that simultaneous emotional states such as anger and happiness can occur at the same time albeit at different intensity levels. As discussed in Section 2.1, Damasio (Damasio 2000) suggests that secondary emotions are a blend of basic emotions, and as such, agents currently based on the E-AI architecture will exhibit a varied range of emotional states beyond the five basic states of anger, happiness, sadness, fear and disgust. The full documentation of these emergent behavioural characteristics (secondary and potentially tertiary emotions) is beyond the scope of this research project, but could form the basis of further work. This further work could be users interacting with agents that show a range of secondary and tertiary emotions and reporting back on their subjective observations. This would start the process of gathering data that could be used to formulate a look up list of secondary and tertiary emotions for further validation or applicability of the proposed architecture.

The previous recommendation of further work using subjective reporting, could also be extended to include personality types as discussed by Allport (Allport 1961), Cattell (Cattell 1965) and Plutchik (Plutchik 1980) in Chapter 2. These personality types are often names attributed to common observable emotional traits; therefore evaluations could be conducted where users report back on their observations of emotionally enhanced characters, in relation to observable personality types. The development of the actual evaluation could be based on the findings of Allport, Cattell and Plutchik to provide some guidance on what the actual personality types might be, compared to observations by the user.

Finally, in its current format, the E-AI architecture presumes that all emotionally enhanced agents regardless of their age or gender, behave and respond emotionally the same way towards stimulus and events. As such, further research needs to be undertaken to investigate whether this is accurate, or whether amendments need to be made to the architecture.

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Appendix 1 Author Publications

Appendix 1.1

Slater, S. (2003). *Are Reusable Engines The Future of Computer Games Development? , ESRC Centre for Research on Innovation & Competition, University of Manchester, September 2003.*

Appendix 1.2

Slater, S., Bechkoum, K. Buckley, K. (2006). *Body Mind and Emotion, An Overview of Agent Implementation in Mainstream Computer Games*. *ICAPS 2006. English Lake District. June 2006.*

Appendix 1.3

Slater, S. ,Bechkoum, K. Buckley, K. Bridges, A (2007). *A Foundation of Emotion Research for Games & Simulations*. AISB 2007. Artificial and Ambient Intelligence. Newcastle University, Newcastle, April 2007.

Appendix 1.4

Slater, S. Moreton, R. Buckley. (2008). *Emotional Agents as Software Interfaces.* Workshop at BCS HCI Conference 2008. Emotions and People. Liverpool 2008.

Appendix 1.5

Slater, S. Moreton, R. Buckley, K. (2008). A Review of Agent Emotion Architectures. Eludamos Online Journal of games and Simulations. www.eludamos.org

Appendix 1.6

Slater, S. Burden,D. (2008). *Serious Games*. BCS IT Now Magazine. September 2008.

Appendix 1.7

Slater, S. Moreton, R. Buckley, K. (2008). *A.I. Techniques for Modelling Anger in Emotional Agents.* CGames International Conference in Games and Simulations. Wolverhampton. November 2008.

Appendix 1.8

Slater, S. Burden, D. Emotionally Responsive Robotic Avatars as Characters in Virtual Worlds. Serious Games 2009. IEEE. Coventry, UK.

Appendix 1.9

Slater, S. Westwood, A. (2008). *Implementing Emotional Agents in Quake 3.* To Be Published.

Appendix 2 Glossary of Emotion Related Terms

Anthromorphic – human like.

Emotions - Emotions are an unconscious reaction, to an appraisal of a stimulus, deemed to require action. This often causes physiological changes and a motivation to act. Emotions originally evolved to aid survival and continued to evolve to deal with ever changing situations in a social context.

Emotion Categories - Two main categories of emotions:

> **Category 1** - Six basic emotions commonly labelled anger, fear, disgust, happiness, sadness and surprise. These emotions appear soon after birth and are visible facially.
>
> **Category 2** – Social or secondary emotions, including - contempt, embarrassment, guilt, jealousy, pride, remorse and shame. There is a wide variation in the number of category 2+ emotions by different researchers. These can be classified as a mix of basic emotions.

Emotion Intensity – Each emotion can have an intensity related to it, this can either be a discrete quantity such as furious for an extreme anger or a more fuzzy range relating to intensity such as I am very angry.

Emotion Learning - Nature/Nurture – It is commonly believed that human beings are born with a number of basic emotions that emerge soon after birth. Other emotions commonly called social emotions emerge later to allow the individual to interact with other people in a social context. We do not as such have the ability to learn new emotions, only new triggers (See Emotion Triggers).

Emotion Malfunction – A research field commonly called the pathology of emotions includes emotions that are to an extreme, or emotions that seemingly malfunction. Sometimes, depending on the researcher, these are referred to as mental disorders, and may include:

> **Anxiety** – Reaction to perceived threat, that leaves the individual in a mental and physical condition similar to fear. This causes worry, induces negative thoughts, and focuses attention and memory on negative feelings. Underlying cause is thought to be a lack of skills to deal with seemingly challenging situations.
>
> **Depression** – Consequence of sadness, usually from a loss in life, typically a death of someone who is close to them. Approx 10% who suffer a loss manifest depression, resulting in a protracted sad and/or negative mood.
>
> **Phobias** – fears of stimulus in excess of threat. Examples include arachnophobia a fear of spiders. The phobia triggers a defensive fear response, without any motivated

behaviour to deal with the stimulus. If phobias are not dealt with they can develop into anxiety.

Panic Disorder – Misinterpreting of body sensations so that the individual thinks that some thing is wrong.

More Information:

DSM IV 2000 for a range of Mental Disorders including related pathological components.

Emotion Models – Two models of emotions were presented, the OCC model a model that is based on a cognitive view of emotions, and the Ekman model which is based on extensive research in emotions especially observable emotions such as facial emotions.

Emotion Triggers - Emotions are innate, i.e. we are born with them, but the actual triggers for emotions can be changed or additional triggers added to our emotional alert database through techniques such as classical conditioning. It is feasible to reduce the effect of triggers on activation of emotions, through the same conditioning process, which can sometimes lead to extinction of the trigger i.e. lack of activation of the emotion when confronted with the stimuli.

Emotion Stages - Five key stages occur during emotion activation:

Cognitive – Unconsciously an emotion is triggered by a stimulus.

Motivated Behaviour – Unconscious (autonomic) action is taken to deal with the immediate stimuli.

Somatic Activity- Body changes occur as a consequence of changes required to deal with the stimuli i.e. sweating.

Subjective Experience – Realisation of bodily changes i.e. I am experiencing an emotion

Post reflective period – Full cognitive control returned, as to be able to take post emotion action if necessary.

Feelings – The conscious realisation, that you are experiencing an emotion based on somatic feedback.

Hedonic – Refers to pleasure or pain.

Memory – When in an emotional state, memory recall becomes focused on information related to the emotion. Memory recall has also been shown to be unreliable based on memories sometimes being remembered in an emotionally gratifying way.

Mood – Emotions typically last only up to a few minutes, should the emotion persist for an extended period; then it is classified as a mood. While in a mood (as well as experiencing an emotion), easier activation of related emotions and memories can occur. It is also been suggested that while in a mood, suppression of emotional trigger activations might be compromised, allowing easier emotion activation.

Motivation – Emotions motivate behaviour towards resolving the cause of the activation, this typically involves, focusing the individual's senses and attention on the stimuli.

Personality – a description of the common emotional characteristics of a person.

Qualia – A human experience.

Somatic – is used when describing the bodies systems.

Specific Emotions

Aggression – (Category 2 – Social emotions) – Includes offensive and defensive aggression. When taken to an extreme, results in violence, i.e. physical harm to others.

Fear – Considered the most primal emotion, it is a commonly supported belief that fear-stimuli activate the fight or flight response when confronted with danger. This occurs in a part of the brain called the amygdala. Cognitive systems can become hijacked to allow the individual to automatically begin dealing with the threat. This prevents a delay that could occur if the individual had time to consider the options.

Autonomic systems activated during fear include:

- Defensive behaviour, such as freezing.
- Pain reduction.
- Reflexes increased.
- Blood flow increased to hands and feet to enable fight or flight.

Sadness – The purpose of this emotion is believed to allow the individual to adjust to loss. The activation of the emotion brings about a drop in energy and enthusiasm, via a slowing of the body's metabolism.

Appendix 3 End-user Evaluations

3.1 The Quake 3 E-bot and Typical End-user Interaction

3.1.1 Participant Pre-Evaluation Questionnaire

1. Do you play computer games on a PC or games console?

Not Really Sometimes Frequently

1 2 3 4 5 6 7

2. Do you play first person shooter (FPS) games like Unreal or Quake?

Not Really Sometimes Mainly

1 2 3 4 5 6 7

3. How often do you play first person shooter games online?

Not Really Sometimes Frequently

1 2 3 4 5 6 7

4. Do you follow the tutorials when playing new first person games?

Not Really Sometimes Usually

1 2 3 4 5 6 7

5. Do you ever play team play in FPS games using the built in computer team players?

Not Really Sometimes Usually

1 2 3 4 5 6 7

3.1.2 Pre-Evaluation Questionnaire Rationale

Question 1: Do you play computer games on a PC or games console?

Asked because the emotional enhancements of bots (in game enemies) will be subtle in this genre of game (FPS). This subtly means it may be difficult for users to identify emotions in fast paced games, because talking to enemy bots is not commonly part of the game, and of course conversation provides much of what we perceive of emotions. With this in mind, it is useful to know whether a user has played games before: if they have, they might have expectations of what the bots and game control systems are, and will simply play the game as they are expected to. If the user is a non-gamer, then they might spend more time trying to work out what they are supposed to be doing and might not notice the emotions at all. Finally it will be interesting to see the observational differences between gamers and non-gamers.

Question 2: Do you play first person shooter (FPS) games like Unreal or Quake?

Builds upon the previous question to clearly identify users who have experience of this genre of game. The results from this will be useful to ascertain any differences in observation between new or existing users of first person shooters.

Question 3: How often do you play first person shooter games online?

Online users do not tend to use bots a great deal and thus it is useful to be able to categorise these users. Users who do not play online would usually play against bots and as such this can be factored in.

Question 4: Do you follow the tutorials when playing new first person games?

Intended to examine whether the user is impulsive and prefers to jump straight into the action, these gamers might not prefer games where the pace is slower due to emotional processing by bots.

Question 5: Do you ever play team play in FPS games using the built in computer team players?

Some FPS games allow users to play in teams with bots as team mates, in these instances users would be able to see the bots clearly, rather than chasing a blur that is an enemy running away.

3.1.3 Participant Post Game Questionnaire

1. Did you enjoy playing Quake 3?

Not Really It Was OK Very Much So

1 2 3 4 5 6 7

2. Did you find the bot's challenging?

Not Really Sometimes Generally

1 2 3 4 5 6 7

3. Did you win many games?

Not Really About Even Most of Them

1 2 3 4 5 6 7

4. Compare to previous first person shooters did you notice anything different about these bot's?

Not Really Sometimes Yes

1 2 3 4 5 6 7

4.1 What did you notice?

……………………………………………………………………………………………………
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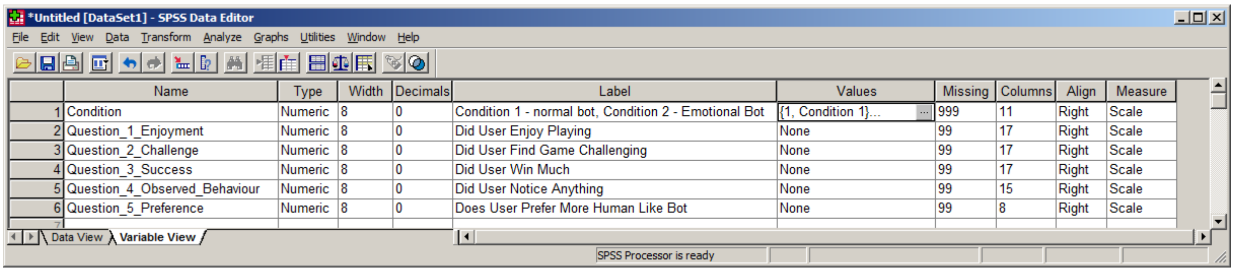
……………………………………………………………………………………………………
……………………………………………………………………………………………………..

5. Would a slower gamer with more human behaving enemies provide a challenge for you?

Not Really Sometimes Probably

1 2 3 4 5 6 7

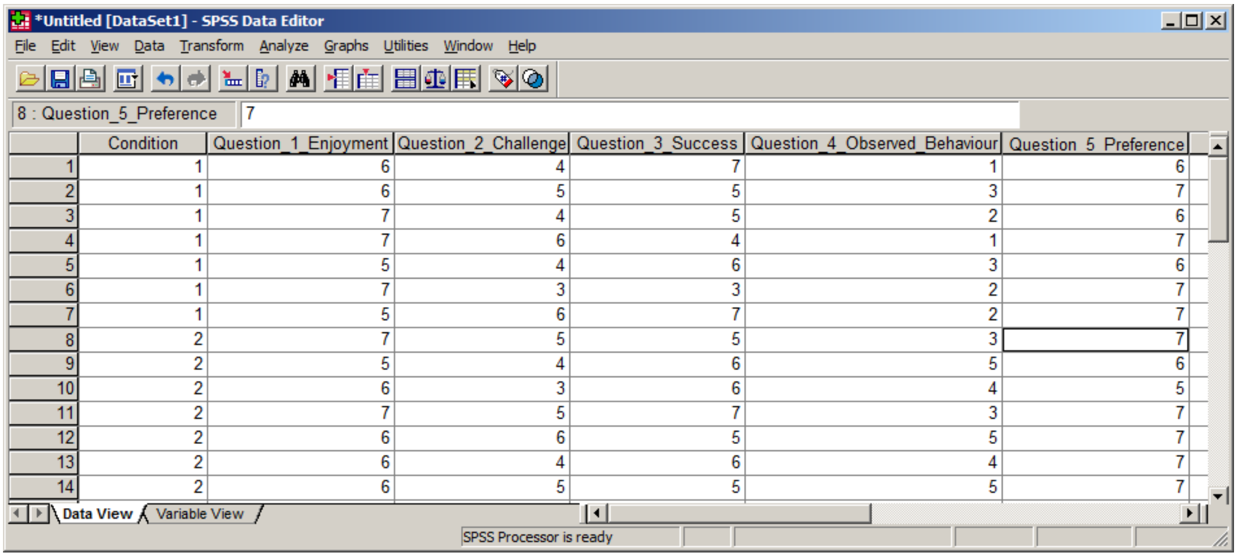
3.1.4 Experiment 1- SPSS Variable Definitions



	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure
1	Condition	Numeric	8	0	Condition 1 - normal bot, Condition 2 - Emotional Bot	{1, Condition 1}...	999	11	Right	Scale
2	Question_1_Enjoyment	Numeric	8	0	Did User Enjoy Playing	None	99	17	Right	Scale
3	Question_2_Challenge	Numeric	8	0	Did User Find Game Challenging	None	99	17	Right	Scale
4	Question_3_Success	Numeric	8	0	Did User Win Much	None	99	17	Right	Scale
5	Question_4_Observed_Behaviour	Numeric	8	0	Did User Notice Anything	None	99	15	Right	Scale
6	Question_5_Preference	Numeric	8	0	Does User Prefer More Human Like Bot	None	99	8	Right	Scale

3.1.5 Experiment 1 – SPSS Raw Data Entries

Once the variable types were defined, the data was entered as shown in Figure 39.



	Condition	Question_1_Enjoyment	Question_2_Challenge	Question_3_Success	Question_4_Observed_Behaviour	Question_5_Preference
1	1	6	4	7	1	6
2	1	6	5	5	3	7
3	1	7	4	5	2	6
4	1	7	6	4	1	7
5	1	5	4	6	3	6
6	1	7	3	3	2	7
7	1	5	6	7	2	7
8	2	7	5	5	3	7
9	2	5	4	6	5	6
10	2	6	3	6	4	5
11	2	7	5	7	3	7
12	2	6	6	5	5	7
13	2	6	4	6	4	7
14	2	6	5	5	5	7

1.1.6 Experiment 1 – Mean & Standard Deviation from SPSS

	Condition 1 - normal bot, Condition 2 - Emotional Bot	N	Mean	Std. Deviation	Std. Error Mean	d
Did User Enjoy Playing	Condition 1	7	6.14	.900	.340	0.000
	Condition 2: Emotional Bot	7	6.14	.690	.261	
Did User Find Game Challenging	Condition 1	7	4.57	1.134	.429	0.000
	Condition 2: Emotional Bot	7	4.57	.976	.369	
Did User Win Much	Condition 1	7	5.29	1.496	.565	0.373
	Condition 2: Emotional Bot	7	5.71	.756	.286	
Did User Notice Anything	Condition 1	7	2.00	.816	.309	2.49
	Condition 2: Emotional Bot	7	4.14	.900	.340	
Does User Prefer More Human Like Bot	Condition 1	7	6.57	.535	.202	0.00
	Condition 2: Emotional Bot	7	6.57	.787	.297	

Where d = effect size

$$d = \frac{\text{Mean A} - \text{Mean B}}{\text{Mean SD}}$$

$$\text{Mean SD} = \frac{\text{SD A} + \text{SD B}}{2}$$

3.1.7 Experiment 1 – t-test Results from SPSS

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Did User Enjoy Playing	Equal variances assumed	1.116	.312	.000	12	1.000	.000	.429	-.934	.934
	Equal variances not assumed			.000	11.244	1.000	.000	.429	-.941	.941
Did User Find Game Challenging	Equal variances assumed	.367	.556	.000	12	1.000	.000	.565	-1.232	1.232
	Equal variances not assumed			.000	11.740	1.000	.000	.565	-1.235	1.235
Did User Win Much	Equal variances assumed	3.099	.104	-.676	12	.512	-.429	.634	-1.809	.952
	Equal variances not assumed			-.676	8.876	.516	-.429	.634	-1.865	1.008
Did User Notice Anything	Equal variances assumed	.401	.539	-4.666	12	.001	-2.143	.459	-3.143	-1.142
	Equal variances not assumed			-4.666	11.889	.001	-2.143	.459	-3.144	-1.141
Does User Prefer More Human Like Bot	Equal variances assumed	.560	.469	.000	12	1.000	.000	.360	-.783	.783
	Equal variances not assumed			.000	10.566	1.000	.000	.360	-.795	.795

For each result, as Levene's Test for Equality of Variances does not indicate statistical significane i.e. Sig is >0.05 Equal variances are assumed

3.1.8 t-test results for Combat Bot Effectiveness Experiment

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
VAR00001	20	10.3500	4.05586	.90692
VAR00002	40	12.2750	3.56613	.56386

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
VAR00001	11.412	19	.000	10.35000	8.4518	12.2482
VAR00002	21.770	39	.000	12.27500	11.1345	13.4155

P value and statistical significance:
The two-tailed P value equals 0.0604
By conventional criteria, this difference is considered to be not quite statistically significant.

Confidence interval:
The mean of Group One minus Group Two equals -2.2000
95% confidence interval of this difference: From -4.5058 to 0.1058

Intermediate values used in calculations:
t = 1.9970
df = 19
standard error of difference = 1.102

Data Review:

Group	Group One	Group Two
Mean	10.3500	12.2750
SD	4.0559	3.5661
SEM	0.9069	0.5639
N	20	40

3.2 The Second Life E-bot - Typical End-user Interaction

3.2.1 Second Life Participant Pre-Evaluation Questionnaire

1. Do you play computer games on a PC or games console?

Not Really Sometimes Frequently

1 2 3 4 5 6 7

2. Have you played World of Warcraft?

Not Really Sometimes Frequently

1 2 3 4 5 6 7

3. Have you within the last 3 months played a role playing game involving non-player characters?

No Sometimes Frequently

1 2 3 4 5 6 7

4. Have you used Second Life?

No Once or Twice Regular User

1 2 3 4 5 6 7

5. Have you used an online chat bot before today?

No I Think So Definitely

1 2 3 4 5 6 7

3.2.2 Participant Post Evaluation Questionnaire

1. Did you complete all of the tasks?

No Most of Them All Of Them

1 2 3 4 5 6 7

2. Did you find the information required?

Not Really Some Yes All Of It

1 2 3 4 5 6 7

3. Did you notice any differences between the Chat bots

Not Really Sometimes They Were Very Different

1 2 3 4 5 6 7

4. Did you notice any human like traits in the Chat Bots's

Not Really Sometimes Yes

1 2 3 4 5 6 7

5. Would you use a chat bot interface if a human operator was not available, or would you prefer to wait to talk to a human operative?

No Don't Care Yes

1 2 3 4 5 6 7

6. Which chat bot would you prefer to chat to in a virtual world?

HALO(A) Don't Mind HALO(B)

1 2 3 4 5 6 7

3.2.3 Participant Pre-Evaluation Briefing

- Thank you for agreeing to participate in this software evaluation session.
- The purpose of the evaluation is to allow you, the participant to interact with two software interfaces and then to ask you to fill in a questionnaire about your experience.
- The software interfaces are in the form of a chat bot, which is a human looking character that can be asked questions using text input to find out anything stored in a back end expert system.
- At any time you would like to leave the evaluation, please do so by asking one of the attending staff.
- No personal details will be recorded, and the results will remain anonymous.
- The results gathered will be used to help the developers decide which interface user's preferred.
- Before we begin the software evaluation we would like to ask you to complete a brief questionnaire to allow us to gauge what experience you may have of similar interfaces.
- The whole evaluation should last no more than 15 minutes and we are happy to answer any questions before we begin.

3.2.4 Participant Instructions During Evaluation

When you are ready to begin, move your avatar using the keyboard and mouse until you are facing HALO. Please feel free to make notes:

1) Introduce Yourself

2) Find Out what services Daden has to offer.

3) Find out What HALO is feeling

4) Find out why HALO is feeling the way she is.

5) Find out what the latest news headline is.

6) Find out if HALO is afraid of anything, is she afraid of snakes?

7) Ask HALO a Knock Knock Joke, start by asking Knock Knock and then something like Rupert Bear as the response to the chat bot.

8) How much does an island cost in Second Life?

When asked to, please move to the other chat bot as directed by the supervisors, and repeat the 8 steps.

3.2.5 Participant Post Evaluation De-Brief

Thank you for participating in the evaluation.

The two chat bots you interacted with have one main difference, this is that one of them has been enhanced to respond partially with some emotions such as happiness and anger. This chat bot is intended to enhance application usage by presenting the user with a more human like interface that can respond emotionally to users. The purpose of the evaluation is to see which interface users prefer.

If you have any further questions then please let us know.

3.2.6 t-test Analysis of Question 6

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
VAR00001	25	4.7600	2.31445	.46289

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
VAR00001	10.283	24	.000	4.76000	3.8046	5.7154

Appendix 4 Sample Physiological Emotion Expressions

4.1 Individual Emotions

Surprise	Location	Description
Motor Expression	Facial Changes (Facial Modelling)	Blank, eyes wide, pause for a moment Tendency to lift the eyebrows, this is thought to allow the visual cortex to take in a larger visual area and allow more light to hit the retina. This offers the brain more visual information to assess the unexpected event
	Posture changes (Body Modelling)	Possibility of pause or stepping back.
	Audio (Speech synthesis)	Slow stuttered speech

Disgust	Location	Description
Motor Expression	Facial Changes (Facial Modelling)	When an individual experiences disgust, there is a tendency for the upper lip to be come curled to the side, as the nose wrinkles, this is believed to be a primordial reaction to close the nostrils against a noxious odour, or to allow the individual to spit out poisonous food
	Posture changes (Body Modelling)	Turn away from stimulus. Tendency to turn away or possibly move backwards away from the source of the activation.
	Audio (Speech synthesis)	

Anger	Location	Description
Motor Expression	Facial Changes (Facial Modelling)	Frowning, not smiling, mean or unpleasant expression. Gritting teeth, showing teeth, breathing through teeth. Red flushed face. Veins in head and neck become more prominent. Glare at source of anger.
	Posture changes (Body Modelling)	Hands clenched into fists. Aggressive threatening movements. Heavy Walk, Stomping. Tightness or rigidity in body; tight rigid movements, body becomes erect. Tendency for the individual to move closer to the emotional trigger, this is possibly to allow the individual to strike out at the source of the anger. During this time the breathing becomes heavier as a consequence of the increased blood pressure, and the body may become erect as muscles tense. Tendency to look down at the emotional trigger, more likely if disgust active at same time.
	Audio (Speech synthesis)	Loud Voice, yelling, screaming, shouting. Metaphor use increase.

Fear	Location	Description
Motor Expression	Facial Changes (Facial Modelling)	Eyes darting, looking quickly around. Hairs may stand on end. Tendency for the face to go pale, as blood is redirected to the hands and legs. Skin contracts. Eyes widen.
	Posture changes (Body Modelling)	Sweating, perspiring. Shaking, quivering, and trembling. Crying. Blood is redirected to the large skeletal muscles such as the legs and arms, this is to prepare the individual for the fight or flight response. Because many predators respond to movement, the individual freezes for a moment while the evaluating the fight or flight choice.
	Audio (Speech synthesis)	Nervous, fearful talk. Shaky, trembling voice. Crying, whimpering. Screaming, yelling. Pleading, crying for help.

Happiness	Location	Description
Motor Expression	Facial Changes (Facial Modelling)	Giggles, laugh and smile. Bright glowing face.
	Posture changes (Body Modelling)	Active movement i.e. jumping up and down.
	Audio (Speech synthesis)	Voice is enthusiastic, excited. Talks a lot.

Sadness	Location	Description
Motor Expression	Facial Changes (Facial Modelling)	Frowning not smiling. Crying, tears, whimpering. Drooped eyes. Corners of mouth go down.
	Posture changes (Body Modelling)	Slow shuffling movement. Slumped posture as the muscles in the body become very relaxed, this is a consequence of a slowing of the bodies' metabolism and thus a reduction in blood pressure.
	Audio (Speech synthesis)	Low, quiet, slow, monotonous voice. Saying sad things.

Appendix 5 Developer Feedback from Second Life Case Study

How useful you found it to understand?
The biggest issue with initial understanding was in assessing what each module meant in virtual world terms. The E-AI came from a background of computer games – where the game designer knows what all the objects/creatures/situations are, the possible reactions to them, and a state-machine which can manage it. Virtual worlds are far more open. Also some things which are quite natural in games (eg the dark) are actually quite hard to evaluate within a virtual world (where not everyone need experience the same thing), or control within a virtual world (eg avatar physiological response).

That said the modular, step-wise nature of E-AI meant that it could be understood module by module and sub-component by sub-component.

Overall we thought that E-AI gave us a very useful foundation for our emotion work.

How easy it was to assimilate into code?
We have approached the implementation module by module. Assimilation was not eased by the fact that our AI is spread over two systems itself, one in Perl and one in C#. It was decided to focus on implementing in C# as this module is the lowest level, and so well-suited to "low rode" type emotional responses, with "high road" responses being managed by the Perl chatbot software.

Detection of stimuli was not too problematic as the avatar is actually overwhelmed with situational information – assuming we can trust the creator labelling of objects. The issue though was that there is no preset lists of objects for Second Life. Initially we manually entered items into the EAD, but this is not a scalable approach. Instead we added rules based around object behaviour – so for instance if an object caused damage it was automatically added to the EAD with a fear response. This approach has generated a lot of interest.

We implemented a basic fuzzy logic algorithm to determine the dominant emotions, an also a conversion from emotions to moods, and then a mood half-life.

At the "high" end we implemented rules within the chatbot to take sensory input (using an XML language we defined called Avatar Sensing Markup Language) and handle this in the same way it does text, resulting in spoken and action responses (the former in AIML, the later in an XML Avatar Action Markup Language). The triggering action is also stored in short-term memory so that the bot is "aware" of the emotional trigger and can answer questions such as "why are you afraid".

Did it simplify the background research phase?
Yes. It gave us a useful structure to use when evaluating other material.

Any problems?
Only as above – moving from a "game" mindset to a virtual world one

Any components that need further work?
The move form emotion to mood seems a critical one to us. If we are using "emotion" to reflect Ekman brief facial expressions, then what most people call emotions are actually what E-AI would call moods. An extended model that showed how emotions relate to moods, and how moods vary over time would be very useful.