

EMOTIONAL MODEL SPECIFICATIONS

Conveying Affectiveness in Leading-edge
Living Adaptive Systems

CALLAS

Project IST-34800

Deliverable D211 WP2.1

Programme Name: IST
Project Number: 34800
Project Title:..... CALLAS
Partners:..... Coordinator: ENG (IT)
 Contractors:
 VTT, BBC, Metaware, Studio Azzurro, XIM,
 Digital Video, Humanware, Nexture, University
 of Augsburg, ICCS/NTUA, University of Mons,
 University of Teesside, Helsinki University of
 Technology, Paris 8, Scuola Normale Superiore
 di Pisa, University of Reading, Fondazione
 Teatro Massimo, HITLaboratory New Zealand

Document Number: callas.D211.ICCS.WP2.1.V1.0
Work-Package: WP2.1
Deliverable Type: Document
Contractual Date of Delivery: 31.10.2007
Actual Date of Delivery: 31.10.2007
Title of Document: Emotional Model Specifications
Author(s):

Approval of this report

Summary of this report:

History:

Keyword List:

Availability This report is: public

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Executive Summary

The core goals of work package 2.1 are to present and analyse prevailing psychological theories of emotion along with corresponding available emotional models and, by taking into account showcases' requirements, choose the suitable model for each showcase. Deliverable D211 provides an extended review of existing theories on emotion, along with the existing computational modelling approaches that are based on these theories. At the same time it provides some guidelines and suggestions regarding the choice of an emotional model by every CALLAS showcase.

Section 1 is an Introduction to the emotional models. Section 2 is trying to define the terms 'emotion' and 'feeling', while Section 3 describes other effective phenomena in order to be distinguished from 'emotion'.

Section 4 is presenting the areas of affective computing, while Section 5 describes the emotions and presents the emotion models. In Section 6 the computational models are presented.

In Sections 7 and 8 we give some suggestions concerning the procedure of choosing the "right" model.

Section 9 includes the relevant references.

1. Introduction

As research has revealed the deep role that emotion and emotion expression play in human social interaction, it has been proposed that more effective human computer interfaces can be realized if such interfaces would model the user's emotion as well as express emotions. Affective computing is computing that relates to, arises from, or deliberately influences emotion or other affective phenomena. According to Rosalind Picard's pioneering article (Picard, 1998), if we want computers to be genuinely intelligent and to interact naturally with us, we must give computers the ability to recognize, understand, and even to have and express emotions. These positions have become the foundations of research in the area and have been investigated in great depth after their first postulation.

Emotion is fundamental to human experience, influencing cognition, perception, and everyday tasks such as learning, communication, and even rational decision-making. Affective computing aspires to bridge the gap that typical human computer interaction largely ignored, thus creating an often frustrating experience for people, in part because affect had been overlooked or hard to measure.

In order to take these ideas a step further, towards the CALLAS objectives, we need to adapt methods of modelling affect to the requirements of the project's showcases. To do so it is fundamental to review prevalent psychology theories on emotion, to disambiguate their terminology and identify the fitting computational models that can allow for affective interactions in the desired CALLAS environments.

2. Terminology Disambiguation

We speak of disambiguation since a lot of confusion exists regarding emotion research terminology, and not without a reason. Different definitions of the role and nature of emotions arise from different scientific approaches since emotion research is typically multidisciplinary. Different disciplines (i.e. psychology, cognitive neuroscience etc) provide theories and corresponding models that are based on diverse underlying assumptions, are based on different levels of abstraction and may even have different research goals altogether.

So what are emotions? It largely remains an open question. Some define it as the physiological changes caused in our body, while the others treat it as purely intellectual thought-process.

In psychology research (Rusting, 1998) the term affect is very broad, and has been used to cover a wide variety of experiences such as emotions, moods, and preferences. In contrast, the term emotion tends to be used to refer to fairly brief but intense experiences although it is also used in a broader sense. Finally moods or states describe low-intensity but more prolonged experiences.

From a cognitive neuroscience point of view Damasio makes a distinction between emotions, which are publicly observable body states, and feelings, which are mental events observable only to the person having them. Based on neuroscience research he and others have done, Damasio argues that an episode of emotion begins with an emotionally "competent" stimulus (such as an attractive person or a scary house) that the organism automatically appraises as conducive to survival or well-being (a good thing) or not conducive (bad). This appraisal takes the form of a complex array of physiological reactions (e.g., quickening heartbeat, tensing facial muscles), which is mapped in the brain. From that map, a feeling arises as "an idea of the body when it is perturbed by the emoting process" (Damasio, 2003).

It is apparent that there is no right or wrong approach, and an attempt on a full terminology disambiguation would not be possible without biasing our choices towards one theory over the other. This is to highlight that the context of each approach has to be carefully defined. Next we are going to enumerate core elements of emotion and ways to distinguish them from other affective phenomena. This will lead us to a short description of the directions of affective computing. Subsequently we will give a short overview of the most prevalent psychological theories of emotion along with corresponding computational modelling approaches and couple them to the affective computing goals and more specifically to the goals of the CALLAS project.

2.1 Defining 'Emotion' and 'Feeling'

Emotion, according to Klaus Scherer (Scherer 1987, 2001), can be defined as an episode of interrelated, synchronized changes in the states of all or most of five organismic subsystems in response to the evaluation of an external or internal stimulus event as relevant to major concerns of the organism. The components of an emotion episode are the particular states of the subsystems mentioned. The process consists of the coordinated changes over time.

Most current psychological theories postulate that

- Subjective experience
- Peripheral physiological response patterns, and
- Motor expression

are major components of emotion. These three components have often been called the emotional response triad. Some theorists include the cognitive and motivational domains as components of the emotion process. The elicitation of action tendencies and the preparation

of action have also been implicitly associated with emotional arousal. However, only after explicit inclusion of motivational consequences in theories (and Frijda's forceful claim for the emotion-differentiating function of action tendencies, see Frijda 1986), these important features of emotion have acquired the status of a major component. The inclusion of a cognitive information-processing component has met less consensus. Many theorists still prefer to see emotion and cognition as two independent but interacting systems. However one can argue that all subsystems underlying emotion components function independently most of the times, and that the special nature of emotion as a hypothetical construct consists of the coordination and synchronization of all these systems during an emotion episode (Scherer, 2004).

How can emotions, as defined above, be distinguished from other affective phenomena such as feelings, moods, or attitudes? Let us take the term feeling first. Scherer aligns feeling with the "subjective emotional experience" component of emotion, thus reflecting the total pattern of cognitive appraisal as well as motivational and somatic response patterning that underlie the subjective experience of an emotion. If we use the term feeling, a single component denoting subjective experience process, as a synonym for emotion (the total multi-modal component process), this is likely to produce serious confusion and hamper our understanding of the phenomenon.

If we accept feelings as components of an emotion, then the next step is to differentiate emotion from other types of affective phenomena. Instances of these phenomena, which can vary in degree of affectivity, are often called "emotions" in the literature. According to Scherer (Scherer 2005), there are five such types of affective phenomena that should be distinguished from emotion: (1) preferences, (2) attitudes, (3) moods, (4) affective dispositions, and (5) interpersonal stances.

In order to differentiate emotions from the rest of the affective phenomena, in the following subsections core elements of emotions are sketched out.

2.1.1 Event focus

Emotions are generally elicited by stimulus events. Something happens to the organism, which, after having been evaluated for its significance, stimulates or triggers a response. Often such events will consist of natural phenomena like thunderstorms, or the behaviour of other people or animals that may have significance for our well-being. In other cases, one's own behaviour can be the event that elicits emotion, as in the case of pride, guilt, or shame. In addition to such events that are more or less external to the organism, internal events are explicitly considered as emotion elicitors. These may consist of sudden neuro-endocrine or physiological changes or, more typically, of memories or images that might come to our mind. These recalled or imagined representations of events can be sufficient to generate strong emotions (Goldie, 2004). The event focus element means that emotions need to be somehow connected or anchored to a **specific event**, external or internal, rather than being free-floating, resulting from a strategic or intentional decision, or existing as a permanent characteristic of an individual.

2.1.2 Appraisal basis

A central aspect of the component process definition of emotion is that the eliciting event and its consequences must be relevant to major concerns of the individual. This seems rather obvious; as we do not generally get emotional about things or people we do not care about. Frijda (1986) talks of emotions as relevance detectors. Componential theories of emotion generally assume that the relevance of an event is determined by a rather complex, yet very rapidly occurring evaluation process that can take place on several levels of processing, ranging from automatic and implicit to conscious conceptual or propositional evaluations (Leventhal & Scherer, 1987). It makes sense to distinguish between intrinsic and extrinsic appraisal. Intrinsic appraisal evaluates the feature of an object or person independently of the current needs and goals of the appraiser, based on genetic preferences (e.g. sweet taste) or learned preferences (e.g., bittersweet food) (see Scherer, 1987, 1988). Extrinsic appraisal

(also known as transactional appraisal; see Lazarus 1991) evaluates events and their consequences in terms of their contribution to the salient needs, desires, or goals of the appraiser.

2.1.3 *Response synchronization*

This element is implied by the adaptive functions of emotion. If emotions prepare appropriate responses to events, the response patterns must correspond to the appraisal analysis of the presumed implications of the event. Given the importance of the eliciting event, which disrupts the flow of behaviour, all or most of the subsystems of the organism must contribute to response preparation. The resulting massive mobilization of resources must be coordinated, a process which can be described as response synchronization (Scherer, 2001). This is in fact one of the most important features of emotion, one that in principle can be operationalized and measured empirically.

2.1.4 *Rapidity of change*

Events, and particularly their appraisal, change rapidly, often because of new information, or due to re-evaluation. As appraisal drives the patterning of the responses in the interest of adaptation, the emotional response patterning is also likely to change rapidly. While we are in the habit of talking about "emotional states", these are rarely steady states. Rather, emotion processes are undergoing constant modification, allowing rapid readjustment to changing circumstances or evaluations. Consider such example: the first thunder of a thunderstorm is far more shocking than subsequent ones, because the individuals acknowledge and adjust to the fact that there is a storm.

2.1.5 *Behavioural impact*

Emotions prepare the ground for adaptive action tendencies and their motivational underpinnings. In this sense they have a strong effect on behaviour resulting from emotion. They often interrupt ongoing behaviour sequences, and generate new goals and plans. In addition, the motor expression component of emotion has a strong impact on communication. This may have important consequences for social interaction.

2.1.6 *Intensity*

Given the importance of emotions for behavioural adaptation, one can assume the intensity of the response patterns and the corresponding emotional experience to be relatively high. This may be an important design feature in distinguishing emotions from moods, for example.

2.1.7 *Duration*

As emotions imply massive response mobilization and synchronization as part of specific action tendencies, their duration must be relatively short in order not to tax the resources of the organism, and to allow behavioural flexibility. In contrast, low-intensity moods that have little impact on behaviour may exist for much longer periods of time without there being adverse effects.

3. Distinguishing ‘Emotion’ from Other Affective Phenomena

3.1 Features of Other Affective Phenomena

Having presented the basic elements of emotions it is now possible to define the other phenomena mentioned earlier in such a way that they can be distinguished from emotions:

3.1.1 *Preferences*

Relatively stable evaluative judgments in the sense of liking or disliking a stimulus, or preferring it over other objects or stimuli, are commonly referred to as preferences. By definition, stable preferences should generate intrinsic appraisal independently of current needs or goals, although the latter might modulate the appraisal (Scherer, 1988). The affective states produced by encountering attractive or aversive stimuli (event focus) are stable, of relatively low intensity, and do not produce pronounced response synchronization. Preferences generate unspecific positive or negative feelings, with low behavioural impact, except for tendencies towards approach or avoidance.

3.1.2 *Attitudes*

Relatively enduring beliefs and predispositions towards specific objects or persons are generally called attitudes. Social psychologists have long identified three components of attitudes (see Breckler, 1984): a) a cognitive component (beliefs about the attitude object), b) an affective component (consisting mostly of differential valence), and c) a motivational or behavioural component (a stable action tendency with respect to the object, e.g., approach or avoidance). Attitude objects can be things, events, persons, and groups or categories of individuals. Attitudes do not need to be triggered by event appraisals, although they may become more salient when encountering or thinking of the attitude object. The affective states induced by a salient attitude can be labelled by terms such as “hating”, “valuing”, or “desiring”. Intensity and response synchronization are generally weak, and behavioural tendencies are often overridden by situational constraints.

3.1.3 *Moods*

Emotion psychologists have often discussed the difference between mood and emotion (e.g., Frijda, 2000). Generally, moods are considered as diffuse affect states, characterized by a relative enduring predominance of certain types of subjective feelings that affect the experience and behaviour of a person. Moods may often develop without an apparent cause that could be clearly linked to an event or specific appraisal. They are generally of low intensity and show little response synchronization, but may last for hours or even days. Examples are being cheerful, gloomy, listless, depressed, or buoyant.

3.1.4 *Affective dispositions*

Many stable personality traits and behaviour tendencies have a strong affective core (e.g., being nervous, anxious, irritable, reckless, morose, hostile, envious or jealous). These dispositions describe the tendency of a person to experience certain moods more frequently or to be prone to react with certain types of emotions, even upon slight provocation. Not surprisingly, terms like “irritable” or “anxious” can describe both affect dispositions and momentary moods or emotions. It is important to specify whether the term is used to qualify personality disposition or an episodic state. Affect dispositions also include emotional pathology: while being in a depressed mood is quite normal, being constantly depressed may

be a sign of an affective disturbance requiring medical attention.

3.1.5 *Interpersonal stances*

This category refers to an affective style that spontaneously develops or is strategically employed in the interaction with a person or a group of persons, colouring the interpersonal exchange in that situation (e.g., being polite, distant, cold, warm, supportive, contemptuous). Interpersonal stances are often triggered by events, such as encountering a certain person. However, they are less shaped by spontaneous appraisal than by affect dispositions, interpersonal attitudes, and, most importantly, strategic intentions. Thus, when an irritable person encounters a disliked individual, that person is more likely to adopt an interpersonal stance of hostility in the interaction, as compared to an agreeable person.

3.2 Emotions in Callas

Having distinguished emotions against other types of affective phenomena it is now of particular interest, in regard to the Callas new media domain, to present a suggested distinction on a different level. Scherer (2004c) questioned the need to distinguish between two different types of emotion: (1) **aesthetic emotions** (2) **utilitarian emotions**. The latter correspond to the “garden variety” of emotions usually studied in emotion research, such as anger, fear, joy, disgust, sadness, shame, guilt. These types of emotions can be considered utilitarian in the sense of facilitating our adaptation to events that have important consequences for our well-being. Such adaptive functions are the preparation of action tendencies (fight, flight), recovery and reorientation (grief, work), motivational enhancement (joy, pride), or the creation of social obligations (reparation). Because of their importance for survival and well-being, many utilitarian emotions are high-intensity emergency reactions, involving the synchronization of many subsystems, as I described earlier. In the case of aesthetic emotions, adaptation to an event that requires the appraisal of goal relevance and coping potential is absent, or much less pronounced. Kant defined aesthetic experience as “disinterested pleasure” (Kant, [1790]1987), highlighting the complete absence of utilitarian considerations. Thus, my aesthetic experience of a work of art or a piece of music is not shaped by the appraisal of the work's ability to satisfy my bodily needs, further my current goals or plans, or correspond to my social values. Rather, aesthetic emotions are produced by the appreciation of the intrinsic qualities of a work of art or an artistic performance, or the beauty of nature. Examples of such aesthetic emotions are: being moved or awed, full of wonder, admiration, bliss, ecstasy, fascination, harmony, rapture, solemnity.

This differentiation of emotions has an impact on the way an appraisal based modelling approach would be implemented. It would not make sense to try and model all the proposed components of an appraisal process in cases where only aesthetic emotions are expected. On the other hand it would make sense to provide a deeper model in cases where anger or frustration are common emotional states such as in the example of interactive Television.

4. Areas of Affective Computing

Affective computing deals with the design of systems and devices which can recognize, interpret, and process emotions. We are going to fledge out the potentials this research domain can provide in the field of new media applications such as the Callas showcases and identify the matching theoretical background which will act as a tool for effectively modelling emotional interaction in such environments.

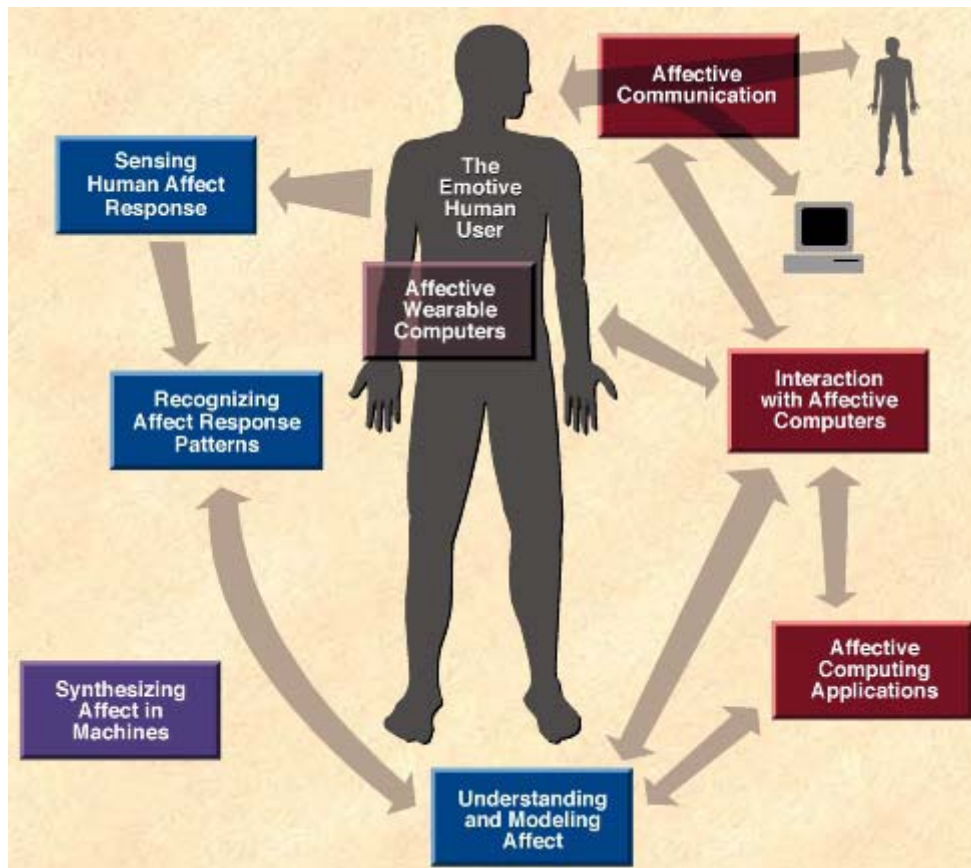


Figure 1 The research areas of affective computing as visualized by MIT (2001)

4.1 Detecting and recognizing emotional information

Detecting emotional information usually involves passive sensors which capture data about the user's physical state or behaviour. The data gathered is often analogous to the cues humans use to perceive emotions in others. For example, a video camera might capture facial expressions, body posture and gestures, while a microphone might capture speech. Other sensors detect emotional cues by directly measuring physiological data; such as skin temperature and galvanic resistance.

Recognizing emotional information requires the extraction of meaningful patterns from the gathered data. This is done by parsing the data through various processes such as facial expression detection, gesture recognition, speech recognition, or natural language processing.

4.2 Emotion in machines

By emotion in machines we refer to the simulation of emotions. The goal of such simulation is to enrich and facilitate interactivity between human and machine. The most common and probably most complicated application of this simulation lies in the field of in conversational agents. Such a simulation is closely coupled with emotional understanding and modelling as explained bellow. This being said it is important to mention that less sophisticated simulation approaches often produce surprisingly engaging experiences in the area of new media. It is often the case that our aim is not to fully simulate human behaviour and emotional responses but to simply depict emotion in a pseudo intelligent way that makes sense in the specific context of interaction.

4.3 Emotional understanding

Emotional understanding refers to the ability of a device not only to detect emotional or affective information, but also to store, process, build and maintain an emotional model of the user. The goal is to understand contextual information about the user and her environment, and formulate an appropriate response. This is difficult because human emotions arise from complex external and internal contexts.

Possible features of a system which displays emotional understanding might be adaptive behaviour, for example, avoiding interaction with a user it perceives to be angry. In the case of Callas, emotional understanding makes sense in tracking the user's emotional state and adapting environment variables according to the state recognised. Questions regarding the level of detail of the tracking performed, the theoretical grounds for the analysis of the data collected and the types of potential output that would make sense for such an interactive process, are paramount.

5. Emotion Descriptions and Emotion Models

Having reviewed the areas of affective computing, it is time to start focusing on the available theories, descriptions and models that can support these goals. We start with reviewing the three big groups of emotion descriptions as identified by the members of the Humaine Network of Excellence.

It is important to stress the difference that exists between emotion models and emotion descriptions. By emotion descriptions we refer to different ways of representing emotions and their underlying psychological theories where as with the term emotional models we talk about the computational modelling of these theories in specific context.

5.1 Categorical representations

Categorical representations are the simplest and most wide-spread term used to describe an emotional state. Such category sets have been proposed on different grounds, including:

- evolutionarily basic emotion categories (i.e. discrete emotion theory),
- common everyday emotions – emotion labelling,
- application-specific emotion sets,
- or categories describing other affective states, such as moods or interpersonal stances. (Feeltrace core vocabulary in Cowie et al. 1999; Ortony, Clore and Collins list of emotion words in Ortony et al. 1988)

Discrete emotion theory is based on the concept that there exist six basic, universally recognized emotions which elicit equivalent prototypical facial expressions (Ekman 1972, Izard 1971). A prototypical expression pattern is considered to be based on innate neuromotor programs. The theory's extension postulates that there also exist *blends* of the archetypal emotions (Ekman 1999). It predicts that specific emotions, basic or blended ones, elicit emotion specific facial expression response patterns. This approach acknowledges that the individual muscle movements that make up a prototypical expression pattern will be produced in a simultaneous fashion (Wherle et al. 2000) thus simplifying the temporal evolution of an expression to a smooth yet temporally short transition from a neutral expression to the emotional one. Ekman does not exclude the possibility that there may be slightly different time courses of individual action units in an expression pattern due to differences in muscle mass to be moved. However, he considers it relatively unlikely that these will lead to visible offsets in the appearance of action unit changes.

5.2 Dimensional descriptions

An alternative method of characterizing affective states and emotions is to focus on the underlying, often physiologically correlated factors and map these onto distinct dimensions. This approach leads to spatial/ dimensional models for emotions. Several such two or three dimensional sets have been proposed. Amongst these approaches, one that has been found more appealing and thus more commonly used, is the activation/ evaluation dimensional space (Figure 2). It is a simple approach which captures a wide range of significant issues in emotion. The concept is based on a simplified treatment of two key themes:

Valence: The clearest common element of emotional states is that the person is materially influenced by feelings that are valenced, i.e., they are centrally concerned with positive or negative evaluations of people or things or events.

Activation level: Research from Darwin and onwards has recognized that emotional states

involve dispositions to act in certain ways. A basic way of reflecting that theme turns out to be surprisingly useful. States are simply rated in terms of the associated activation level, i.e., the strength of the person's disposition to take some action rather than none.

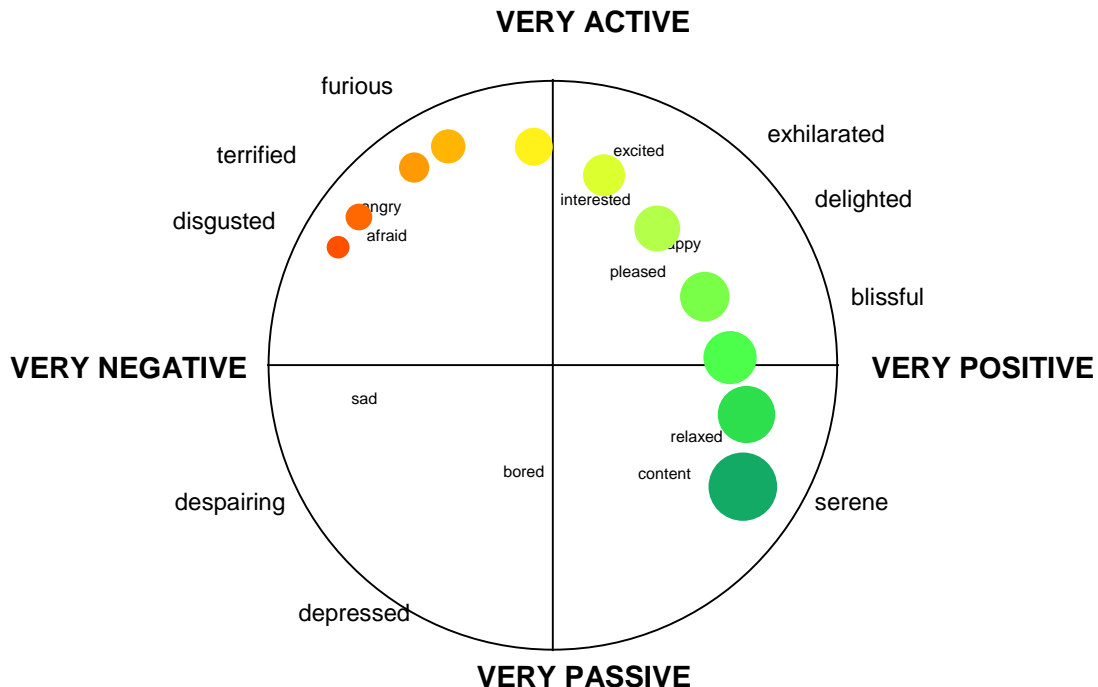


Figure 2 Dimensional Representation

In addition to these two, there are a number of other possible dimensions, such as power, control, or approach / avoidance, which add some refinement. The most obvious is the ability to distinguish between fear and anger, both of which involve negative valence and high activation. In anger, the subject of the emotion feels that he or she is in control; in fear, control is felt to lie elsewhere.

Dimensional representations are attractive mainly because they provide a way of describing emotional states that is more tractable than using words. This is of particular importance when dealing with naturalistic data, where a wide range of emotional states occur. Similarly, they are much more appropriate to deal with non discrete emotions and variations in emotional state over time. Moreover dimensional descriptions can be translated into and out of verbal descriptions (linking this approach with labelling emotions). This is possible because emotion words can, to an extent, be understood as referring to positions in activation-evaluation space.

5.3 Appraisal theories and representations

Appraisal theories focus on the emotion elicitation process in contrast with the previously mentioned approaches that emphasize on the consequences/ symptoms of an emotional episode. Appraisal representations characterise emotional states in terms of the detailed evaluations of eliciting conditions, such as their familiarity, intrinsic pleasantness, or relevance to one's goals. Such detail can be used to characterise the cause or object of an emotion as it arises from the context, or to predict emotions in AI systems (Lazarus, 1991; Frijda, 1986; Scherer, 1984).

Appraisal theories are very common in emotion modelling since their structure makes it feasible for simulating their postulations in computational models. Moreover it is often the

case that an appraisal theory was formulated explicitly in order to be implemented in a computer. Such an example is the OCC theory (Ortony, Clore and Collins 1988). This is sometimes a source of confusion, since the underlying emotion theory is unavoidably very closely linked with the actual modelling approach.

According to cognitive theories of emotion (Lazarus 1987), emotions are closely related to the situation that is being experienced (or, indeed, imagined) by the agent. Below we are going to briefly present four of the most prevalent theories in the field.

5.3.1 OCC theory

The theory of Ortony, Clore and Collins assumes that emotions develop as a consequence of certain cognitions and interpretations. Therefore it exclusively concentrates on the cognitive elicitors of emotions. The authors postulate that three aspects determine these cognitions: events, agents, and objects. Emotions represent valenced (positive/ negative) reactions to these perceptions of the world. One can be pleased about the consequences of an event or not (pleased/displeased); one can endorse or reject the actions of an agent (approve/disapprove) or one can like or not like aspects of an object (like/dislike).

A further differentiation consists of the fact that events can have consequences for others or for oneself and that an acting agent can be another or oneself. The consequences of an event for another can be divided into desirable and undesirable; the consequences for oneself as relevant or irrelevant expectations. Relevant expectations for oneself finally can be differentiated again according to whether they actually occur or not (confirmed/disconfirmed).

With the help of such a formal system a computer should be able to draw conclusions about emotional episodes which are presented to it. The authors are not interested in the question if machines are actually 'experiencing' emotions. Rather than that they only focus on the ability to understand emotions, reason about them and express them.

5.3.2 Scherer's Appraisal Theory

Scherer's appraisal theory (Scherer, 1984; Scherer 2001) is more commonly known as the component process model. For Scherer five functionally defined distinct subsystems are involved with emotional processes:

- An information-processing subsystem, which evaluates the stimulus through perception, memory, forecast and evaluation of available information.
- A supporting subsystem, adjusting the internal condition through control of neuroendocrine, somatic and autonomous states.
- A leading subsystem plans, which prepares actions and selects between competitive motives.
- An acting subsystem, controlling motor expression and visible behaviour.
- A monitor subsystem, which controls the attention assigned to the present states and passes the resulting feedback to the other subsystems.

Scherer is especially interested in the information-processing subsystem. According to his theory this subsystem is based on appraisals which Scherer calls *Stimulus Evaluation Checks* (SEC). The result of these SECs causes again changes in the other subsystems.

Scherer enumerates five substantial SECs, four of which possess further sub-checks. The novelty check decides whether external or internal stimuli have changed; its sub-checks are suddenness, confidence and predictability. The intrinsic pleasantness check specifies whether the attraction is pleasant or unpleasant and causes appropriate approximation or avoidance tendencies. The goal significance check decides whether the event supports or prevents the goals of the person; its sub-checks are goal relevance, probability of result, expectation, support character and urgency. The coping potential check determines to what extent the person believes to have events under control; its sub-checks are agent, motive,

control, power and adaptability. The compatibility check finally compares the event with internal and external standards; its sub-checks are externality and internality.

Each emotion can, according to Scherer, thus be clearly determined by a combination of the SECs and sub-checks. An appropriate table with such allocations can be found in (Scherer, 1988).

5.3.3 Roseman's theory

The theory of Roseman, which he first presented in the late seventies, was then modified by him several times in the years to come. Five cognitive dimensions determine whether an emotion arises and which one it is. These dimensions were re-visited several times. Nevertheless the model proposed was never empirically validated thus leading to new revisions/ additions (Roseman, 1984, Roseman et al. 1990).

The first dimension describes whether a person possesses a motivation to a desired situational state ("positive" state) or a motivation away of an unwanted situational state ("negative" state). The second dimension describes whether the situation agrees with the motivational state of the person ("situation present") or not ("situation absent"). The third dimension describes whether an event is noticed as certain ("certain" state) or only as a possibility ("uncertain" state). The fourth dimension describes whether a person perceives the event as deserved or undeserved, with the two states "deserved" and "undeserved". The fifth dimension finally describes the origin of the event and is comprised of three states: "the circumstances", "others" or "oneself". From the combination of these five dimensions and their values a table can be arranged (Roseman, 1984), from which, according to Roseman, emotions can be predicted. Altogether 48 combinations can be derived out of Roseman's dimensions:

- positive/ negative
- present/ absent
- certain/ uncertain
- deserved/undeserved
- circumstances/ others/ oneself.

According to Roseman, these 48 cognitive appraisals correspond to 13 emotions. Their structure is simple, thus making it easy for them to be translated quickly into rules. These rules define exactly which appraisals elicit which emotions. This is the reason why Roseman's models were received very positively in AI circles. Picard writes: "Overall, it shows promise for implementation in a computer, for both reasoning about emotion generation, and for generating emotions based on cognitive appraisals." (Picard, 1997).

5.3.4 Frijda's theory

Frijda points out that the word "emotion" does not refer to a "natural class" and that it is not able to refer to a well-defined class of phenomena which are clearly distinguishable from other mental and behaviour events. For him, therefore, the process of emotion emergence is of larger interest.

The center of Frijda's theory is the term concern. A concern is the disposition of a system to prefer certain states of the environment and of the own organism over the absence of such conditions. Concerns produce goals and preferences for a system. If the system has problems to realize these concerns, emotions develop.

The strength of such an emotion is determined essentially by the strength of the related concern(s). For Frijda, emotions are absolutely necessary for systems which realize multiple concerns in an uncertain environment. If a situation occurs, in which the realization of these concerns appears endangered, so-called action tendencies develop. These action tendencies are linked closely with emotional states and serve as a safety device for what Frijda calls concern realization (CR).

6. Computational Models

Emotion models are computational approaches that are based on descriptions/theories illustrated in chapter 5, and often combinations of more than one theory have been adopted in models. They aspire to validate them and possibly to extend them. They allow the simulation of behaviour and aid in both recognising and understanding human emotions as well as generating synthetic emotional responses. Keeping in mind these descriptions, emotion models can be divided into two categories:

- ones that take into account the situations that initiate the emotions and how they are construed by the user and that focus on the predicted emotion – from now on we shall refer to them as ‘**deep models**’.
- ones that deal with the ‘results’ of an emotional episode i.e. facial expression, voice, etc. – from now on we shall refer to them as ‘**shallow models**’.

What is the motivation for the development of a computational model implementing a particular emotion theory, or attempting to account for particular data? On a research level, it provides an opportunity for validation of the theory’s claims. It also allows for the generation of alternative hypotheses explaining specific affective data or phenomena. The aim of this report is to investigate existing modelling approaches and to identify the ones that would potentially meet the requirements of CALLAS showcases. In order to do that first we shall go through a general overview of emotion modelling literature.

6.1 Computational Models - Levels of abstraction

A number of computational models addressing emotion have been developed in cognitive science and AI. These models range from individual processes to integrated architectures, and explore several of the emotion theories outlined in chapter 5. One thing that differentiates these modelling approaches is the **level of abstraction**. At the higher level of abstraction are architecture-level models which embody emotional processing. At an intermediate level of abstraction are task-level models of emotion, which focus on addressing a single task, such as natural language understanding or specific problem solving. At lower levels of abstraction are mechanism-level models, which attempt to emulate some specific aspect of affective processing. The level of abstraction is found to be a key criterion in the selection of the appropriate models for the CALLAS showcases.

6.1.1 *Cognitive appraisal emotion model*

According to a review on emotional models by Hudlicka (Hudlicka, 2003) the most frequently modelled process has been cognitive appraisal, whereby external and internal stimuli (emotion elicitors) are mapped onto a particular emotion. Several alternatives have been hypothesized for these processes in the psychological literature (Frijda, 1986; Lazarus, 1991b; Scherer, 1993; Ortony, Clore and Collins, 1998; Smith and Kirby, 2000).

A number of these models have been implemented, both as stand-alone versions, and integrated within larger agent architectures (e.g. Scherer, 1993; Velasquez, 1997; Canamero, 1998; Castelfranchi, 2000; deRosier et al., 2003; Breazeal, 2003). The most frequently implemented theory is the OCC appraisal model (Ortony, Clore and Collins, 1998), implemented in a number of systems and agents (Bates et al., 1992; Andre et al., 2000; Elliot et al., 1999; Martinho et al., 2000).

There also exist models that function as goal management mechanisms (Frijda and Swagerman, 1987), models based on the interaction of emotion and cognition (Araujo, 1993), explicit models of the effects of emotion on cognitive processes (Hudlicka, 2002b), and finally on the effects of emotions on agent’s belief generation (Marsella and Gratch, 2002).

6.1.2 Emotion models based on facial expression

Other emotion model implementations focus on the image analysis of a user's facial expression and the synthesis of emotional expression in virtual agents. These include models of emotions based on Ekmanian basic emotions and on dimensional representations of emotion (Ioannou et al., 2005 on facial expression recognition; Raouzaïou et al., 2005 facial expression synthesis), models of emotion based on blends of basic emotions (Raouzaïou et al. 2002) and models of emotion based on Scherer's appraisal theory (Malatesta et al. 2007).

Dimensional models are helpful in both recognition and expression, as well as in models of emotion generation, in situations where sufficient data may not be available for more highly differentiated responses. On the other hand, appraisal theories are commonly used to implement the "cognitive" component of an emotional interface. In the case of facial expression recognition/ synthesis the outcome of the appraisal process can be mapped into an emotion category, which determines which facial features (and to what extent) participate in the respective facial expression pattern. When the stimulus eliciting the emotion is available, as well as some goal/belief structure, then it is possible to predict the emotion category of the participant (in recognition) or the agent (in synthesis).

6.1.3 Integrated architectures emotion models

Examples of integrated architectures focusing on emotion include most notably the work of Sloman and colleagues (Sloman, 2000), but also more recent efforts to integrate emotion effects in Soar (a general cognitive architecture for developing systems that exhibit intelligent behaviour) by Jones and colleagues (Jones et al., 2002).

Sloman's work introduces an approach to search for deeper explanatory theories of emotions and many other kinds of mental phenomena. It includes an attempt to define the concepts in terms of: the underlying information processing architectures, the classes of states and processes that they can support. A serious problem with this programme is the difficulty of *finding good constraints on theories*, since in general observable facts are consistent with infinitely many explanatory mechanisms. To such problem he offers, as a partial solution, the requirement that the proposed architectures must be similar to those produced by biological evolution. This is an architecture-based theory that allows to distinguish primary emotions, secondary emotions, and tertiary emotions.

Jones et al (2002) integrate a connectionist model of emotional processing with a synthetic force model. Their intent is to investigate improved realism in generating complex human-like behaviour that is sensitive to emotional assessments related to fear, anger, joy, etc. Their work focuses on the interfaces required to integrate behaviour moderators (represented by sub symbolic signal-processing systems) with higher cognitive processes (represented in a symbol-processing reasoning system). The interfaces include the transmission of emotional signals from the connectionist system to the symbolic system's perceptual and cognitive processes.

7. How to choose the ‘right’ model?

Throughout this document it has been clarified that, the choice of the emotion modelling approach for the CALLAS showcases does not consist in a one phrase answer. In order to facilitate the model choice, by in pointing which emotion model is more fitting for which type of application, we propose a participatory design approach.

7.1 Participatory Design

Participatory design has been characterised as the ‘third space’ in Human Computer Interaction (Muller, 2003). In the world of software development participatory design is an approach to design that attempts to actively involve the end users in the design process to help ensure that the outcome designed meets their needs and is usable. In participatory design end-users (putative, potential or future) are invited to cooperate with researchers and developers during an innovation process. Potentially, they participate during several stages of an innovation process: they participate during the initial exploration and problem definition both to help define the problem and to focus ideas for solution, and during development, they help evaluate proposed solutions (Schuler et al. 1993).

Participatory design in Callas can be seen as a way to move end-users views into the world of researchers and developers, whereas an empathic design approach would move researchers and developers into the world of end-users. Participatory design is expected to add an extra feedback loop in the showcase design phase. Each showcase designer will be able to put forward the detailed requirements that arise from corresponding use case scenarios. These use case scenarios can consequently be tested with the participation and active feedback of actual users. Such an approach is feasible with the Callas showcases thanks to their componential/modular structure. This structure allows for flexible decisions in the design process governed by the vital comments of end users. The suggested approach is similar to a formative evaluation of a system under development. It empowers users to engage in informed participation rather than being restricted to the use of existing, fully deployed and unchangeable systems.

This approach will help address open-ended and possibly multidisciplinary design problems that typically involve a combination of social and technological issues and don’t have a clear right or wrong answers.

7.2 Open Affective Human-Computer Interaction Questions

The vast amount of existing research and empirical findings provides a rich foundation for addressing the challenge of affective human-computer interfaces in CALLAS. Open questions have to be answered, such as which emotions should be considered within particular contexts, the level of abstraction that corresponds to the needs of each showcase and the choice of underlying theories for the model to be adopted. Hudlicka (Hudlicka, 2003) identifies some key questions for affective HCI research that are found relevant to the CALLAS project. Such questions are reported below, after being adapted to the CALLAS showcase requirements.

- What is the context where affect is crucial?
- Which emotions must be considered, in which contexts and for which types of users? Are the existing taxonomies of emotions adequate? Or do we need to define more complex cross-products of person-emotion-task features to help answer this question?
- What are the most appropriate methods for affect assessment, for the expected

users and contexts of the showcases?

- Under what circumstances should showcase systems adapt to user affect and when should affect not play a role?
- How must existing usability criteria be augmented to include affective consideration?

8. Model Choice Requirements-“Guidelines” for the Showcases

In practical terms it is necessary to couple emotion modelling requirements with specific showcases and the requirements they dictate. The questions to be answered regard

- the computational model level of abstraction that should be adopted,
- the choice of the specific theory or theories,

that can provide an emotional state classification that makes sense in the showcases scenarios. Restrictions will also apply depending on the component requirements in environment conditions (lighting, sound quality etc).

8.1 Model requirements vs. application/ showcase requirements

It has been made clear throughout this text that the choice of the emotion modelling approach allows for flexible decisions and combinations of approaches in order to meet the showcase requirements. At this point we are going to identify some core requirements that make sense in all the showcases and then look into specific requirements that arise in each showcase separately.

Since we are talking about new media applications where interaction with the users is in the centre of attention we have to make sure it abides all basic usability restrictions. It is also crucial that the level of intrusiveness and overhead, of the emotion tracking and recognition process, is kept low. The ease of use of each showcase setup might conflict with the level of user engagement it manages to attain. It is obvious that the quality of the experience is prioritised highly and thus it is important to define the thresholds of acceptable intrusiveness conditions and complexity of setups in order to ensure it.

As highlighted previously, context information during emotion modelling facilitates the process by providing knowledge about the event focus and the way it is appraised. Thus for each showcase the specific context is expected to dictate its own requirements about:

- the level of abstraction to be adopted,
- the deep or shallow modelling approach,
- and the way temporal evolution of emotional measurements is dealt with.

In this perspective it could make sense to claim that a more detailed modelling approach is matching to the interactive-TV showcase, whereas a more elementary modelling approach could correspond to a public space installation, where the number of users and the environment noise constrain the level of detail of information collected.

8.2 Summary of Model Choice Requirements

Putting it all together the following table summarises all the constraints illustrated in the current document. The contents of this table are to be used as a guide for specifying the model approach to be adopted for each showcase.

Underlying Theory	<ul style="list-style-type: none"> • Appraisal theories • Universal emotions • Emotion labelling • Dimensional descriptions • Combination of available approaches
Modelling Approach	<ul style="list-style-type: none"> • Level of abstraction • Deep or shallow modelling • Temporal evolution of emotional measurements
Affective HCI constraints	<ul style="list-style-type: none"> • Importance of affect: context definition • Selection of emotions • Choice of emotion assessment method • When does the showcase adapt to affect and when not?
Showcase Constraints	<ul style="list-style-type: none"> • Usability • Low level of Intrusiveness

Table 1 Summary of requirements

Note: The showcase constraints are indicative and it is expected that they will be enriched by each showcase designer in future work.

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