Deliverable 3.5

"Facial and body expressions for companions"

Contract number**: FP7-215554 LIREC**

LIving with Robots and intEractive Companions

Start date of the project: 1st March 2008 Duration: 54 months

The research leading to these results has received funding from the European Community's Seventh Framework Programme (*FP7/2007-2013*) under *grant agreement* n° 215554.

Identification sheet

Project ref. no.	**FP7-215554**
Project acronym	LIREC
Status & version	[Final] D3.5
Contractual date of delivery	28th of February 2011
Actual date of delivery	18th of March 2011
Deliverable number	D 3.5
Deliverable title	Facial and body expressions for companions
Nature	"report"
Dissemination level	**PU** Public
WP contributing to the deliverable	WP3
WP / Task responsible	- **T3.4** Facial and body expression of the robots and embodied graphic characters - **T3.5** Non-verbal communication expression relevant for developing long term relations: addressing aspects of affective communication; empathy and mimicry
Editor	Ana Paiva (INESC-ID)
Editor address	INESC-ID / Instituto Superior Técnico - Tagus Park Av. Prof. Dr. Cavaco Silva, 2780-990 Porto Salvo, Portugal
Author(s) (alphabetically)	Ruth Aylett (HWU), Ginevra Castellano (QM), Luísa Coheur (INESC), Tiago Correira (CNOTINFOR), Secundino Correia (CNOTINFOR), Kerstin Dautenhahn (UH), João Dias (INESC), Paulo Gomes (INESC), Kheng Lee Koay (UH), Iolanda Leite (INESC), David Matos (INESC), Carlos Martinho (INESC), Peter McOwan (QM), Francisco Melo (INESC), Michael Kriegel (HWU), Adam Oleksy (WRUT), Luís Caldas de Oliveira (INESC), Ana Paiva (INESC), André Pereira (INESC), Cristina Pinho (CNOTINFOR), Tiago Ribeiro (INESC), Krzysztof Tchon (WRUT), Isabel Trancoso (INESC), Michael Walters (UH)
EC Project Officer	Pierre-Paul Sondag
Keywords	Non-verbal behaviour, facial and body expressions, lights, sound, empathy.
Abstract (for dissemination)	This deliverable summarizes the work that has been conducted in terms of expressive behaviour in LIREC. We present a list of expressive and other task-related behaviours that can be shaped by affect parameters, describe the expressive capabilities of the companions used in the different showcases, explain how expressive behaviours are handled as competencies of the architecture and present a study conducted to evaluate the influence of empathic behaviours on user's perception of the companions.

Contents

1 Introduction

Non-verbal communication serves very important functions in human social relationships (Patterson, 1990). As stated in D2.1, non-verbal communication is useful, for example, to regulate social interactions (e.g., by turn-taking or proximity mechanisms) and is considered a very efficient and genuine way of expressing emotions. For these reasons, non-verbal communication is also a very important requirement in artificial companions that interact with users in social settings. There is evidence that affective behaviour plays an important role in long-term human-computer relationships (Bickmore, 2005).

One of the main goals of WP3 is to develop expressive behaviours for LIREC companions that will contribute for sustaining long-term interactions with users. These behaviours are conveyed through different modalities such as facial and body expressions, but also lights and sounds, especially in the robotic embodiments where the "body" and "face" expressivity is more limited. LIREC companions may take different forms (e.g. robots, graphical virtual characters in a computer screen or handheld device) and even within the same showcase there are different robots or graphical characters. Therefore, selecting the appropriate expressive behaviour for each embodiment is a very challenging task, as we need to make sure that users properly understand the expressions conveyed across the different embodiments and platforms. Further, as some of the companions do not have facial or body capabilities that allows them to convey complex emotions or affective states, expressive behaviour can also be integrated in task-related behaviour (e.g., a robot may walk faster if it is in a positive mood and walk slower when it is in a negative mood).

In this deliverable, we summarize the work that has been conducted in terms of expressive behaviour in all of the robots and virtual agents of the project. This document is organised as follows. We start by presenting a list of expressive and other task-related behaviours that can be shaped by affect parameters (Section 2). In Section 3, we provide a brief summary of the expressive capabilities of the companions of the different showcases. After that, in Section 4, we describe how expressive behaviours are handled as competencies of the LIREC 3-layer architecture. Section 5 describes the work that has been done in the Affect Sensitivity competence, with special emphasis on a study that was conducted to evaluate the influence of empathic behaviours on user's perception of the companions. Finally, in section 6, we present some conclusions and final remarks.

2 Emotional Expressions and Behaviours Shaped by Affect Modulators

An important requirement for artificial companions is the ability to socially interact with users in a similar way that users interact with each other. To accomplish this, LIREC companions should be able to convey expressions and behaviours that provide information about their affective and motivational state, so that interactions with users become more intuitive, natural and enjoyable. We separate these behaviours in two distinct groups, emotional expressions and expressive behaviours shaped by affect modulators. In the remaining of this section, we define and provide examples of these two groups of behaviours.

2.1 Emotional Expressions

This category contains the repertoire of expressions that companions display with the purpose of showing their internal affective state to the user. Considering the diversity of scenarios and embodiments of the several robots and graphical characters in the project, we do not commit ourselves to a common set of emotional expressions applicable to all scenarios and companions. Instead, our aim is to provide a common list of possible emotional expressions that companions can express depending on their embodiment and expressive capabilities.

In (Ekman&Friesen, 1975) we can find the expression of six **basic emotions**, along with psychological and physical descriptions of their reflection in the human being, especially on the face. For each of these expressions, they also describe different possible **blends** between them and different **sub-expressions**, which represent variations of the base emotions with different intensity, context or cause. This enables us to express more complex and specific emotions in certain situations, as long as the companion is able to produce such expression, and of course, if the appraisal model can detect and generate such variation.

Therefore, depending on the scenario and the companion's embodiment, emotional expressions may include the basic set of emotions, more "complex" emotions, or even emotions generated by an anticipatory appraisal mechanism (as in the MyFriend Scenario). To confirm if a companion is capable of expressing the emotions listed below, thorough user tests shall be conducted, in order to evaluate the expressivity capabilities of each companion.

2.1.1 Basic

The following list enumerates the six basic emotional expressions considered in (Ekman&Friesen, 1975). These basic emotions are relevant to the behaviour-based control of facial expressions developed in (Breazeal, 2003):

- Surprise (and Startle)
- Disgust
- Fear
- Anger
- Happiness
- Sadness

There are some considerations that are important for the use of some of the expressions. **Surprise** is the only neutral expression, which means that it is rarely used by itself. In most cases, surprise is followed or blended with one of the other basic emotions, except for sadness, which is rarely expressed along with surprise. This is one of the less enduring expressions, because surprise only lasts while the situation is surprising. Startle is an almost immediate and more extreme surprise reaction, and can be considered the only use of the neutral surprise expression, being followed by the most appropriate blend for the situation and usually includes a blink of the eyes. Surprise is also the expression most subject to history and decay, as the same situation, when repeated, causes less surprise each time it happens. This expression is also widely used for non-emotional expressions, such as **speech support**, providing punctuations and emphasis, and also for some social expressions, like greeting or listening.

Fear can cause tremble of the lower face, and a posture of withdrawal, and can also be blended with startle. It can also occur gradually, lasting longer than most of the other expressions, however, there is eventually a physiological need to release the expression due to muscle fatigue. **Anger** is a very dominant expression, because it requires that all the face exhibits anger in order for it to be properly perceived. **Happiness**, however, is expressed specially in the eyes and lower face. **Sadness**, contrary to surprise, is rarely brief, and is generally accompanied by a hanging head.

In (Ekman, 1972) we can also find a summary of different basic expressions that have been presented by different authors. These expressions may eventually be regarded as important and useful for a most correct and practical emotional expression of the companions, so they shouldn't remain fully unconsidered. However, due to the fact that we want a plausible list of basic emotions to be expressed by our robotic embodiments, the more compact set previously described seems more adequate. Some of them have actually been considered in our study as being complex expressions, thus being stated in section 2.1.3.

Ekman also proposed that each basic emotion can be recognized in five different **intensities**. He refers to those intensities as 'A', 'B', 'C', 'D' and 'E', being 'A' the less intense, and 'E' the most.

2.1.2 Blends

In (Ekman&Friesen, 1975), each basic expression is described along with some possible blends, which can be useful when there are two explicitly dominant emotions, and not only one. These expressions should only be used by companions with enough level of expressivity to make them identifiable by human observers, as long as such information is provided by the appraisal model. Those blend expressions are:

- Surprise-Disgust
- Surprise-Fear
- Surprise-Anger
- Surprise-Happy
- Disgust-Fear (Horror)

- Anger-Fear
- Happiness-Anger
- Happiness-Fear
- Sadness-Fear (Distress)
- Sadness-Disgust (Pout)
- Sadness-Anger
- Sadness-Happiness (Nostalgic/Bittersweet)

2.1.3 Complex

We have also found several expressions, which are derived from the basic and the blend ones that can also be useful to more properly express different and more complex situations. Only companions with even more expressivity than that required by the blend expressions can take these into account. The list consists of expressions that were defined and identified in the work of Ekman and Friesen, and which we considered that could eventually be relevant for some scenarios, although we do not guarantee they could actually be used, due to limitations on the appraisal model. If we find that some of these expressions do not make sense of being included in our study, due to the fact that the companions will never actually understand that they should be expressed, then they will forwardly be removed from this list. Those complex expressions are:

- Doubt/Questioning
- Incredulity/Amazement
- Dumbfounded
- Mock
- Annoyance
- Mild Dislike
- Contempt
- Disbelief
- Worry/Apprehensive Fear
- Anxiety
- Horrified Fear
- Frozen Fear
- Shocked/Incredulous Fear
- Disgust Emblem
- Excitement
- Scornful
- Blue
- Mourning

- Concentrating/Thinking
- Accentuated Concentrating/Thinking
- Interest

2.2 Behaviours Shaped by Affect Modulators

This category includes functional actions of the companions that can be parameterized by affect modulators. These behaviours differ from emotional expressions because companions display their affective state as a side effect, while performing actions in the environment or interacting socially with the user. This is important especially for scenarios where the companion's embodiment is limited in terms of expressivity, and consequently the set of emotional expressions that companions can convey is limited (for example in mobile robots without facial expression capabilities).

As emotional expressions are usually of short duration, the affect modulator that we selected to shape these behaviours is mood, a longer lasting affective state which is often seen as our affective disposition while doing something. In our scenarios, mood is represented as a valence variable (positive or negative) with an intensity value. The behaviours that can be regulated by the companion's mood can be categorized in three main groups: social communicative, interaction with the environment and locomotion.

Social communicative behaviours include behaviours that are relevant for the social interaction between the user and the companion, for example:

- greet <character/person>
- listen <character/person>
- talk <character/person> <speech-act>
- nod <character/person>
- look at <position/object/character/person>
- touch <position/object/character/person>
- point at <position/object/character/person>

Speech support behaviours include behaviours that are used to help express speech, just like italic or punctuation marks in text:

- Emphasis (italic)
- Punctuation (comma)
- Punctuation (period)
- Exclamation

Other behaviours that can be shaped by the companion's mood are the actions that the companion performs to **interact with the environment**, such as:

- pick <object>
- drop <object> <position>
- carry <object>

Finally, when considering embodiments of mobile robots, the way robots navigate in the environment can also be shaped by their mood. The **locomotion** behaviours that can be performed differently considering the affect modulators include:

- approach <position>
- retract from <position>
- move along <line>
- approach <object/character/person> <social distance>
- follow <object/character/person> <social distance>
- turn <angle>
- turn-back
- orient-towards <object/character/person> <social distance>

2.3 Expressing Emotions in Companions through Facial Expression

In this section we present a model for facial expression on the companions whose embodiment supports such kind of expression, namely EMYS and iCat. We will start by looking at two existing models, which are FACS (Ekman&Friesen, 1975) and MPEG-4 (Pandzic&Forchheimer, 2003). The first is oriented especially for the recognition of emotional expressions in the human face, and not necessarily for creating such expressions. The latter is oriented at expressing facial emotions in virtual characters. However, for our companions, both of them suffer in complexity: the human face is much more complex than any of the LIREC companions, and virtual characters also provide much more complexity and flexibility than robots.

There is also an additional component of facial expression that we are not considering so far, which is timing. Timing is extremely important for correctly expressing emotions; not just the speed and duration of the whole expression, but also the delay between different facial features (the eyes opening faster than the mouth, for example). On this preliminary study, we propose a model of expressions to be used by our companions, which only include the postures required for such expressions, in order to build a shared lexicon and notation. The timing shall be studied further, and shall be included more specifically into each companion, depending on its own expression abilities. For now, we will only distinguish the duration of the whole expression, as being “slow”, “moderate” or “fast” motion, with regard to the description of such emotions in the aforementioned study.

Therefore, we have analysed the expressions described by Ekman and Friesen, in order to understand how they might be decomposed in a most simple set of expressive features, plausible of being used in our robotic companions, and still expressive enough for all the expressions that we listed in the above sections. We will use the concept of expressive effectors, to refer to the physical means and degrees of freedom of the embodiment that can be used for expressing emotions.

The following table proposes a list of those features, which we designate of COmpanions Facial Features for Expressive Agents (COFFEA), which can be identified in the human face, and that will help us in the process of mapping a human-identifiable expression to the expressive effectors for both EMYS and iCat.

We also include the corresponding FACS Action Unit and Mpeg-4 Face Animation Parameter, so that they may be more easily understood. These features can also be visualized on **Error! Reference source not found.**.

Our ID	Human facial feature	FACS AU	Mpeg-4
IB	Lower/Raise Inner eyeBrows	1+4	31+32+37+38
OB	Lower/Raise Outer eyeBrows	2	33+34+35+36
UE	Close/Open Upper Eyelid	5	19+20
LE	Close/Open Lower Eyelid	6+7	21+22
JA	Close/Open JAw	26+27	3
SL	Squash/Stretch Lips	18+20	6+7
LC	Lower/Raise Lip Corners	12+15	12+13
UL	Lower/Raise Upper Lip	9+10	4+8+9
HT	Down/Up Head Tilt	85	48

Table 1: COFFEA features, mapped to FACS and Mpeg-4.

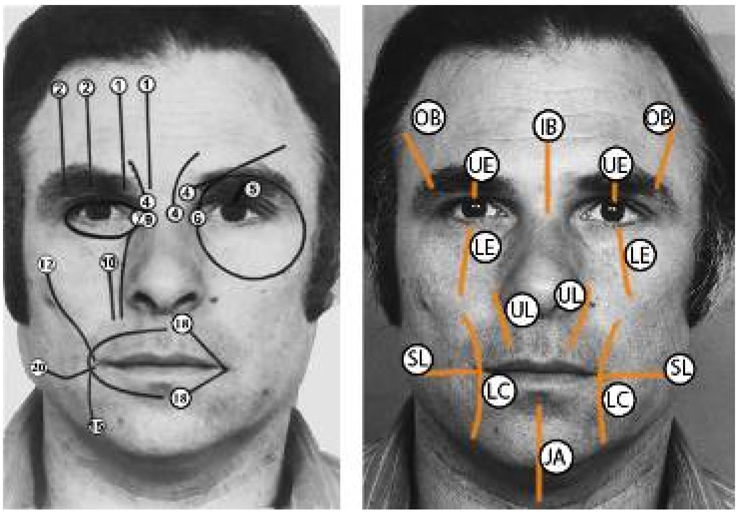

Figure 1. Some of the FACS Action Units (left) and COFFEA features (right).

Each feature is a discrete valence, meaning that it represents two opposite states, with intensity, defined in an interval between -5 and 5. Lower, Close, Squash and Down are considered to have negative valence, while Raise, Open, Stretch and Up are positive valence. The five point intensity scale follows Ekman's suggestion, which means that the ordered full set of intensities of an ID is **(-5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5)**. The value '0' in this list denotes neutral, representing not only the scale's intensity midpoint, but also, and more importantly, the intensity that would correspond to a neutral face posture. This scale should help us to define and verify different types of expressions with a less ambiguous notation, as two actions that cannot happen at the same time (for example, lower or raise lip corners) are merged into a single feature.

This way, the notation that will be used in the following sections for defining expressions will be **ID**(**INTENSITY**). Happiness, for example, encoded in FACS as 6+12, would be, in our notation, represented by **LE(-3)+LC(3)**. A more extreme Happiness expression, which would also include an open mouth, could be **LE(-5)+JA(3)+LC(5)**. This way we can define different emotions using a simple configuration, which can be modulated by intensity, in a common notation, which can be mapped by each embodiment into its own expressive effectors.

It is important to add another definition to this notation, which actually enables modulations from intensity. That means that each feature can instead be defined as **ID**(**LOW**,**HIGH**), where ***LOW*** represents the feature's intensity when the expression's intensity is at its lowest value, and ***HIGH*** following the same rule, for high intensities. Happiness could be defined as **LE(-1,-5)+JA(0,3)+LC(1,5).** This way, feature ***LE*** can have intensity varying from -***1*** to -5, feature ***JA*** from ***0*** to 3 (because an extremely open mouth would be an awkward smile), and feature ***LC*** also from ***1*** to 5. Finally, the mapping of the intensity of the expression into each of the features would be a straightforward mapping, in the sense that each emotion can also be represented with 5 different intensities **(1, 2, 3, 4, 5)**, meaning that, for each feature, ***1*** will map to the feature's low value, and ***5*** to its high value. Note that the ***Low*** and ***High*** values defined for a feature do not need to be ordered. What this means is that in the LE feature in our example, an intensity of ***1*** would imply the ***LE*** to be ***-1***, and an intensity of ***5*** would make ***LE*** lower to ***-5***.

One might notice that no feature for nose wrinkling was defined. This is both because the nose does not possess independent movement, and also because none of our companions support nose movement. In humans, wrinkling of the nose, which could be considered an expressive feature, is actually accompanied by raising the upper lip. So if the robots could express a wrinkling of the nose, they should have it wrinkling along with the movement of the upper lip. That way, we only consider the upper lip for this expressive feature. For the same reason, we also did not include a feature for cheek raise, as this generally follows the lower eyelid raise.

It would also be useful to add timing or synchronization definitions to this notation, however, for now that study has still not been conducted, so we will not consider it. For now we will only include a feature for speed, represented by SPEED (slow), SPEED (moderate) or SPEED(fast). We also predict that for each embodiment, different timings and synchronizations shall be used, in order to better express and distinguish each of the emotions. That way, timing and synchronization shall be considered locally for each of the companions, with no general rule, except for that of considering some of the cartoon theory further presented in section 2.4.

This notation will be better understood throughout the following sections, in which we provide the definition for the six basic expressions. The following sections, which present a definition proposal for the various expressions, are all based on the analysis of the work of (Ekman&Friesen, 1975) and (Ekman, 1972), in the context of what we consider interesting and feasible for LIREC. These proposals will then be tested in the embodiments, in order to understand if they work or make sense, thus remaining subject to modifications.

2.3.1 Basic Expressions Definition

2.3.1.1 Surprise (Startle)

Surprise is described as having the eyebrows raised, eyes wide open, the jaw drop open, and the head tilts upward. In terms of timing, it is a fast motion. In our notation, we define it as:

IB(1,5)+OB(1,5)+UE(1,5)+LE(1,5)+JA(1,4)+HT(1,3)+SPEED(fast)

2.3.1.2 Disgust

Disgust is described as having lowered eyebrows, lower eyelids up, upper lip raised, and nose wrinkled. In terms of timing, it is a moderate motion. In our notation, we define it as:

IB(-1,-5)+OB(-1,-5)+LE(-1,-3)+UL(1,5)+SPEED(moderate)

2.3.1.3 Fear

Fear is described as raised eyebrows, semi-open mouth, open eyes, raised lower eyelids, and soft upwards head tilt. In terms of timing, it is generally a slow motion, and can be accompanied by trembling of the jaw. In our notation, we define it as:

IB(1,5)+OB(1,5)+JA(1,3)+UE(3,5)+LE(-1,-3)+HT(0,2)+SPEED(slow)

2.3.1.4 Anger

Anger is described with lowered inner eyebrows, raised outer eyebrows, raised lower eyelids, eyes semi-closed, lips squashed, and head slightly tilted downwards. In terms of timing, it is a moderate motion. In our notation, we define it as:

IB(-1,-5)+OB(1,5)+LE(-1,-3)+UE(-1,-3)+SL(-1,-5)+HT(-1,-3)+SPEED(moderate)

2.3.1.5 Happiness

Happiness is described as having the lips closed and stretched, jaw may be open, lip corners raised, lower eyelids raised, and raised upper eyelid. In terms of timing, it is a moderate motion. In our notation, we define it as:

SL(2,5)+JA(0,3)+LC(1,5)+LE(-1,-5)+UE(1,5)+SPEED(moderate)

2.3.1.6 Sadness

Sadness is described with raised inner eyebrows, raised lower eyelid, upper eyelid softly raised, lips squashed with corners pulled down, and head tilted down. In terms of timing, it is a slow motion, and is sometimes accompanied by trembling of the jaw. In our notation, we define it as:

IB(1,5)+LE(-3,-5)+UE(1,3)+SL(0,-3)+LC(-1,-5)+HT(-1,-5)+SPEED(slow)

2.3.2 Blend Expressions Definition

The blend expressions description will not be so exhaustive, so we will only present the proposed definition, in our notation. Surprise-blends have the particularity that they may be completely blended, or used in succession. This is because, most of the times, the blend is actually an instant startle, followed by another expression. However, this startle may, in fact, represent a full blend of surprise with that expression, which is then transformed into just that pure expression. In terms of user testes, both these situations should be tested, in order to understand if users distinguish both, and if not, which of the situations they more easily perceive.

2.3.2.1 Surprise-Disgust

Surprise brow, disgust mouth, cheeks raised, upper eyelid up:

IB(1,5)+OB(1,5)+UE(1,5)+LE(1,5)+JA(1,4)+HT(1,3) + UL(1,5)

2.3.2.2 Surprise-Fear

Surprise brow, fear eyes and mouth:

IB(1,5)+OB(1,5)+HT(1,3) + JA(1,3), UE(3,5), LE(-1,-3)

2.3.2.3 Surprise-Anger

Surprise mouth, anger brows and eyes:

JA(1,4) + IB(-1,-5)+UE(-1,-3)+LE(-1,-3)+SL(-1,-3)+HT(1,-3)

2.3.2.4 Surprise-Happy

Surprise brows, happy eyes and mouth:

IB(1,5)+OB(1,5)+HT(1,3) + UE(1,5)+LE(-1,-3)+SL(2,5)+LC(1,5)+JA(0,3)

2.3.2.5 Disgust-Fear (Horror)

Closed mouth, cheeks raised, upper lip raised, fear eyebrow, fear upper eyelid:

JA(0)+LE(-2,-4)+UL(1,5) + IB(1,5)+OB(1,5)+UE(3,5)

2.3.2.6 Anger-Fear

Anger brows and eyes, fear mouth:

IB(-1,-5)+UE(-1,-3)+LE(-1,-3)+SL(-1,-5)+HT(-1,-3) + JA(1,3)

2.3.2.7 Happiness-Anger

Happy mouth, anger eyelids and brows:

SL(2,5)+LC(1,5)+JA(0,3) + IB(-1,-5)+UE(-1,-3)+LE(-1,-3)+HT(-1,-3)

2.3.2.8 Happiness-Fear

Happy mouth, fear eyes and brows:

SL(2,5)+LC(1,5)+JA(0,3) + UE(3,5), LE(-1,-3)+IB(1,5)+OB(1,5)

2.3.2.9 Sadness-Fear (Distress)

Sad brow and eyes, fear/open mouth:

IB(1,5)+UE(1,3)+LE(-3,-5)+HT(-1,-3) + JA(2,4)

2.3.2.10 Sadness-Disgust (Pout)

Sad brow and eyes, disgust mouth:

IB(1,5)+UE(1,3)+LE(-3,-5)+HT(-1,-3) + UL(1,5)

2.3.2.11 Sadness-Anger

Sad mouth, anger brows and eyes:

SL(0,-3)+LC(-1,-5)+HT(-2,-5) + IB(-1,-5)+UE(-1,-3)+LE(-1,-3)

2.3.2.12 Sadness-Happiness (Nostalgic/Bittersweet)

Sad brows and upper eyelids, happy mouth and lower eyelids:

IB(1,5)+UE(1,3) + LE(-1,-3)+SL(2,5)+LC(1,5)+JA(0,3)

2.4 Cartoon Theory in Expression

(Thomas & Johnston, 1981) present a series of principles that should be taken into account while performing animation. From the twelve principles of animations, the ones that are most important for us to consider are the principles of exaggeration, slow in/slow out, arcs and timing.

Exaggeration can be used on some features to make sure that people understand what is being expressed. This means that we do not need to follow hard rules about keeping the movement slight and steady, and can instead exaggerate some of the movements, in some situations, and depending on the embodiment.

Slow in/slow out is important for a robotic companion, so people can feel that the robot can be calm and smooth, and not just a hard-solid machine. This means that we should pay attention to some movements that may seem too abrupt, and try to soften them, in order to seem less threatening. Trying to use arcs for trajectories whenever possible will also help with this aspect, especially when rotating the whole head sideways.

Timing has already been mentioned, and is also an important aspect. Sometimes cartoons break some rules of physics, in terms of timing, so that certain events or features are more noticeable. In the same way, we may use different timings on expressions, not following the physiological procedure, but a more flexible one, to enhance the noticeability of each of the features that compose the expressions.

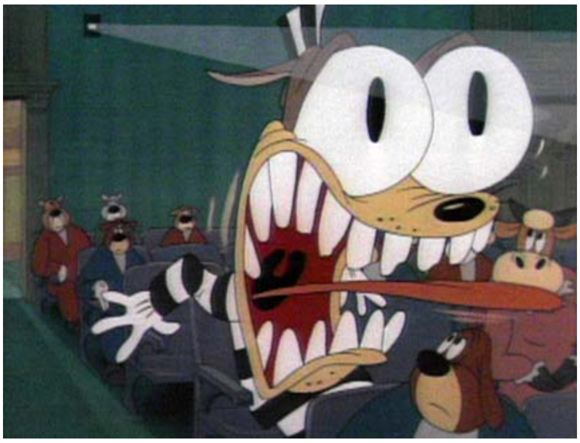

Figure 2. Tex Avery's eyes-popping expression.

Tex Avery was one of the greatest animators of all time (Canemaker, 1996), and created lots of concepts and gags that have remained not just as animation *clichés*, but also as expressive guidelines. He was especially a master in exaggeration, being credited as the creator of the eyes-popping-out expression that is now sometimes called "the Tex Avery expression", or just "a Tex Avery". He thus represents an important reference in LIREC project, as our robotic companion EMYS supports that expression.

2.5 Expressing Emotions in Companions through Lights and Sound

Expressing emotions in companions that do not have any kind of expressive effectors (face, expressive arms and legs, etc.) is challenging. Solving this problem can thus be a very creative work. One solution may be to perform a locomotive gesture that attempts to portray such emotions. However, besides being an extremely ambiguous manifest, such gesture may not be used while the companion moves around, or performs other activities. Embodiments like those of Sunflower or People Bot should rely on lights and sounds to express emotions.

Expressing emotions through lights and sound is a subject that one can vastly find in some performative arts, for example, in music, theatre or movies. However, in these media, such emotions are subject to the creative prospect of the artist, and are generally created specifically for each work of art. It is hard to find a generalization that could be used to make an artificial agent capable of artistic expression which would actually be emotionally understood by humans. However, one may find studies about the psychological reactions to colour and sound, in order to try to extract some knowledge about how to use those elements for emotional expression in our scenarios, so that we can test and validate it with users.

(Heller, 2000) provides a very complete study about the emotions and ideas associated with colours. Twelve different colours were analyzed, and user studies were conducted in order to evaluate what kind of emotions and concepts people relate to each of the colours. The book provides an index and statistics on the colours and on the concepts/emotions, along with extensive cultural and social background of the use of those colours. This book also presents an important concept for colour expression, which is the concept of *chromatic combination*.

A chromatic combination is a mix of two or more colours (generally up to five) that is easily associated with a concept or emotion. Chromatic combinations are important, because colour interpretation is dependent on context, so providing a combination instead of a single colour helps to establish a context. Red can be associated to love, or to blood and war. However, a combination of red and white is unmistakably associated to love, while a combination of red, black and a pinch of yellow is associated to war and violence.

Heller provides a list of the chromatic combinations, which contain not only the colours that compose each combination, but also the spatial proportion that each of the colours should represent in that combination.

With this in mind, we can equip the most limited companions with an array of three or four independent and expressively visible lights, in order to use them to irradiate the companion's emotion. Some of the embodiments, like iCat or NAO already provide expressive lights, which can more effectively be used if we take this study in consideration.

In Figure 3 we present some possible colour combinations for expressing the six basic emotions. Although Heller does not directly provide combinations for these specific emotions (except for joy and anger), they were designed with full consideration for her work and her own list of combinations. These and other possible combinations will be tested with users in order to understand the best way of expressing the basic emotions using a limited array of lights. There is a remark that we had into account that was the fact that black should not be considered, because we want to use the colors with lights, so we won't be able to emit black. That way, we decided to replace black with brown, and user test will help us to understand if that works. Grey could also suffer from this problem, however, we can try to consider grey to be a low intensity white, or to mix it with brown, resulting in a desaturated brown.

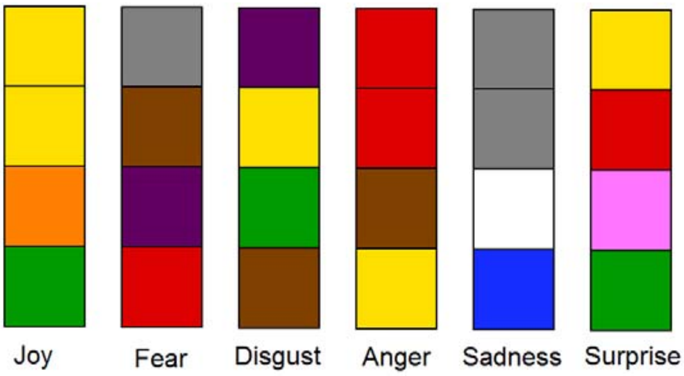

Figure 3. Colour combinations for the six basic emotions (Heller, 2000)

Some studies about the relationship between auditory stimuli and emotions have also been conducted, being (Scherer & Oshinsky, 1977) a great reference, which provides organized attribution of emotions to acoustic parameters. The following table is based on this reference, and provides some background that can be used to generate different sounds for expressing some different emotions, which may be useful in the LIREC scenarios.

	Harmonics	Pitch Level	Pitch Variation	Contour	Tempo
Surprise	Many	High	High	Up	Fast
Disgust	Many	High	Small	Up	Fast
Fear	Many	High	Small	Up	Fast
Anger	Many	High	Small	Up	Fast
Happiness	Few	Middle	High	Up	Fast
Sadness	Few	Low	High	Down	Slow

Table 2: Emotions related to acoustic parameters (Scherer & Oshinsky, 1977).

Interpretation of this data and subsequent translation into actual sounds may not seem trivial; however, using some simple music theory (Gardner, 1912), we can establish a base musical point, it work from there.

For expressing an emotion, one may use a sequence of notes of some chord (arpeggio), on some scale, based on variations of these parameters. The choice of the musical scale may help define the mood, and the chord may be used to express different personas, due to the fact that a chord by itself does not generally transmit an emotion. For experimentation purposes, we can start by using the C Major Scale, which is the most common, and use arpeggios of the C chord, as represented in the next figure. The left side shows a piano, marking each of the notes, with a red dot on the keys that define the C chord. On the piano, pitch is lower at the left, and rises to the right. The right side shows a score with an arpeggio of the C chord, meaning that each of the four keys is played in sequence.

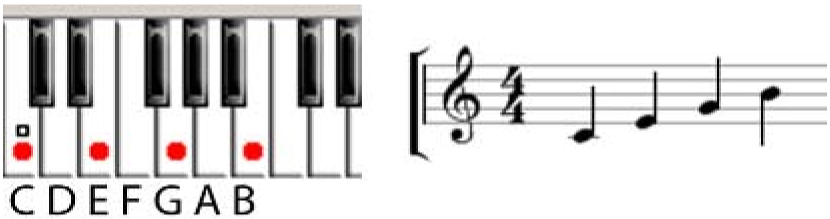

Figure 4. CMaj Chord on the piano (left) and on the sheet (right).

Without extending much into musical theory, we just define that two of the possible ways of expressing a chord is by a group of three notes (a triad) or four notes (a seventh chord). Thus, the C-chord may be C-E-G, or C-E-G-B. These two can represent the high and low pitch variation acoustic parameters.

The contour can go Up and Down, meaning that the arpeggio could be performed in the order C-E-G-B (Up), or B-G-E-C (Down).

Pitch level can define the octave used. An octave is the interval between a musical pitch, and other with half or double of its frequency. In Figure 5, at the left, the C represented is the middle C, also known as C4, because it is the C of the 4^{th} octave, and it represents the frequency of 261.5Hz. After the B will come C5, which is an octave higher, so its frequency is 523Hz.

This is better understood in the following picture:

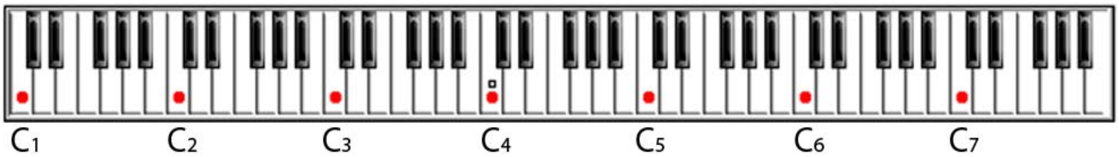

Figure 5: C note in different octaves.

We can thus define that a low pitch level will correspond to starting on C_3, high pitch level on C_5, and if unspecified, we can start on C_4.

The harmonics of a note are the same note, in other octaves, both higher and lower. That means that the harmonics count may be expressed as the number of harmonics that are being played at the same time. Few harmonics will only play one note at a time, for example, C_4. Many harmonics will mean to play two or three notes at the same time, for example C_4+C_5 or C_3+C_4+C_5, instead of just C_4. The harmonics parameter should then also be used for the rest of the notes of the arpeggio.

Finally, the tempo is the easiest parameter. It just represents how fast the arpeggio is played.

One may also notice that some of the emotions on Table 2 are represented by the same parameters. Based on (Mehrabian, 1996), we can educately identify that the harmonics count can help to distinguish dominance between emotions, the contour and pitch level can help to distinguish pleasure, and tempo and pitch variation to distinguish arousal. Thus, Anger and Disgust may have a down contour, and a low pitch level, which efficiently distinguishes them from Surprise, Fear and Happiness. Disgust and Fear should be less dominant than Anger or Surprise, so reducing the harmonics also distinguishes these emotions. All the fast expressions except surprise can have their tempo lowered to Moderate, so that Surprise becomes more distinguishable. Anger gets a higher pitch variation, due to its high arousal when faced with fear or disgust. Fear and Happiness swapped their pitch level, because happiness should have high pleasure, while in fear, pleasure should be low. We now have a table that better distinguishes the basic emotions in terms of acoustic parameters:

Table 3: Proposed relation of emotions to acoustic parameters.

	Harmonics	Pitch Level	Pitch Variation	Contour	Tempo
Surprise	Many	High	High	Up	Fast
Disgust	Few	Low	Small	Down	Moderate
Fear	Few	Middle	Small	Up	Moderate
Anger	Many	Low	High	Down	Moderate
Happiness	Few	High	High	Up	Moderate
Sadness	Few	Low	High	Down	Slow

We finally present in the following figure, a proposal for expression of the six basic emotions, using C chords of the C major scale. For evaluation purposes, a test with users must also include the other six main chords of this scale, in order to find out if some chord transmits the emotions more easily, or if the choice of the chords is indifferent to perception of the emotion, thus remaining just a matter of taste and aesthetic.

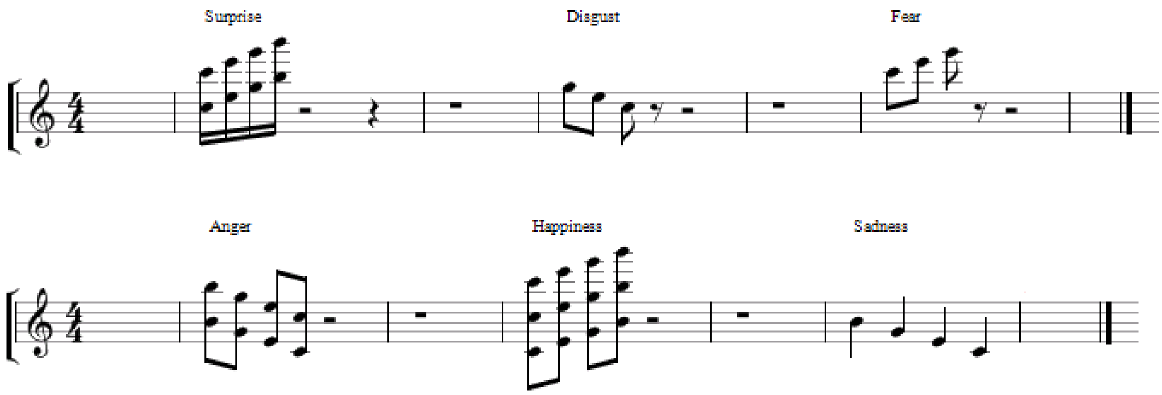

Figure 6. Six basic emotions in arpeggios of Cmaj.

3 Expressive Modalities of LIREC Companions

This section contains a brief description of the expressive modalities of the robots and virtual agents of LIREC scenarios. This information is complemented with online videos in http://vimeo.com/lirec.

3.1 iCat

The iCat robot is used in some scenarios of MyFriend Showcase. The robot is 38 cm tall and is equipped with eleven RC servos and two DC motors that control different parts of the face such as the eyebrows, eyes, eyelids, mouth and head position (see Figure 7). In addition, the iCat has a web-cam installed in the nose and a stereo microphone that can be used to determine the direction of the sound or for speech recognition. A speaker and a soundcard are installed to play sounds and speech. Finally, the robot has multi-coloured LEDs and touch sensors in both pawns and ears. The iCat can generate several different facial expressions such as happiness, sadness, surprise or disgust.

Figure 7. Hardware setup of the iCat robot.

In the Game Companion scenario, where the iCat plays chess against a human player, the iCat's expressive behaviour is determined by its affective state that consists of two main parts: emotional reactions and mood (http://vimeo.com/10799224). Emotional reactions (see Figure 8) are triggered every time iCat's opponent makes a move.

They are computed using the emotivector model, an anticipatory mechanism that generates one (out of nine) affective signals resulting from the mismatch between an expected and a sensed value. Each affective signal is then mapped into an expressive behaviour that reflects an emotion (e.g. sad, happy, surprised…). For example, if the iCat has a small advantage in the game and suddenly its opponent commits a mistake that allows the iCat to capture her queen, the triggered sensation will be a "stronger reward", which will lead to an emotion of surprise (the sensation is better than we were expecting). We used the animations provided by the iCat's platform because they have already been submitted to tests which verify that users perceive those emotional expressions on iCat's embodiment (REF).

Figure 8. iCat's emotional expressions.

Mood (see Figure 9) is a relatively lasting affective state. It is less specific, often less intense and thus less likely to be triggered by a particular stimulus or event. In our scenario, mood is the affect modulator that influences the overall expression of the iCat every time the robot is not displaying an emotional expression. To do so, we use two predefined facial parameterizations, one for positive mood at the highest intensity and another for negative mood with higher intensity. The facial expressions for the remaining intensity mood values are computed by interpolation of those parameterizations, resulting in "happy" or "sad" faces with different intensities. When the mood intensity is low, facial expressions tend to become neutral.

Figure 9. iCat's mood.

In this scenario, two other different embodiments were used (see Figure 10). In some experiments, instead of the iCat robot, an identical 3D screen based version of the iCat displayed on a 17 inch TFT monitor displaying in full screen was used (approximately with the same size of the real robot). In the application running on the android mobile phone, we have developed a 2D version of the iCat's embodiment. In this version, the iCat displays the emotional reactions similar to the ones in the robot, but mood is expressed in a more limited manner: there is no intensity, only two fixed "expressions", one for positive and another for negative mood.

Figure 10. Graphical version of the iCat on a computer screen (left) and on android mobile device (right).

3.2 Pleo

This scenario consists of a virtual pet with two embodiments: the Pleo robot (Copyright 2010 Innvo Labs Corporation) and a virtual version for a mobile device (“MyPleo”).

The Pleo robot has the following 14 motors: two for each leg, one for the torso, two for the tail (horizontal and vertical movement), two for the neck (horizontal and vertical movement) and one for the eyes and mouth (complete eye extension opens mouth and the mouth cannot open with the eyes closed). It also supports playback of sound files in the following format: 11k sample rate, 8-bit, mono. The robot’s SDK comes with a set of behaviours, some of which combine motion and sound. These include: biting, wagging tail, sniffing the ground, walking forward or backward slowly, laying down, and getting up. There are also some behaviours that appear to represent mental states: angry, bored, happy and sad. However, it is unclear if the interpretation of these behaviours, that have several variations for the same state, has ever been validated by user-testing. All behaviours can be authored, and new ones can be created using the MySkit application.

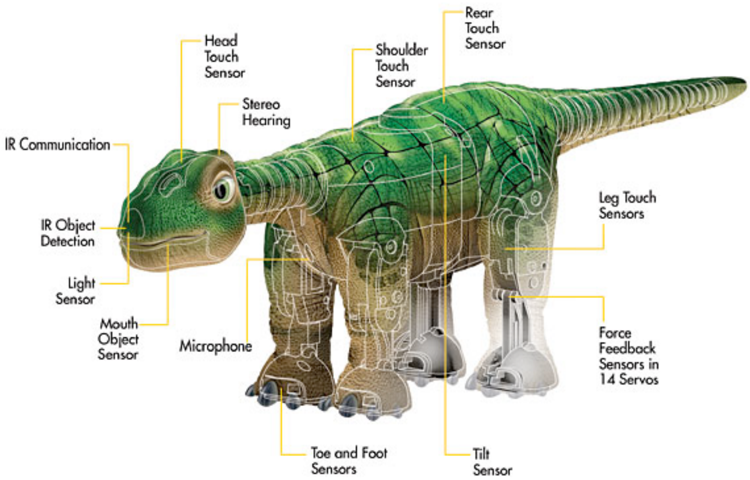

Figure 11. Technical details of the Pleo Robot.

Currently, there are three main sets of behaviours being used:

- Social: wagging tail, raising head, opening mouth, and breathing sound.
- Grazing: sniffing the ground, biting, turning its neck from side to side, lowering tail, and chewing sound.
- Needy: reduced overall movement, lowering tail, lowering head, quiet growling and short cries.

Turning to the embodiment in the mobile device, Pleo can perform the following actions: walking around a small confined open area; consuming food and water when supplied; raising its neck; pooping; and going through an obstacle course in a pre-scripted path. Concerning expression if its internal state, it sits down and cries when its energy is low.

Figure 12. Pleo's embodiment in the mobile application.

For a video displaying the social and grazing behaviour sets of the Pleo robot, as well as some of the embodiment in the mobile device, see:

http://www.youtube.com/watch?v=jgjWtlm3S1o.

3.3 Emys

In Deliverable D6.2 we have distinguished a number of preliminary EMYS head configurations, realised as a visualisation of the EMYS 3D model. A collection of these pictures (Figure 13) has been presented to the public with the purpose of identification of basic emotions. The interviewed group that consisted of students, adults and children, has been asked to assign to the pictures the following emotions: neutral, anger, disgust, fear, joy, sadness and surprise. Additionally, we add a configuration of neutral expressivity.

In the majority of the cases, the configurations were correctly identified and associated with the canonical emotions. Actually, the most difficult to identify were fear and joy. Results have been included in the D6.2.

For a more final set of EMYS expressions, which are designed to be modulated by intensity, we will also consider those six basic emotions, following the study of section 2.1. We also include the neutral expression. (Osipa, 2003) defines the neutral pose as being bored.

This companion is the first embodiment in which we shall test our expression proposals from section 2.3. There is also some cartoon theory that should be considered, especially because EMYS supports protrusion (popping) of the eyes. This is a concept that was created in the cartoon world by Tex Avery (Canemaker, 1996), and has since then been an important feature to express surprise and fear.

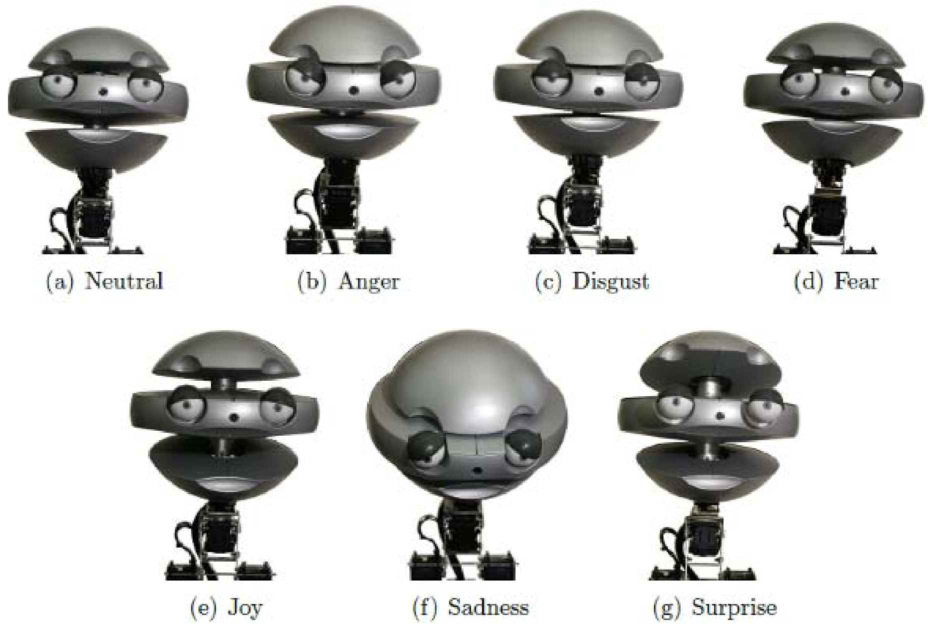

Figure 13. Preliminary basic expressions for EMYS, from Deliverable D6.2.

First of all, a mapping of the COFFEA features to EMYS expressive effectors must be defined, so we must start by analysing the expressive effectors of EMYS. Its embodiment contains eleven degrees of freedom, from which six are paired (three left and three right). Thus, the list of expressive effectors, illustrated in Figure 14, can be summarized in:

- Lower/Raise upper plate (UP) - Can be used as outer eyebrows;
- Lower/Raise lower plate (LP) - Represents the Jaw;
- Lower/Raise head (HT) - Can be used by head tilt, or to give impression of cheek raising/lower eyebrow, as the middle plate, when raised, causes occlusion over the eye;
- Lower/Raise neck (NT) – Can be used to support head tilt;
- Rotate In/Out eyelid (RE) (paired) – Can simulate inner eyebrows;
- Close/Open eyelid (CE) (paired) – Used as upper eyelid;
- Pop eyeball (PE) (paired) – Not used in COFFEA, however, will be included in some expressions, by cartoon theory.
- Head pan (HP) – Not used in COFFEA. Will be used for exaggeration of some negative feelings.

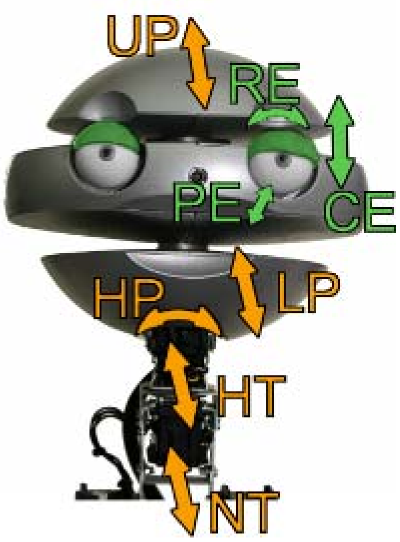

Figure 14. EMYS expressive effectors

The COFFEA mapping for EMYS is summarized in the following table:

COFFEA feature	EMYS mapping
IB	RE - Rotate In/Out eyelids (in for lower, out for raise)
OB	UP - Lower/Raise upper plate
UE	CE - Close/Open eyelids
LE	HT - Raise/Lower head
JA	LP - Raise/Lower lower plate (raise for close, lower for open)
SL	HT - Slightly tilt head down/up (down for squash, up for stretch)
LC	LP - Slightly raise/lower lower plate
UL	LP / HT - Lower/raise lower plate, or Slightly tilt head up (only for upper lip raise)
HT	HT - Lower/Raise head if not being used, or else use Lower/Raise neck

Table 4: COFFEA features mapped to EMYS expressive effectors.

There are a set of conflicts in our mapping that must be resolved. This happens because EMYS' head is not capable of expressing all of the COFFEA features. The conflicts happen on the lower plate, and on the whole head tilt. Thus, a set of priorities must be defined for the conflicting features.

- Lower/Raise head: LE > SL > UL > HT

The priority order is defined so that the expressivity associated to the eyes is more valuable than the others, being pure head tilt the feature with less priority.

- Lower/Raise lower plate: LC > UL > JA

Once again, the pure jaw movement is given a less priority, and the expressivity of the smile and frown has the top priority.

It is now possible to map the basic expressions to EMYS using the relationship between COFFEA features, and EMYS expressive effectors:

3.3.1.1 Surprise (Startle)

COFFEA: IB(1,5)+OB(1,5)+UE(1,5)+LE(1,5)+JA(1,4)+HT(1,3)

EMYS: RE(1,5)+UP(1,5)+CE(1,5)+HT(-1,-5)+LP(-1,-5)+NT(1,5)+PE(1,5)

3.3.1.2 Disgust

COFFEA: IB(-1,-5)+OB(-1,-5)+LE(-1,-3)+UL(1,5)

EMYS: RE(-2,-5)+UP(-1,-5)+HT(2,4)+LP(3,5)+HP(0,1)+LE(-1)

3.3.1.3 Fear

COFFEA: IB(1,5)+OB(1,5)+JA(1,3)+UE(3,5)+LE(-1,-3)+HT(0,2)

EMYS: RE(1,5)+UP(1,5)+LP(3,-2)+CE(3,5)+HT(1,-1)+NT(0,3)+PE(0,3)

3.3.1.4 Anger

COFFEA: IB(-1,-5)+OB(1,5)+LE(-1,-3)+UE(-1,-3)+SL(-1,-5)+HT(-1,-3)

EMYS: RE(-3,-5)+UP(-1,-5)+HT(1,3)+CE(0,-1)+NT(-1,-3)

3.3.1.5 Happiness

COFFEA: SL(2,5)+JA(0,3)+LC(1,5)+LE(-1,-5)+UE(1,5)

EMYS: LP(-1,-5)+HT(2,5)+CE(2,5)

3.3.1.6 Sadness

COFFEA: IB(1,5)+LE(-3,-5)+UE(1,3)+SL(0,-3)+LC(-1,-5)+HT(-1,-5)

EMYS: RE(3,5)+HT(-3,-5)+CE(1,3)+LP(3,5)+NT(-1,-5)+UP(2,5)

The resulting new expressions are presented in Figure 15.

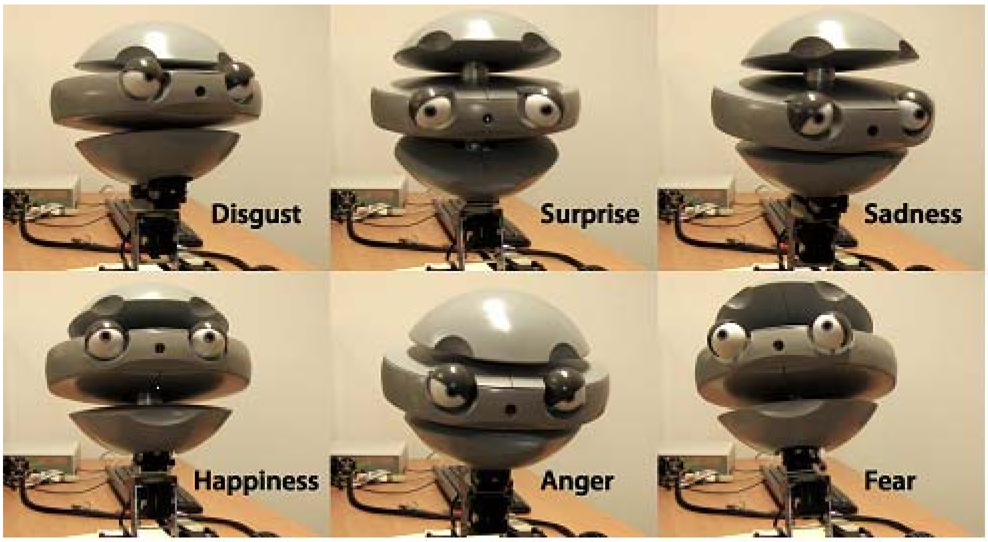

Figure 15. : Basic expressions for EMYS.

A video with a strong and soft intensity for each of the expressions can be found in http://vimeo.com/21156336. These twelve animations were used on a preliminary evaluation with six children, with ages between 8 and 12. The results were compiled into the graph in Figure 16. Each expression was exhibited twice, in a random order, for each of the users, thus resulting in 24 views in each run (6 emotions x 2 intensities x 2). We can from Figure 17, Anger and Sadness were easily identified, while Fear and Joy were very confused with Surprise, and also with other emotions. That way, Surprise also revealed to be an ambiguous expression. Disgust was mainly confused with anger. This preliminary study enabled us to refine the expressions before creating the animations for the other three intensities on each emotion, and before conducting a more intensive evaluation with a much larger group of people.

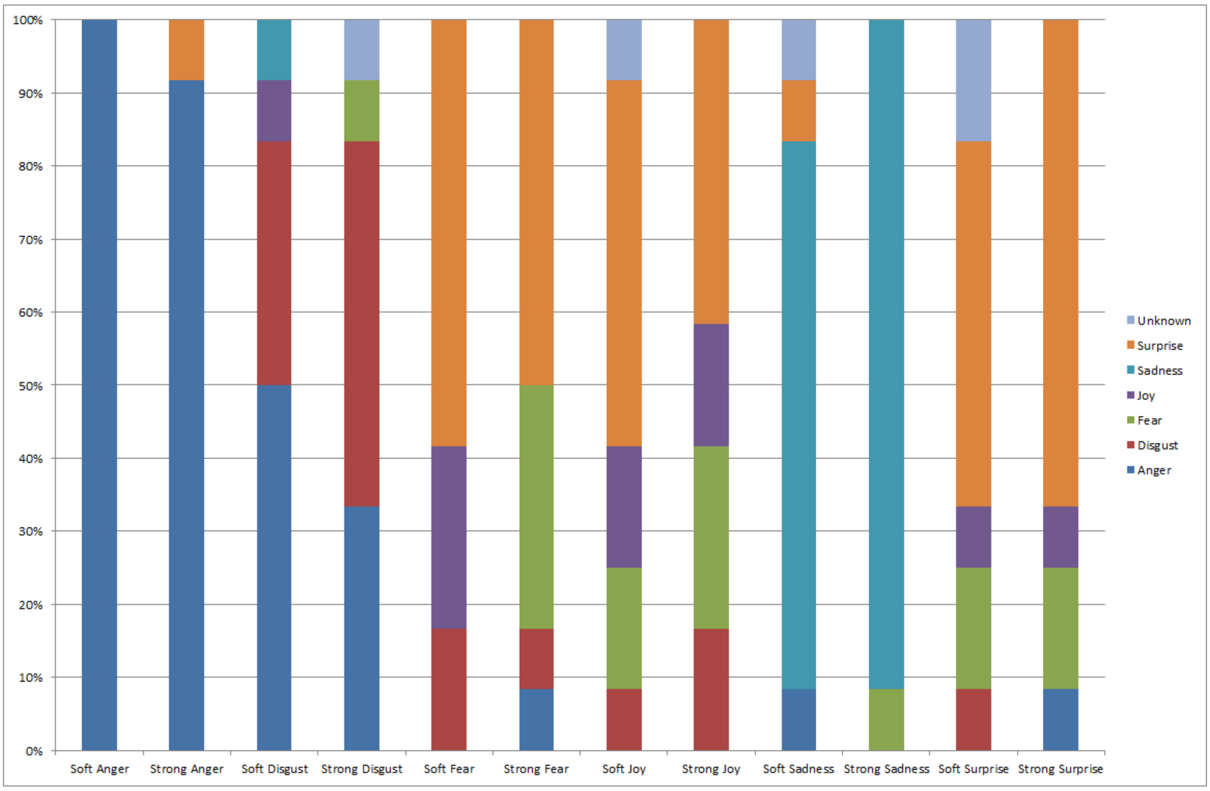

Figure 17: Results of the preliminary evaluation on EMYS emotional expressions.

3.4 Sunflower

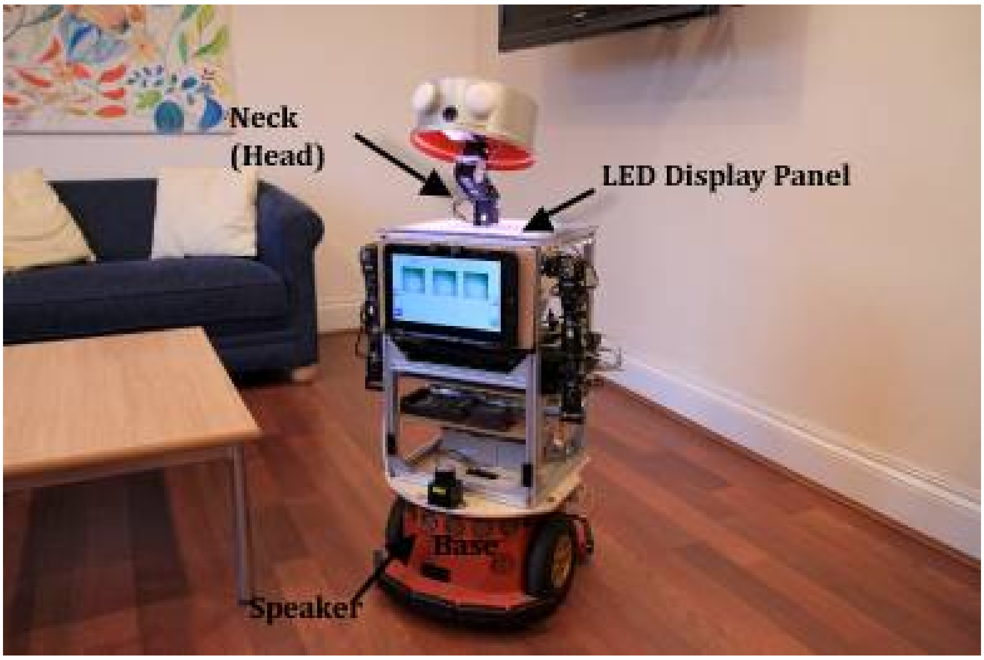

Figure 18. UH Companion Prototype - Sunflower

Sunflower will be used in the Robot House Showcase scenarios and studies. It was designed with the abilities to express its internal states through body and head motions, sound, and LED display panels. Sunflower currently has 6 expressive behaviours (Migration In, Migration Out, Happy, Excited, Bored and Tired) utilising a combination of its expressive channels.

Sunflower was designed with a simple face (compared to the relatively high expressivity of Emys and the iCat face) as one of the main aims is to investigate other non-facial modalities for expressive behaviours. This is particularly important to help the understanding of how users perceive the consistency of agent's behaviours across different embodiments in cases where the agent's mind e.g. migrates from a humanoid platform (e.g. CHARLY) to a mechanoid (our original "Pioneer" robot) or zoomorphic platform (AIBO).

3.5 CHARLY

The Companion Humanoid Autonomous Robot for Living with You (CHARLY) will be used in the Robot House Showcase and scenarios, in particular those targeted at HRI user studies which investigate aspects related to companion embodiment. As appearance is an important aspect of embodiment, the appearance of CHARLY was designed to be relatively easily changable by the use of easily replaceable body covers and multiple heads. CHARLY is a humanoid robot; that is, a robot that is not supposed to be realistically human-like in appearance, but has a number of simplified human-like characteristics in order to facilitate human-like expressive behaviours. CHARLY has two arms, with 6 DoF, primarily to be used for gestures, but can also be used for some very limited manipulation of objects. As the range of appearances and expressive capabilities even for humanoid robots is large, initially two sets of body covers and associated heads will be used: One set will have a more human-like overall appearance with a simple actuated face (based on the existing UH developed robot, KASPAR) which allows CHARLY to open/close mouth, smile, look up/down and close eyes (see Figure 19 below). The second set of covers and head will provide a more mechanical, but still humanoid, appearance and will mainly use light signals, in conjunction with arm gestures to perform expressive behaviours. CHARLY can be used to investigate how its internal state can be expressed using arm gestures in conjunction with different expressive functionalities including light signals and simple facial expression.

Figure 19. CHARLY with human-like head and without body covers.

3.6 AIBO

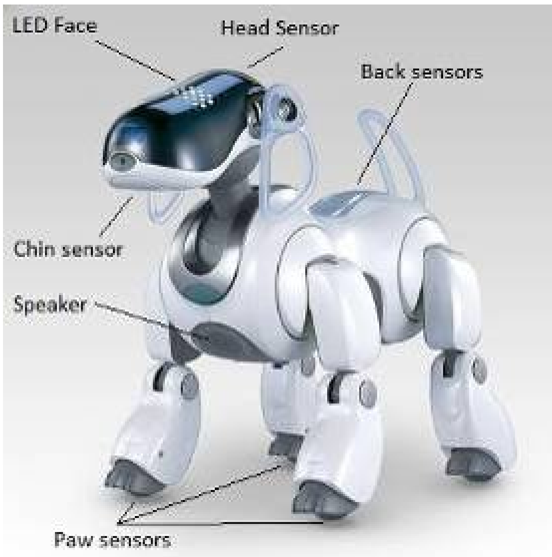

Figure 20. Sony AIBO ERS-7 Robot

In the Robot House social mediator scenario, a Sony AIBO ERS-7 robot shown in Figure 20 is used as a social mediator. This AIBO is capable of expressing its internal state utilising its actuators (in its legs and head), led displays (face) and speaker (barking). The AIBO is capable to express behaviours such as Boredom, Happy, Tired and Excited based on its internal state when interacting with the user in a social mediator game (Papadopoulos et al., 2010).

Figure 21. AIBO expressing Boredom behaviour (attention seeking) - in this behaviour AIBO executes a combination of movements, sounds and LED display in order to attracts the user's attention. It then lifts it paw and waits for the user to interact with it (pressing its paw).

3.7 Little Mozart

Little Mozart is a virtual companion in an interactive environment that allows children or adults to compose their own melodies.

Figure 22. Little Mozart graphical character.

3.7.1 The important role of emotions

In LIREC research context emotion plays a major role in the establishment of a relationship between humans and virtual companions, therefore it is essential to understand how emotions can influence our actions and our ability to relate and empathize with others.

For example, evidence suggests that emotions are crucial for effective decision making (Damasio 1994; LeDoux 1996; Mele 2001), memory (Bower 1991; Nasby and Yando, 1982), teaching (Lepper 1988), coping with environmental stressors (Lazarus 1991), communication (Brave and Nass 2002), and social reasoning (Forgas 1991; Frank 1988)" (apud Gratch & Marsella, 2005). Damásio and his studies on patients with lesions on the prefrontal region of the brain proved the direct relationship between emotions and rational thinking. (Damásio, 1996, 2000).

This finding contributed to the idea that emotion is a key element to make a robot or virtual companion more engaging and effective in its interaction, since it provides him with the tools to relate to the user and process the user's feedback and actions, and more importantly to develop an emotional intelligence. By recognizing and expressing emotion the virtual companion captures the attention of the user and is able to respond accordingly to the user's emotional state, detecting states of boredom or frustration and giving a motivating and engaging feedback (Johnson, Rickel & Lester, 2000).

3.7.2 Expression of emotion

All of our behavior, verbal or non-verbal, is communicative, it is impossible not to communicate (Watzlawick, Beavin e Jackson, 2000). This fact emphasis the importance of providing our virtual companion with proper expression of emotion, this can be achieved by developing methods to express emotion through all different channels of communication.

Figure 23 - Little Mozart face prototype, when morphing facial expressions

The face is the richest source of information about our emotions and emotional state. The face and the body support non-verbal communication with its many facial and bodily features. Complex facial expressions are produced in result of emotions and feelings and can vary in intensity, meaning and role in interaction. In facial expressions the muscles play a major role since they are responsible for skin deformations (ul-Hasan, 2006).

If we as humans express our emotions and feelings through our face and body language, conscious or unconsciously, and if that is the way we communicate with others, then it is necessary that the virtual companion also has the means to produce these instinctive responses and assure identification by the user.

In order to make our virtual companion more believable and real we provided Little Mozart with facial expressions (Correia, 2009) basing this process on a study that led us to Ekman's six basic emotions and his Facial Action Coding System, FACS. Considering the six basic emotions: happiness, sadness, fear, anger, disgust and surprise, we supported the design process on the previous studies on facial expression and emotion expression. The FACS model allows the categorization of the physical expressions of emotion and offers a detailed description of them based on Action Units, AU, which represents the physical changes that occur in the face while we experience an emotion (Donato *et al.,* 1999, Lien *et al.,* 1999).

To correctly apply this knowledge we studied which AUs were linked with each facial expression. Then the next step was to know which facial muscles were associated with the AUs, so that we could know which muscles to modify and alter. The final step was to manipulate the muscles using morphing technique, which allows modelling portions of the face and makes them as realistic as possible and then the portions are glued and used as morph targets in smooth transitions (Lerios, Garfinkle & Levoy, 2002). The result is a more expressive Mozart that reacts accordingly to the learner's actions and thereby engages in a more natural interaction based on a natural process of communication.

Figure 24: Little Mozart's facial expressions: happy, sad, surprised, scared, angry and disgusted

Endowing Little Mozart with a more varied range of facial expressions, mimicking human facial expressions, is relevant to assure a natural communication with the user. This makes it possible for the user to have a more intuitive interaction with the virtual companion, since it is based on face to face communication and that is the type of communication the user is used to using in his everyday life.

3.7.3 Body language and verbal communication

Gestures can be used independently of or in parallel with verbal speech. The process of expressing emotion doesn't always happen just through facial expressions, our emotional state is also perceived with the observation of our body movements and posture (Haake & Gulz, 2008).

Darwin's studies proved that certain movements and postures are accompanied by distinct emotions. Consistent movements, jumping, dancing and other frantic actions are seen in people experiencing joy and happiness whereas a more passive and calm body might indicate sadness. Fear can be detected by the lowering of the head into the shoulders, rising of the arms for protection and closing and opening the hands repeatedly. On the other hand body trembles, frantic movements, shaking fists and squared elbows represent strong signals of anger and rage (Wallbott, 1998).

A straight body posture is uncommon when someone is experiencing sadness or boredom. However when someone lifts their shoulders it expresses joy or anger. The shoulders are a good source of information about our emotional state; when we move our shoulders forward may be we experiencing disgust or despair and fear. The position of the head is also indicative of how we may feel, when it's leaning down it might be a sign of sadness and keeping the head up might a sign of joy and pride. Hand and arm movements and posture can also be significant in understanding emotional state, for example, a constant movement of opening and closing hands might be typical in experiencing anger and joy or also despair and fear (Wallbott, 1998).

It is not only our face that is able to convey what we are feeling, the way we talk and how we talk can also be an accurate source of our emotional state. During our dialogues, our interjections and voice tone can be indicative of states of anger or fear (Scherer, 1995). A state of joy and happiness is usually expressed by a person being very talkative, saying very positive things, sharing and communicating positive feelings. On the opposite side stands sadness which is characterized by not speaking much, speaking in low and monotonous tone and talking about sad events. Another extreme emotion like anger is frequently associated with loud, screaming and attacking speaking and sometimes cursing (Fernández, *et al.*, 2000). Each different channel of communication has its own relevance in the process of expressing our emotional state, hence the importance of endowing Little Mozart with all these resources to make a meaningful connection with the user.

3.7.4 Next challenges

We are now working on putting together facial, body and verbal expressive behavior. We face a new challenge when migrating Mozart to mobile devices, and we are doing studies with children looking for the best design solutions. The implies the following steps:

- Doing the right animations of each expressive behavior and how to fade in and out between them;
- Setting a complex and coherent set of pre-recorded verbal expressions and synchronizing them with face and body expressions;
- Integrating all this consistently with FATIMA’s mind and allowing flexible and meaningful migration between laptops and mobile devices.

Figure 25 - Next implementation of mobile Little Mozart, sad on the left and happy on the right.

3.8 Summary

Companion	Body	Head	Face	Sound	Lights
iCat	no	yes (2 DOF)	yes (eyebrows, eyelids, lips)	yes (TTS and speech)	yes
Pleo	yes	yes	no	yes	no
Emys	no	yes	yes	yes	no
Sunflower	yes	Yes (3 DOF)	no	yes (midi)	yes
AIBO	yes	yes	yes	yes	yes
CHARLY	yes	yes	yes	yes	yes
Little Mozart	yes	yes	yes	yes	yes

4 Expressive Behaviours as Competences in the Architecture

The LIREC Architecture is described in detail in the Work Package 9 deliverables, most recently and up-to date in D9.4.

The agent's emotional state is generated at level 3 inside FAtiMA and consists of a set of OCC emotions that the agent currently feels, each associated with a certain numeric intensity. Emotional states can occasionally trigger Emotional Expressions if certain conditions are met, which can be individually authored for each agent and scenario using emotion reaction rules. These rules should take into account:

- Policies for how to fuse multiple (possibly conflicting) emotional states
- Policies for timing emotional expressions (how often do we want the companion to perform emotional expressions)

The Emotional Expressions are sent to CMION and the competency manager treats them like other actions, i.e. a competency execution plan is selected to realize them. That means it is possible to use several competencies in parallel and/or sequence to perform a single emotional expression, which can be important for embodiments with multiple expressive modalities.

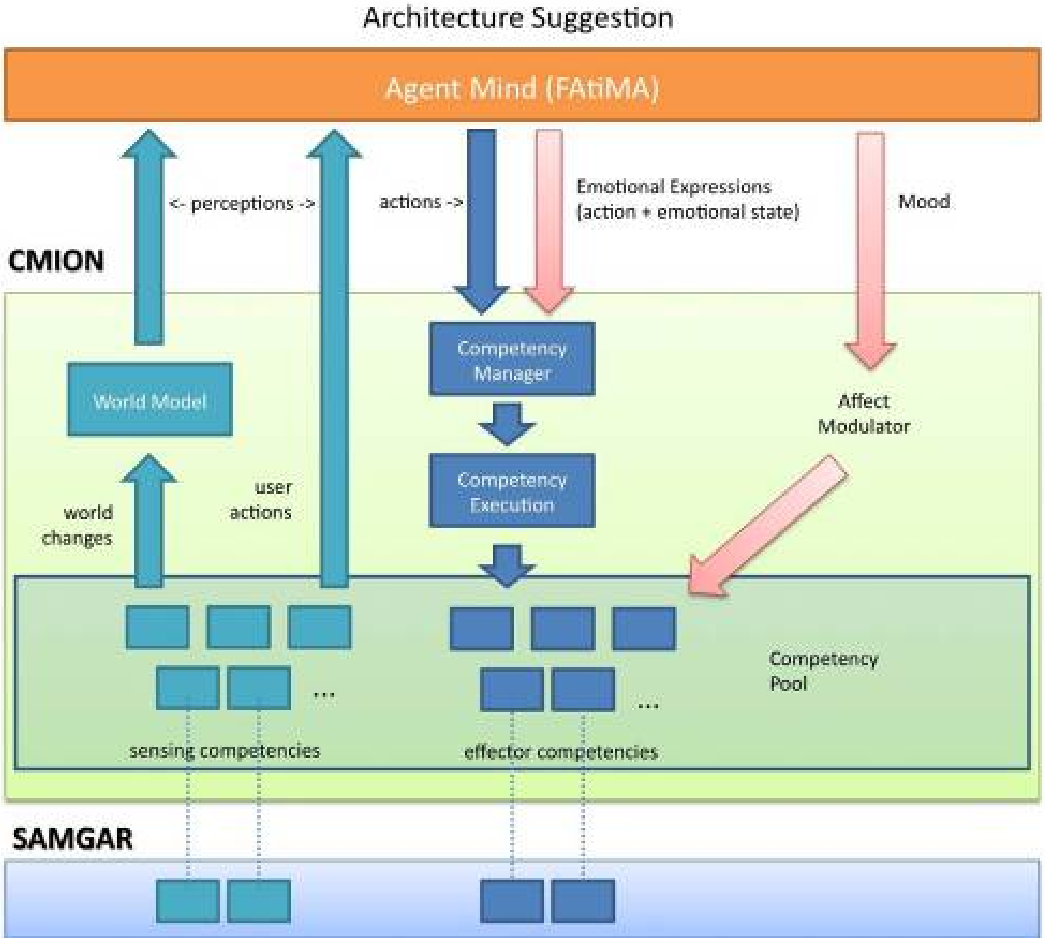

Figure 26.Lirec Architecture Diagram (expressive behaviour in pink)

Additionally FAtiMA also keeps track of the agent's mood, a numeric summary of all current emotions. The Mood is sent to CMION in regular intervals on a channel parallel to those on which actions and perceptions are communicated.

Inside CMION the mood is available to effector competencies (which can act as proxies for competencies implemented as SAMGAR modules) as an affect modulator. Using this modulator allows the companion to express its emotional state during the execution of its regular behaviours, e.g. it can move to the user in a happy or sad way. Once the execution of a competency has started, the current architecture does not allow its modulator value to be updated anymore. This was not considered as a problematic issue within the LIREC context, as mood is a rather slow changing modulator and there are no competencies, which execute for a very long time.

To summarize, the architecture allows sharing the same high-level mechanisms for generating emotional expressions among systems with vastly varying expressive capabilities. Only the competency implementations necessarily have to differ in those cases. However, in those cases where partners are using the same expressive embodiments, it also allows us to go one step further and easily share the competencies for displaying emotions as well. This is for example the case with the EMYS robotic head which is used by 3 partners in the project.

5 Addressing aspects of affective communication in MyFriend Showcase

Most of the existing robots and virtual agents lack social capabilities that allow them to engage users in the long-term, especially when it comes to affective communication. We argue that artificial companions capable of behaving in an empathic manner, which involves the capacity of understanding the user's affect and responding appropriately, will be more successful at establishing and maintaining a positive relationship with users. Most researchers agree that empathy can be achieved by two distinct phases: (1) inferring the other's affective state and (2) responding emotionally to that state. In the following subsections we describe how these two phases are being implemented in the Game Companion, one of the scenarios of the MyFriend Showcase.

5.1 First integration with the Affect Recognition Competence

The prototype system for smile detection is based on Support Vector Machines (SVMs) and it was trained using 512 samples of indicators of the mouth regions extracted using an approach based on the FacET library from naturalistic video data of children playing chess with the iCat. The detector extracts the following mouth region's indicators: (1) lips bounding box ratio, (2) lips corners' distance and (3) mouth bounding box image norm. The final indicators used for training the prototype system are based on the comparison of the above indicators and a behaviour baseline computed at a local and global level: the difference between the value of the above indicators at the current frame and a local and global baseline is performed. The idea behind the behaviour baseline is to abstract from individual differences, which allows for a person-independent expression detector to be obtained. Figure 27 shows an overview of how the prototype system for automatic smile detection works.

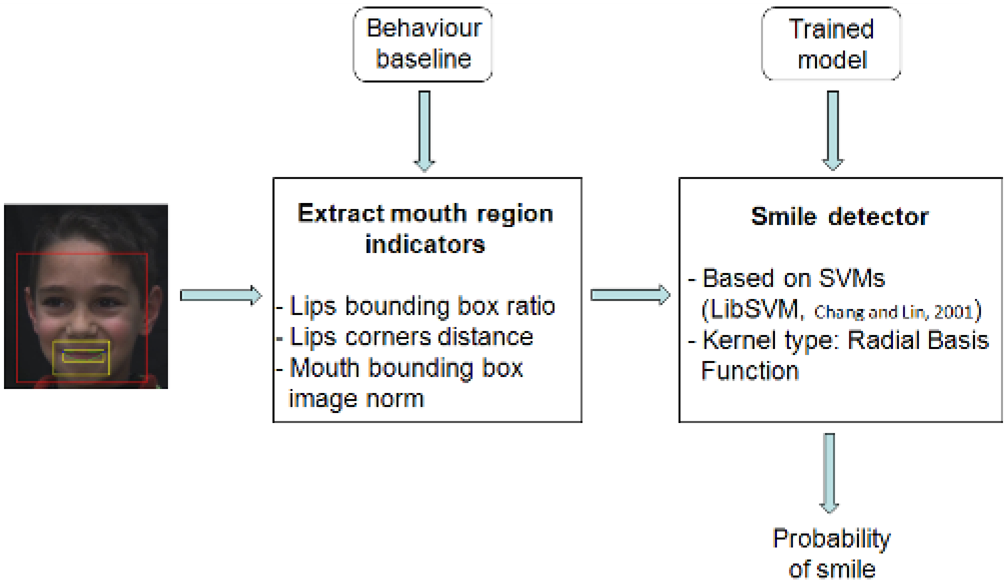

Figure 27. Overview of the modules composing the smile detection prototype system.

The system provides as output a value of the probability of smile for each frame. Figure 28 shows an example of output of the smile detector prototype system.

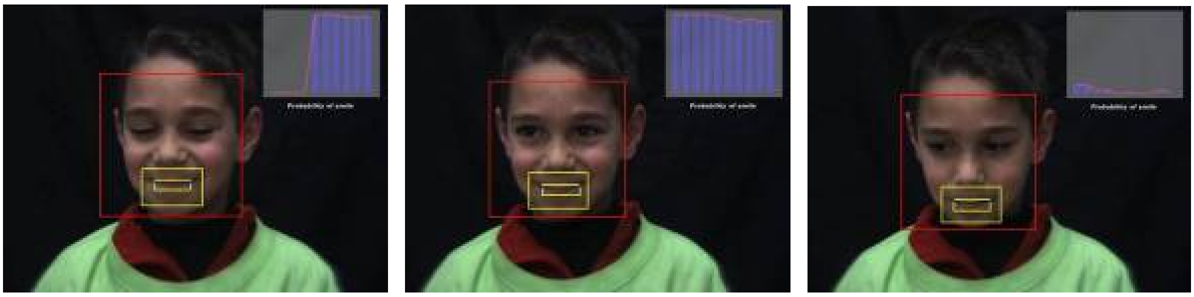

Figure 28. Example of the output of the smile detector prototype.

5.2 Evaluating the role of empathic behaviours on user's perception of companions

In parallel with the development of the affect recognition system, we have been studying the role that empathic behaviours plays on user's perception of the companion. To do so, a slight variation of the Game Companion scenario was implemented, where the iCat observes and comments a chess match between two human players. The robot exhibits empathic behaviours towards one of the players and neutral comments to the other player through facial expressions and verbal comments (for a sample video see http://vimeo.com/10798345). As the multimodal affect recognition system is still under development, for this study we inferred the user's affective state based on contextual information of the game only. The goal of this experiment was to evaluate both quantitatively and qualitatively the influence of empathic behaviours on user's perception of a social robot. We started from the hypothesis that subjects towards whom the robot behaves empathically will provide better ratings in terms of perceived friendship than subjects to whom the robot behaved in a neutral way.

5.2.1 Modelling Empathy in a Robot Companion

To re-create empathic behaviours in our robot, we took inspiration from the work of Cooper et al. (1999), where different characteristics of empathic teachers were identified and grouped by the following categories: body-language, positioning, and content of teaching, method of teaching, voice, attitudes, facial characteristics and verbal responses. Given the limitations of our scenario in terms of the robot's embodiment and interaction context, we only considered differences in facial characteristics and verbal responses.

5.2.1.1 Facial Characteristics

Empathic teachers are constantly reflecting the student's emotions in their facial expressions, while non empathic teachers are often not in tune with what they are saying. Likewise, our robot expresses its affective state using a facial expression that tries to reflect the companion's affective state by assessing its situation in the game. For instance, if the companion is constantly playing bad moves and plays another bad move, the iCat's affective state would return the empathic state of "expected punishment", which means that the change in the current state of the game is bad for the companion player, but the robot was already expecting that. In this case, the iCat would express a low intensity (because it was already expected) sad expression as a result of its empathy towards the companion who has lost advantage. For a complete overview of the robot's affective expressions see Figure 1.

Empathic teachers also tend to use lots of eye-contact. This characteristic was also modelled in our robot: while players are thinking on their next moves, the iCat displays idle behaviours such as looking at the chessboard and looking at the players. These behaviours were weighted in a way that the robot looks two times more to its companion than it does to the other player.

5.2.1.2 Verbal Responses

After reacting emotionally to an event on the chessboard, the robot also comments verbally that move. These comments depend not only on the iCat's empathic state, but also on the player who made that move. Therefore, for each affective state, two sets of utterances were defined: empathic utterances, to be used when the robot addresses its companion, and neutral utterances, to be used when the robot comments the moves of the other players. While neutral utterances merely indicate the quality of the move in a very straightforward way (e.g. "bad move", "you played well this time"), empathic utterances often contain references to possible companion's emotions, and try to encourage and motivate the companion (e.g. "you're doing great, carry on!"). As it happens with eye-contact, when the iCat speaks to its companion, it uses the companion's name two times more than when speaking to the other player. In addition to the feedback after the moves, the iCat also congratulates the companion when she/he captures an opponent's piece, and encourages her/him in the critical moments of the game - for example, when the chances of winning (or loosing) become evident. At the end of the game, the robot's behaviour is also different depending on who won the game. If the companion wins, the robot says "Congratulations! You are a very good chess player!" (while displaying a happy facial expression), whereas if the other player wins it simply says "Checkmate, see you on the next match" (displaying a sad expression).

5.2.2 Experimental Procedure

The scenario presented in the previous section was used to evaluate our hypothesis. A between-subject experiment where participants played a chess game against each other having the iCat commenting their games was performed. Forty subjects, 36 male and 4 female, with ages ranging from 18 to 28 years old, were recruited via e-mail. All subjects were Portuguese undergraduate or graduate students that knew how to play chess. They were assigned to a time slot (2 participants in each slot) depending on their availability. At the scheduled time, the two participants were asked to sit on a table in front of each other, having the iCat on their side commenting the game. They played an entire chess game as depicted in Figure 29. Interactions lasted on average one hour. At the end of the game, participants moved to another room where they filled in a questionnaire and answered a set of open-ended questions.

Figure 29. Users interacting with the iCat.

5.2.3 Conditions

The behaviour of the iCat varied whether the robot was addressing the player controlling the white or the black pieces. Participants controlling the black pieces belonged to the empathic condition, which means that the iCat behaved towards them according to the empathic behaviours described in the previous section. Participants playing with the white pieces were part of the control condition (neutral), and the robot addressed them in a neutral way. The assignment of subjects to the different conditions was done randomly. At the beginning of each game, players were free to choose the side of the board that they prefer to play, without knowing that the iCat's behaviour would be different.

5.2.4 Measures

The dependent variable in this study was perceived friendship. Even though friendship is a concept that is strongly related to long-term social relations, this measure was adopted in the attempt to understand participants' perception of the robot, and how such perception may vary if the robot behaves empathically. As the subjects' native language was Portuguese, we used an adaptation of a validated Portuguese version (Souza, 2006) of the McGill Friendship Questionnaire (MFQ) (Mendelson and Aboud, 1999). This questionnaire quantifies the degree to which a friend fulfils the most common functions existing in most of the friendship definitions: (1) *stimulating companionship* – doing enjoyable or exciting things together; (2) *help* – providing guidance and other forms of aid; (3) *intimacy* – being sensitive to the other's needs and states and being open to honest expressions of thoughts, feelings and personal information; (4) *reliable alliance* - remaining available and loyal; (5) *self-validation* - reassuring, encouraging, and otherwise helping the other maintain a positive self image; (6) *emotional security* - providing comfort and confidence in novel or threatening situations. The questionnaire contains a set of five-point Likert scale items for each friendship function. We are aware that a friendship relation, in similar patterns as human-human friendship, cannot be established between a human and a robot, especially in an interaction of approximately one hour. Nevertheless, as empathy is a characteristic that people value in friendships (Adams et al., 2000), we believe that by analysing participant's perceived friendship towards the robot, some indicators on how to improve long-term interaction between humans and robots can be retrieved. We hypothesise that subjects towards whom the robot displays empathic behaviour will rate some of these friendship functions more positively.

Since some of the items in the McGill Friendship Questionnaire were not applicable to the interaction experience that users had with the iCat, these items were replaced by assertions obtained in an online survey. In the online survey, subjects were given the definitions of MFQ's friendship functions and were asked to associate a set of assertions (defined by the authors of this paper) to one of the six friendship functions. Sixteen subjects participated in this survey, and there was no overlap between these subjects and the ones who participated in the experiment. The English translation of the assertions that were used in the final questionnaire is depicted in Table 1. In addition to the perceived friendship measure, we were also interested in understanding the overall goals and expectations of users after interacting with the iCat. To do so, we also analysed participants' responses to the following open-ended questions: "I liked that iCat...", "When I played bad, iCat...", “When I played well, iCat...”, “When I was feeling insecure about the game, iCat...”, “What would make me interact again with iCat would be...”.

5.2.5 Quantitative Results

To test our hypothesis, we first performed a Cronbach alpha test to evaluate the internal consistency of the modified version of the Friendship Questionnaire. The index was reliable for stimulating companionship (α=.79), help (α=.86), reliable alliance (α =.69), self validation (α =.8) and emotional security (α =.71), but not reliable for intimacy (α =.56). After that, outliers in the data were identified according to the following criteria: 1.5**stdev*. Four outliers were removed in the empathic condition and five in the neutral condition. After the outlier removal, we conducted Mann-Whitney analyses for each friendship function. Each function was calculated by the sum of all questionnaire items associated to that friendship function.

5.2.5.1 Stimulating Companionship

Subjects in the empathic condition significantly rated this function higher than subjects in the neutral condition ($U = 72.5$, $p < 0.05$, $z = -1.893$). The boxplot chart in Figure 30 shows the sum of the ratings for the Stimulating Companionship function. Given that this function is about spending time doing things together, these results suggest that empathic robots are more enjoyable to interact with. As such, users may eventually spend more time interacting, which is important if we aim to build artificial companions capable of engaging users in long-term interactions.

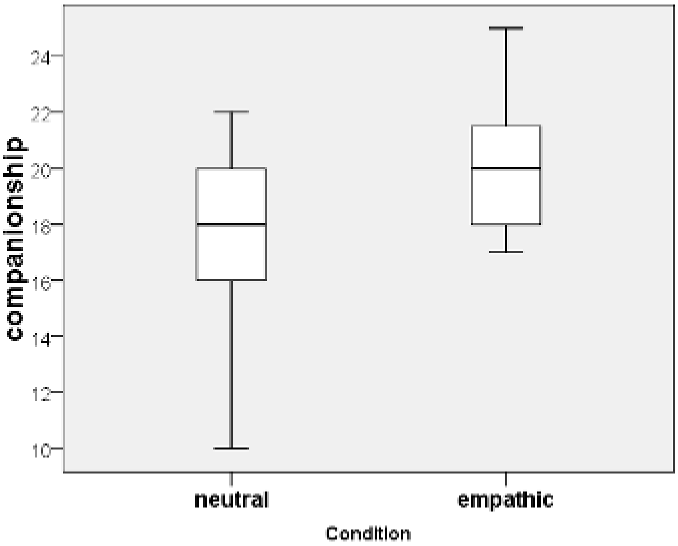

Figure 30. Boxplot for the ratings of the Companionship function in the empathic and neutral conditions.

5.2.5.2 Help

As illustrated in Figure 31, empathic and neutral conditions are not significantly different with regard to the Help function ($U = 118$, $p = 0.47$, $z = -0.79$), which means that the addition of empathic behaviours does not seem to affect the helping behaviour of the companion. These results were quite expected because, even though the iCat gives feedback on the players’ moves (in a more empathic manner for subjects in the empathic version), it does not provide any sort of tips on how to play the game better.

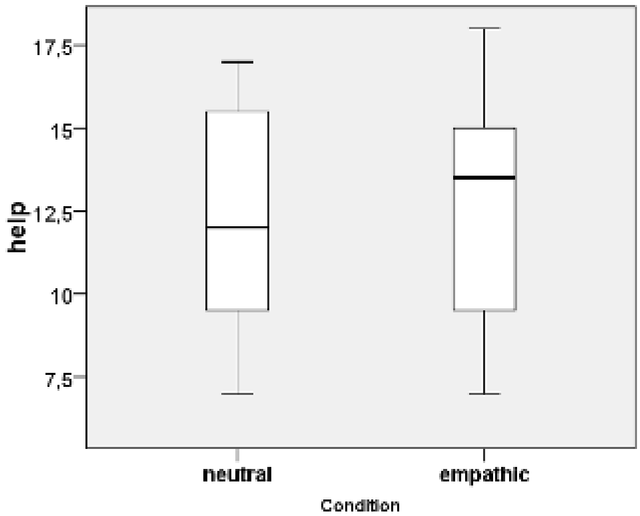

Figure 31. Boxplot for the ratings of the Help function in the empathic and neutral conditions.

5.2.5.3 Intimacy

As we could not guarantee the reliability of this function, we will present the results of the proposed assertions for Intimacy separately (see Figure 32). The results of the two statements, "iCat knew when something was bothering me" and "iCat knew when I was upset", differed significantly with better ratings for the empathic condition (respectively, U = 69.5, $p < 0.05$, z = -2.058 and U = 71.5, $p < 0.05$, z = -2.033). Considering that we are inferring the user's affective state taking into account his/her situation in the game, these results support our previous work Castellano et al. (2009) in which we found that task-related features are very important to discriminate among user's affective states.

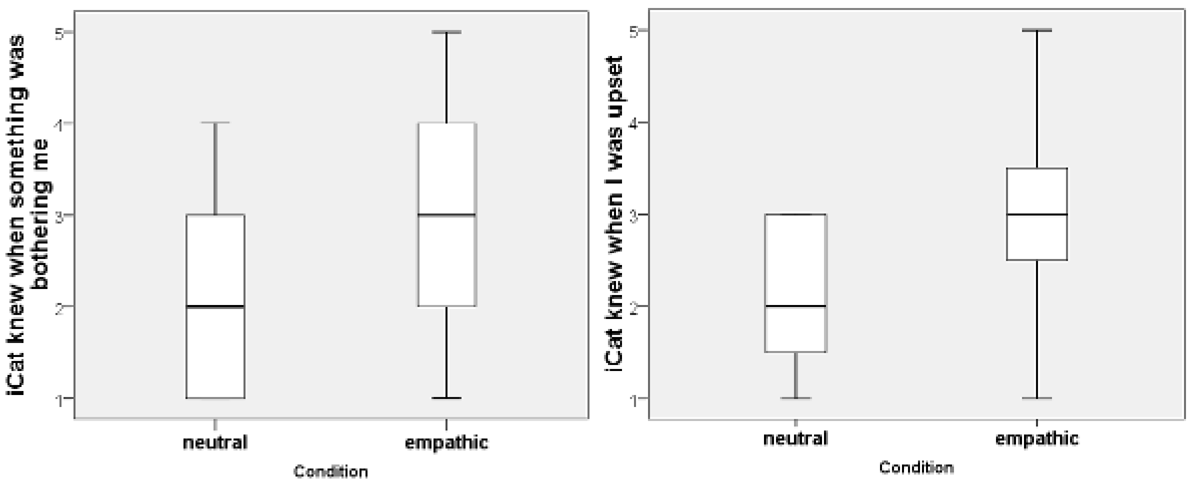

Figure 32. Boxplot for the ratings of the assertions proposed for the Intimacy function in the empathic and neutral conditions.

5.2.5.4 Reliable Alliance

The ratings on the Reliable Alliance function were significantly higher in the empathic condition than in the neutral condition (U = 46, $p < 0.01$, z = -2.954), as depicted in

Figure 33. This result can be explained by the fact that the iCat only supports the user in the empathic condition, whether s/he is winning or losing the game.

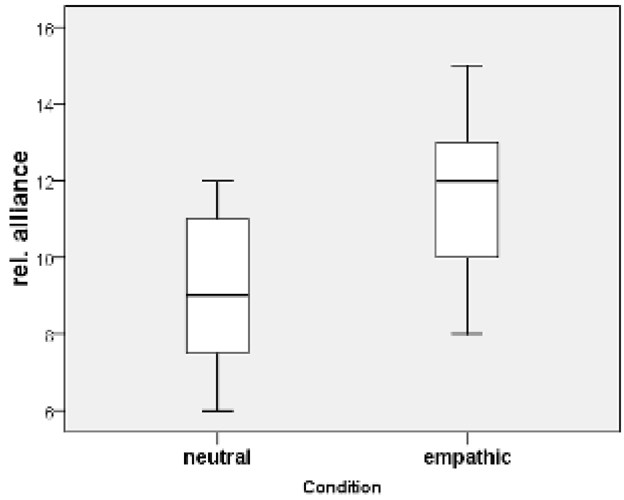

Figure 33. Boxplot for the ratings of the Reliable Alliance function in the empathic and neutral conditions.

5.2.5.5 Self-Validation

In this function, there was also a significant difference in the direction of the empathic condition (U = 66.5, $p < 0.05$, z = -2.131). This can also be verified in the boxplot chart of Figure 34. The encouraging behaviours the iCat displays only towards participants of the empathic version seem to have a positive effect on users. Note that in both conditions, the iCat says if the player did a good or bad move, which is also a form of reassurance.

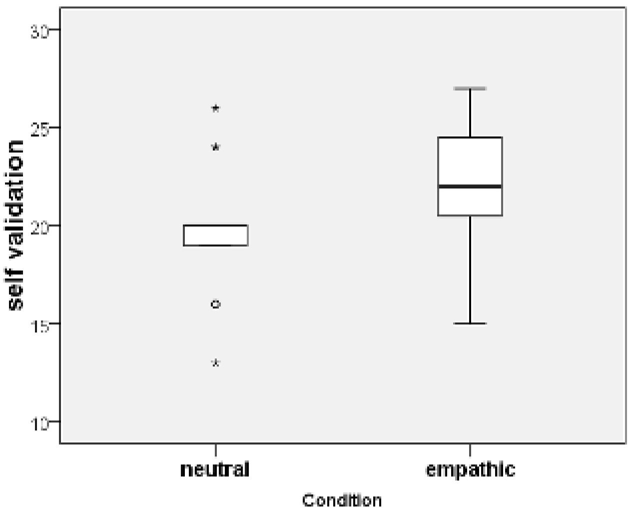

Figure 34. Boxplot for the ratings of the Self Validation function in the empathic and neutral conditions.

5.2.5.6 Emotional Security

There was no significant difference between the two groups in terms of Emotional Security (U = 95, p = 0.159, z = -0.998), as suggested by Figure 35. Possibly this is a function that requires long-term interaction before users consider that the iCat or other entity is able to comfort them.

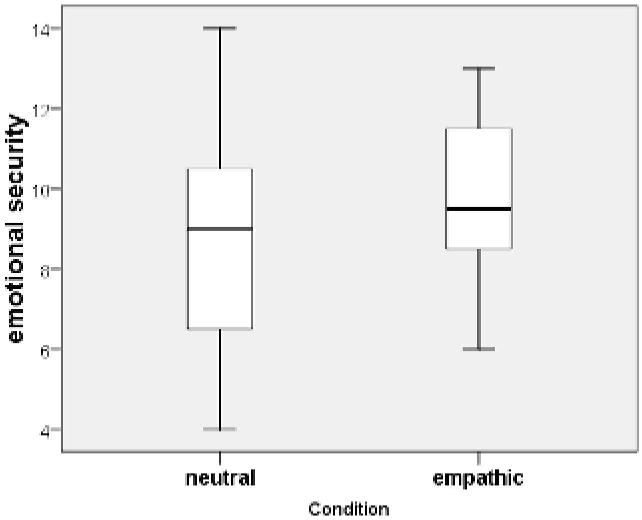

Figure 35. Boxplot for the ratings of the Emotional Security function in the empathic and neutral conditions

5.2.6 Qualitative Results

In this subsection, the most relevant findings collected throughout the content analysis of the open ended questions are presented.

5.2.6.1 *I liked that iCat...*

In both conditions, more than half of the participants liked the fact that the iCat provided feedback on their moves, and that the robot used their names when speaking-three in the empathic condition (20%) and two in the neutral condition (13%). In the empathic group, almost half the subjects also mentioned that they liked the iCat because it encouraged them in the difficult moments of the game: “iCat knew exactly the best moves I should play, and even when the game was almost lost it kept giving me hope to continue (...)”. One of the participants in this condition even mentioned that the iCat elicited an empathic feeling on him: “I liked that the iCat used my name and commented my moves. Its facial expressions and movement made me feel empathy”. These results suggest that some of the empathic behaviours implemented in the robot were well understood (and accepted) by users. For example, using the players’ name when speaking was even noted by participants in the neutral condition, where the iCat uses the player’s name half the times than it does to subjects in the empathic condition.

5.2.6.2 *When I played bad, iCat...*

Most users (in both conditions) acknowledged that the robot warned them about their bad moves. In addition, some subjects in the empathic condition answered that the iCat got sad when they played bad. The opposite happened for the participants in the neutral condition (they noticed the iCat got happy when they played bad). Four participants (27%) in the empathic condition also mentioned that when they played bad moves, the robot encouraged them to play better. The answers to this question suggest that not only users valued the robot's feedback, but also recognised some of the robot's utterances as encouraging (for players in the empathic condition).

5.2.6.3 *When I played well, iCat...*

Almost all subjects answered that the iCat congratulated them when they played good moves. Some participants in the empathic condition stated that the robot got happy when they played good moves, and subjects in the control condition often said that the robot got sad. Like in the previous open-ended question, eight subjects (53%) from the empathic condition also added that the robot encouraged them to play better: "When I played a good move, iCat demonstrated his support, and I felt good with myself.".

5.2.6.4 *When I was feeling insecure about the game, iCat...*

Nearly one third of the participants indicated that they did not feel insecure in any part of the game and therefore did not answer this question. For those who answered, the opinions differed among conditions. While most of the participants in the neutral group did not notice any differences in the iCat's behaviour, six subjects (40%) in the empathic group stated that the robot encouraged them when they felt insecure during the game: "When I felt insecure during the game, the iCat tried to make me calm, so I could better play my next moves.". Some of the subjects in the neutral condition recognised that the iCat supported more their opponent. This strengthens our hypothesis that the implemented behaviours were well interpreted by participants: "It didn't help much... I got the feeling that iCat was supporting my opponent the whole time and didn't care about me.".

5.2.6.5 *What would make me interact with iCat again would be...*

Participants from both conditions proposed several motives for interacting again with the iCat. While in the neutral condition almost half subjects would like to interact again with the robot just for fun, six participants (40%) in the empathic group would like to play another game in this same setting to improve their chess skills. This suggests that even though the neutral version of the robot might be perceived as more fun, the empathic behaviours are important for users who want to improve their chess skills. Seven participants stated that they would like to play against the iCat, instead of having the robot commenting their game - respectively, three participants (20%) from the empathic group and four participants (25%) from the neutral condition). Also, five participants from the empathic condition (33%) would like to play another match in this same setting, in contrast to only two (12,5%) from the neutral version. To summarise, the answers to this question could be categorised in four different topics: (1) subjects who would like to interact with the robot again because they had fun during the interaction, (2) subjects who would like to play against the iCat, (3) those who wanted to improve their chess skills and (4) participants who would like to repeat the interaction as it is (playing another chess match with the iCat commenting the game).

5.2.7 Discussion

This study addressed the role of empathic behaviours on users' interaction with artificial companions. Empathic behaviours reported in the literature were modelled in a social robot capable of reacting emotionally and commenting a chess game, and an experiment where users interacted with such robot was conducted. Perceived friendship was measured using an adaptation of a Friendship Questionnaire.

The results of the friendship questionnaire suggest that our initial hypothesis is valid for most of the friendship functions measured by the questionnaire. Participants who interacted with the empathic version of the robot gave significant higher ratings in terms of companionship, reliable alliance and self validation. Only with regard to help and emotional security the hypothesis was not validated. However, given the design of the scenario and the length of the interaction, such results were not totally unexpected: the robot provided help for players in both conditions, and emotional security might not be an appropriate measure for an interaction that lasts not more than one hour. The overall impression and understanding of the interaction was investigated by content analysis of participants' answers to open-ended questions. By analysing participants' answers to the open-ended questions, we found that subjects towards whom the iCat behaved in an empathic manner considered the robot more encouraging and sensible to their feelings. Also, more subjects from the empathic condition would like to interact again with the robot in the same setting.

6 Conclusions

In this document, we reported the work that has been done towards developing expressive behaviours for LIREC companions. We have focused on expressive behaviours that convey some affective or motivational states of the companion to the user, rather than in task related behaviour. However, as the expressive capabilities are limited in some of the embodiments, some task-related behaviours (such as moving) can also be shaped by the companion's mood.

We started by presenting and discussing possible ways of expressive behaviour that include not only the traditional facial and body expressions, but also other less conventional forms such as lights, sound and colours that usually are not used by humans but in cartoons or other media. After that, we described the expressive capabilities of the robots and graphical characters used in the three LIREC Showcases. We then explained where emotional expressions and affect modulators fit in the three-layer architecture, and present the progress on the Affect Sensitivity competence, that allows companions to understand some of the user's affective states and respond appropriately (by employing empathic strategies).

It is important to stress that the work on expressive behaviour consists not only in developing expressions considering the available modalities in each companion's embodiment, but also in evaluating if such expressions are well interpreted by users in the context of the scenarios (as it was done in the empathy experiment reported in Section 5). While most of the robots and virtual agents already have a repertoire of expressive animations that allows them to convey some of their internal states to the user, some of these behaviours were not deeply evaluated yet. To address this issue, we are planning for example an online survey to evaluate some of the basic emotions in the EMYS head. Another relevant step consists of evaluating the impact that expressive behaviours play in the long-term relationships established between users and the companions.

7 References

Adams, R., Blieszner, R., De Vries, B., (2000). Defnitions of friendship in the third age: Age, gender, and study location. Journal of Aging Studies 14, 117–133.

Bartneck, C., Reichenbach, J., Breemen, A.: In your face, robot! The influence of a character's embodiment on how users perceive its emotional expressions In: Design and Emotion, Ankara, Turkey (2004)

Canemaker, John, Tex Avery: The MGM Years, 1942-1955. Atlanta: Turner Press, 1996. ISBN 1-57036-291-2.

Castellano, G., Leite, I., Pereira, A., Martinho, C., Paiva, A., McOwan, P., sept. (2009). It's all in the game: Towards an affect sensitive and context aware game companion. In: Affective Computing and Intelligent Interaction, 2009. ACII 2009. 3rd International Conference on. pp. 1--8.

Cooper, B., Brna, P., Martins, A., (1999). Effective affective in intelligent systems - building on evidence of empathy in teaching and learning. In: Paiva, A. (Ed.), IWAI. Vol. 1814 of Lecture Notes in Computer Science. Springer, pp. 21–34.

Correia, S., Costa, J., Estanqueiro, M., Antunes, M. J., Oliveira, L. (2009) Emotion: development of the mind and physical expression. In Proceedings 9th Conference of European Sociological Association, Lisbon.

Cynthia Breazeal. Emotion and sociable humanoid robots. *International Journal of Human-Computer Studies*, pages 119–155, 2003.

Damásio, A. (1996). *O erro de Descartes: emoção, razão e cérebro humano.* Lisboa: Publicações Europa-América.

Damásio, A. (2000). O Sentimento de Si: o corpo, a emoção e a neurobiologia da consciência. Lisboa: Publicações Europa-América.

Donato, G., Bartlett, M. S., Hager, J. C., Ekman, P., & Sejnowski, T. J (1999). Classifying Facial Actions. *IEEE Transactions on pattern analysis and machine intelligence*, pp. 974-989.

Eva Heller, Wie Farben auf Gefühl und Verstand wirken. Farbpsychologie Farbsymbolik, Lieblingsfarben, Farbgestaltung. Droemer Verlag, München 2000. ISBN 3-426-27174-5.

Fernández, I., Carrera, P., Sánchez, F., Paez, D., Candia, L. (2000). "Differences between cultures in emotional verbal and non-verbal reactions" in *Psicothema*, Vol. 12, pp. 83-92.

Fotios Papadopoulos, Kerstin Dautenhahn, Wan Ching Ho, Michael L. Walters (2010) AIBOCOM: Designing robot enhanced human-human remote communication technology. in Carole Bouchard, Ameziane Aoussat, Pierre Levy, Toshimasa Yamanaka (Eds.), Proceedings of the Kansei Engineering and Emotion Research International Conference 2010 (KEER2010), 2-4 March 2010, Arts et Metiers ParisTech, Paris, France. ISBN: 978-4-9905104-0-4, pp. 671- 682.

Gardner, C, 1912, Essentials of Music Theory, C. Fisher. Mehrabian A. Pleasure-arousal-dominance: A general framework for describing and measuring individual differences in temperament. Current Psychology, vol. 14, 1996, 261-292.

Gratch, J., & Marsella, S. (2005). "Lessons from Emotion Psychology for the Design of Lifelike Characters" in *Applied Artificial Intelligence,* Vol. *19*, pp. 215-233.

Haake, M. &. Gulz, A. (2008). "Visual Stereotypes and Virtual Pedagogical Agents" in *Educational Technology & Society*, pp. 1-15.

Igor Pandzic and Robert Forchheimer, MPEG-4 Facial Animation: The Standard, Implementation and Applications. John Wiley & Sons, Inc, New York, NY, USA, 2003

Johnson, W. L., Rickel, J. W., & Lester, J. C. (2000). "Animated Pedagogical Agents: Face-to-Face Interaction in Interactive Learning Environments" in *International Journal of Artificial Intelligence in Education*.

Lerios, A., Garfinkle, C., Levoy, M., (2002) *Feature-Based Volume Metamorphosis*. Stanford University.

M. Patterson (1990). *Functions of non-verbal behaviour in social interaction*. Handbook of language and social psychology, pages 101-120.

Martinho, C., Paiva, A.: Using Anticipation to Create Believable Behaviour. In: Proceedings of the 21st National Conference on Artificial Intelligence and the 18th Innovative Applications of Artificial Intelligence Conference, Stanford, California, USA. AAAI Press (2006)

Mendelson,M. J., Aboud, F. E., Apr (1999). Measuring friendship quality in late adolescents and young adults: Mcgill friendship questionnaires. Canadian Journal of Behavioural Science 31 (1), 130–132.

Osipa, Jason, (2003), Stop Staring! Facial Modelling and Animation Done Right, Sybex

Paul Ekman (1972), Emotion in the Human Face. Cambridge University Press.

Paul Ekman and Wallace V. Friesen (1975). Unmasking the face: A guide to recognizing emotions from facial clues. Prentice-Hall.

Preece J, Rogers Y & Sharp H (2002) Interaction Design. Beyond Human-Computer Interaction. John Wiley & Sons Inc.

Scherer, K and Oshinsky, J., 1977, Cue Utilization in Emotion Attribution From Auditory Stimuli.pdf

Scherer, K. (1995). “Expression of emotion in voice and music” in *Journal of Voice*. Vol. 9, pp. 235-248.

Souza, L. K., (2006). Amizade em adultos: adaptação e validação dos questionários mcgill e um estudo de diferenças de género. Ph.D. thesis, Universidade Federal do Rio Grande do Sul.

Syrdal, D. S., Koay, K. L., Walters, M. L., & Dautenhahn, K. (2009). "The boy-robot should bark!" – Children’s Impressions of Agent Migration into Diverse Embodiments. Proceedings New Frontiers in Human-Robot Interaction, pp 116 - 121.

Thayer, R.E.: The Biopsychology of Mood and Arousal. New York: Oxford University Press (1989)

Thomas, F. and Johnston, O., (1981), Disney Animation: The Illusion of Life. Abbeville Press, New York.

Timothy W. Bickmore and Rosalind W. Picard. (2005). Establishing and maintaining long-term human-computer relationships. *ACM Trans. Comput.-Hum. Interact.* 12, 2 (June 2005), 293-327. DOI=10.1145/1067860.1067867 http://doi.acm.org/10.1145/1067860.1067867

ul-Hasan, W. (2006). “Anthropomorphism in Computer Generated Facial Expressions: Impact of character’s colour and detail in emotional evolution of character animation”. International School of New Media, University of Luebeck.

Wallbott, H., (1998) “Bodily expression of emotion” in *European Journal of Social Psychology*. Austria: University of Salzburg, Vol. 28, pp. 879-896.

Watzlawick, Paul; Beavin, Janet H.; Jackson Don D. (2000). *Pragmática da Comunicação Humana*. 11ª Edição. São Paulo: Editora Cultrix.