EXPLORING THE AFFECTIVE LOOP

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ABSTRACT

Research in psychology and neurology shows that both body and mind are involved when experiencing emotions (Damasio 1994, Davidson et al. 2003). People are also very physical when they try to communicate their emotions. Somewhere in between beings consciously and unconsciously aware of it ourselves, we produce both verbal and physical signs to make other people understand how we feel. Simultaneously, this production of signs involves us in a stronger personal experience of the emotions we express.

Emotions are also communicated in the digital world, but there is little focus on users' personal as well as physical experience of emotions in the available digital media. In order to explore whether and how we can expand existing media, we have designed, implemented and evaluated *eMoto*, a mobile service for sending affective messages to others. With eMoto, we explicitly aim to address both cognitive and physical experiences of human emotions. Through combining affective gestures for input with affective expressions that make use of colors, shapes and animations for the background of messages, the interaction "pulls" the user into an *affective loop*. In this thesis we define what we mean by affective loop and present a user-centered design approach expressed through four design principles inspired by previous work within Human Computer Interaction (HCI) but adjusted to our purposes; *embodiment* (Dourish 2001) as a means to address how people communicate emotions in real life, *flow* (Csikszentmihalyi 1990) to reach a state of involvement that goes further than the current context, *ambiguity* of the designed expressions (Gaver et al. 2003) to allow for open-ended interpretation by the end-users instead of simplistic, one-emotion one-expression pairs and *natural but designed expressions* to address people's natural couplings between cognitively and physically experienced emotions. We also present results from an end-user study of eMoto that indicates that subjects got both physically and emotionally involved in the interaction and that the designed 'openness' and ambiguity of the expressions, was appreciated and understood by our subjects. Through the user study, we identified four potential design problems that have to be tackled in order to achieve an affective loop effect; the extent to which users' *feel in control* of the interaction, *harmony and coherence* between cognitive and physical expressions, *timing* of expressions and feedback in a communicational setting, and effects of users' *personality* on their emotional expressions and experiences of the interaction.

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1 INTRODUCTION

Emotions make life more interesting. Without emotions living would be a static performance that we would never know when to appreciate. Only experiencing positive and enjoyable emotions would probably also lead to the same boring state – negative emotions play a huge part in our lives. The whole complex spectrum of emotions is the reason to why people can spend endless hours analyzing their own but also others' emotional behavior. How we react emotionally is highly personal and getting to know others emotional behavior is an important part of living together in a society.

Emotions are evolutionary important. Emotional reactions that make us run when we are in fear and avoid things that make us feel disgusted are essential for our survival. It has also been proven that without emotions we are incapable of rational thinking and decision making (Damasio 1994). To make the right decisions can sometimes be of crucial importance.

Research in psychology and neurology shows that both body and mind are involved when experiencing emotions (Damasio 1994, Davidson et al. 2003). Emotions can be evoked by a number of stimuli, both cognitive and physical, like external events or behaviors, internal neurophysiological changes, or memory recall. Independent of how an emotion is initiated, it will entail both cognitive and physical reactions since there is a very strong coupling between the cognitive process and physical experience of emotions. This means that an emotion evoked by a memory will also bring about physical reactions. Physical reactions to emotions, like blushing, tone of voice, body posture and gestures, can be quite apparent to other people, but there are also more hidden reactions, such as respiration, heart beat, temperature, perspiration, muscle activity and blood pressure.

Somewhere in between being consciously and unconsciously aware of it, we communicate emotions to others, not just in what we say, but also in our physical appearance. We use body language and other physical signs to strengthen or alter something we verbally express. An emotional story can be enhanced by gestures, tone of voice and other emotional expressions but we can also express irony if we mix emotional clues from contradicting emotions. "It was great", can in reality mean something totally different if the person who says it frowns or communicate a feeling of disgust while saying it.

There is no clear distinction between emotions that are communicated because we really have them and emotions we more deliberately want to tell people about. To some extent people can choose what they physically communicate, although, some physical reactions, such as blushing cheeks or nervously shivering legs, are hard to hide. A cheerful voice and large wavy gestures are often interpreted as signs of happiness, but it can be hard to know if the person truly is happy or if she uses these signs to cover her real feelings. Because of the strong coupling between the cognitive and physical processing of emotions we can also,

more or less, make ourselves happy by consciously performing the physical signs of happiness – by "acting" happy.

Communicating emotions by the use of gestures and other physical means is part of our nature, and we are not always aware of what emotions we physically express. It is also not so easy to say what emotions we have and what emotions we want to communicate, we most often want to communicate a feeling of "something". Quite frequently that feeling is a mix of different emotions. The response from the people we communicate with in combination with our own experience of the emotional expressions we use will tell us if we make ourselves understood or not. Other people's emotional reactions to what we communicate will also, in turn, influence our emotional state.

Emotions are also communicated in the digital world in applications using techniques such as email, SMS[1], MMS[2] and instant messaging. To begin with, emotions could only be expressed through the available textual media, but now there are also smilies or emoticons that are used to communicate a notion of arousal and emotion but still there is little physical experience of emotions. In order to adhere to our reasoning above, we want to create systems that use both physical and cognitive modalities so that users get a strong experience of the emotions they communicate. We want users to be engaged in an *affective loop* where emotions are treated as processes instead of being empowered through labels or facial expressions of interactive characters.

1.1 DEFINING THE AFFECTIVE LOOP

The basic idea of the affective loop is to allow for powerful emotional experiences. Therefore both physical and cognitive aspects of emotions need to be addressed. Some form of communication is required, human to human, human to computer, or human to human through computer. The existence of a communicational process of emotional expressions and related affective response is essential. In order to design for an affective loop it is important that there is depth to the communication that makes it possible to explore and reflect upon the fuzziness, the mystery and the fascinating aspects of emotions.

The core research idea of the proposed project is to explore, experiment with and test the idea of an affective loop used in digital communication; to see if we can improve design by letting us be inspired by real life communication. To clarify what we intend by an affective loop we see it as an interaction process where:

➢ the user first expresses her emotions through some physical interaction involving the body, for example, through gestures or manipulations of an artifact,

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[1] SMS: Short Messaging Service.
[2] MMS: Multi-Media Messaging Service.

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> ➢ the system (or another user through the system) then responds through generating affective expression, using for example, colors, animations, and haptics,
> ➢ this in turn affects the user (both mind and body) making the user respond and step-by-step feel more and more involved with the system

Throughout the thesis we will exemplify and expand on this definition of the experience of an affective loop.

1.2 DESIGN PRINCIPLES

To better understand whether and how it is possible to create systems that allow for an affective loop we have taken design inspiration from recognized ideas within the field of Human Computer Interaction (HCI). The four inspirational, interrelated, design ideas are generic design principles, not specifically aimed at emotional communication, but with a strong bearing on what we aim to achieve. The four, principles are; *embodiment* (Dourish 2001) as a means to address how people communicate emotions in real life, *flow* (Csikszentmihalyi 1990) to reach a state of involvement that goes further than the current context, *ambiguity* of the designed expressions (Gaver et al. 2003) to allow for open-ended interpretation by the end-users instead of simplistic, one-emotion one-expression pairs and *natural but designed expressions* to address people's natural couplings between cognitively and physically experienced emotions. Theses design principles and how we reformulated them to fit with special case of emotional communication through digital media, are described in more detail in chapter two.

1.3 EMOTO

To explore whether the affective loop description, briefly outlined above, could indeed be used to generate good applications, we have designed, implemented, and evaluated a prototype named *eMoto*, that aims to embody some of the affective loop properties with a basis in the four design principles. eMoto is a mobile messaging service using affective gestures as input (Figure 1.1) and affective expressions, combining colors, shapes and animations, as the backgrounds to users' messages (Figure 1.2). To focus on subjective experience of emotions we have used a *dimensional model* of emotions (Russell 1980) to let users combine their gestures with various emotional expressions. Dimensional models are presented in more detail in chapter three, but in short, emotions are treated as processes that blend into each other and not as discrete states.

eMoto entails both a *personal affective loop*, which concerns a person's inner creativity and experience while expressing emotions, and a *communicative affective loop*, which involves expressions directed towards and sent to other users and interpretation of other users' messages. The focus of this thesis is on the personal affective loop. Still, the communicational affective loop contributes to the personal experience and is therefore interesting.
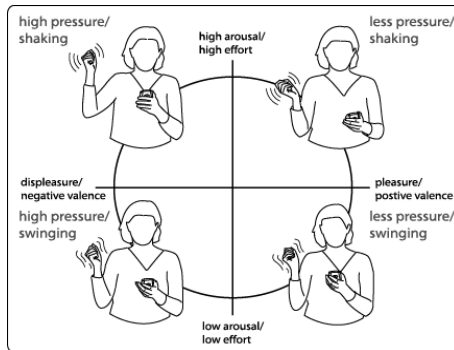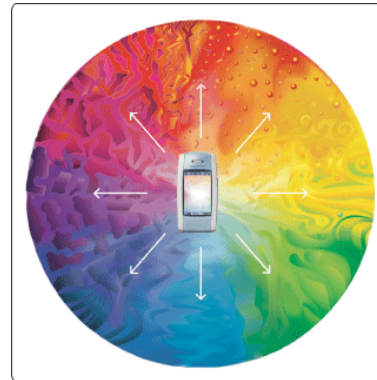
Figure 1.1: The affective gestures

Figure 1.2: The affective background circle (the animations can be seen on www.sics.se/~petra/animations)

eMoto is described in more detail in chapter four and in paper B.

1.4 METHODOLOGY

By addressing human emotions explicitly in the design of interactive applications, the hope is to achieve better and more pleasurable and expressive systems. The work presented here is inspired by the field of *affective computing* (Paiva 2000, Picard 1997), even if our aim is to take a slightly different stance towards how to design for affect than normally taken in that field – a more *user-centered* approach.

Affective computing, as discussed in the literature, is computing that relates to, arises from, or deliberately influences emotions (Picard 1997). The most discussed and widely spread approach in the design of affective computing applications is to construct an individual cognitive model of affect from first principles and implement it in a system that attempts to recognize users' emotional states through measuring biosignals. Based on the recognized emotional state of the user, the aim is to achieve an as life-like or human-like interaction as possible, seamlessly adapting to the user's emotional state and influencing it through the use of various affective expressions (e g Ark et al. 1999, Fernandez et al. 1999). This model has its limitations (Höök 2004), both in its basic need for simplification of human emotion in order to model it, and its difficult approach on how to infer the end-users emotional states through various readings of biosignals.

To get the users involved in a more active manner we would, instead, like to propose *affective interaction*, a user-centered approach to affective computing (Sengers et al. 2004). Our aim is to have users voluntarily expressing their emotions rather than having their emotions interpreted or influenced by the system. Still we wish to maintain the mystery and open interpretation of emotional interaction and expression.

The user-centered approach belongs to the field of HCI. A common assumption is that user-centered design is the same thing as participatory design.

We do not want to argue against participatory design; users are highly valuable to the design process but it is not always suitable to have them as a participating partners in a design team. User-centered design is about having the values of an intelligent and active user reflected in the design process as well as in the resulting applications. We have used a prototype-driven approach, interleaving design, implementation and user studies.

The procedure for this work can roughly be divided into:

1. Brainstorming using established methods to find a suitable application scenario

2. An analysis of emotional body language using the movement analysis notation system by choreographer and movement analyzer Rudolf Laban (1974)

3. Design and implementation of an application that exemplifies an affective loop

4. Several user studies and redesign after each

5. A final evaluation conducted in a natural setting conducted on "real" usage

Chapter four and paper A and C describes the design process and methodology in greater detail.

1.5 CONTRIBUTION

This thesis is mainly composed of three papers. Paper A and B have been published while paper C has been accepted as short paper to CHI'05 to be held in Portland, Oregon, April 2005. (which implies that the paper has to be shortened to four pages from the current ten). The research is a joint effort by the three authors of the papers. However, while this thesis is written more from the perspective of HCI and contributes more to the knowledge of the affective loop, a future licentiate thesis to be written by interaction designer Anna Ståhl has a greater focus on the graphical design of eMoto. Even if all design activities were extensively discussed by all three authors, Anna Ståhl had the main responsibility for the design of the colors, shapes and animations used as affective expressions in eMoto. My own main focus was on the design of gestures for input and the overall design of eMoto as a communication channel. I also implemented the service.

This thesis main contribution lies in bringing a user-centered perspective to affective computing. It defines one possible way to achieve a user-centered interaction with an affective interaction application: the affective loop. It also contributes with re-formulation of a set of design principles from an emotional perspective. A more physical and concrete contribution is the example prototype, eMoto, that we have designed, implemented and evaluated from these design principles.

Paper A presents an analysis of emotional body language, analyzed according to *shape*, *effort* and *valence*. The shape and effort variables were

extracted from the work of Laban and combined with valence, extracted from Russell's work on peoples' mental map of emotional states. Paper B shows how that analysis is used in the design of eMoto, both for the affective gestures and the emotional feedback and their combining parts. Finally, paper C describes a user study of eMoto mostly focused on how well we managed to design for the personal affective loop but also containing indications about the success of and input to the design of the overall communicative process.

1.6 OUTLINE

In chapter two we describe the four modified design principles in more detail. Chapter three gives a background to affective interaction and also puts our research on the affective loop in a broader context. In chapter four we describe the design, implementation and evaluation of eMoto from a methodological point of view. Chapter five provides a summary of the three papers in this thesis and also describes how the design process has evolved. Finally, chapter six revisits the aims and discusses four design issues that need to be addressed properly when designing for an affective loop. The four issues also indicate where future work is needed.

2 DESIGN PRINCIPLES

In chapter one, we summarized our design aims into what we named the affective loop. In an affective loop, users may voluntarily express an emotion to a system that they may or may not feel at that point in time, but since they convey the emotion through their physical, bodily, behavior, they will get more and more involved. If the system, in turn, responds through appropriate feedback conveyed in sensual modalities, the user might get even more involved. Thus, step by step in the interaction cycle, the user is "pulled" into an affective loop.

Our ambition is to create affective loop applications for communication between people. The process of determining the meaning of a message with some emotional expression is, similar to any human communication, best characterized as a negotiation process. The message is understood from its context, who the sender is, his/her personality, the relationship between sender and receiver, and their mutual history. However, we do not solely want users to be able to express themselves. The goal of an affective loop design is also, and perhaps, foremost to address users' personal experience of the emotions they attempt to express to the system.

To better understand whether and how it is possible to design for an experience of an affective loop, we have taken design inspiration from recognized ideas within the field of HCI and from that formed four, interrelated design principles. Initially, in paper A, we started with a set of design principles where the affective loop idea was regarded as one of the principles and user-centered design was the overall ambition. The design process has taken us to a slightly different position, where user-centered design is fundamental to our research but where we have focused on the affective loop and where we have listed *embodiment*, *flow*, *ambiguity* and *natural but designed expressions* as the design properties needed to allow for such an experience.

2.1 EMBODIMENT

Dourish (2001; p. 3), defines embodied interaction as

"[…] *interaction with computer systems that occupy our world, a world of physical and social reality, and that exploit this fact in how they interact with us.*"

Dourish means that embodiment focuses not only on *what* is being done but also on *how* something is being done. The concept of embodiment allows Dourish to combine two trends from the HCI area: *tangible interaction* where interaction is distributed over the abstract digital world and objects in the physical world (Ishii and Ullmer 1997), and *social computing* where social practice and the construction of meaning through social interaction is core in design (e g Höök et al. 2003). Dourish points to the fact that both these ideas are based on the same essentials, in that they use our familiarity with the everyday world to improve design. By this

Dourish suggests that design should be based on how we act, learn and create knowledge in our everyday life.

Dourish' definition of embodiment concurs nicely with how we have chosen to base our idea of an affective loop on how people naturally express and experience emotions. We do not intend to design for a digital, stylized, symbolic body language. Instead we wish to be inspired by how people in real life use both body and mind to express and experience emotions. Our intention is to bring this inspiration into the design process so that we can generate an idea that is intuitive to users but which also gives them a stronger experience of their emotions. To achieve this we have analyzed emotional body language that people in real life use to communicate emotions.

2.2 FLOW

Csikszentmihalyi (1990) has defined flow as the state people get in when they become so involved in doing something that they loose track of time and place. To get to a state of flow people need to feel that something is complicated enough for them to feel proud of themselves when they make achievements and be motivated to enter the next level. To reach a state of flow it is important that there are always new levels to reach. When people feel they can master it all they will loose interest. However, they should never feel that it is impossible for them to make improvements or to get anywhere at all, which will have the opposite affect to flow. It will make them feel stupid and incapable and they will never even become interested.

Csikszentmihalyi uses rock climbing, computer programming and gaming as good examples that can take people to a state of flow. He also mentions reading as something that keep people's attention for hours. As long as people do not feel that they have understood it all they want to continue reading. If the book is too hard or if it is too easy to see how it is going to end reading will not bring people to a state of flow.

We do not wish to challenge users in the sense of climbing or gaming instead we want to reach some of the characteristics of a reading experience. Our intention is that users shall stay interested and feel that there are new things to discover. We do not want them to find the interaction simplistic and easy to comprehend and therefore boring, but on the other hand we do not want them to feel that the application is uncontrollable and too hard to understand. To have users emotionally involved we aim for the interaction to be somewhat ambiguous and open for interpretation and also a little bit mysterious.

2.3 AMBIGUITY

Most designers would probably see ambiguity as a dilemma for design. However, Gaver and colleagues (2003; p. 1) look upon it as:

"[…] a resource for design that can be used to encourage close personal engagement with systems."

They argue that in an ambiguous situation people are forced to get involved and decide upon their own interpretation of what is happening. As affective interaction oftentimes is an invented, on-going process inside ourselves or between partners and close friends, taking on different shades and expressions in each relationship we have with others, ambiguity of the designed expressions will allow for interpretation that is personal to our needs. For example, if a system had buttons where each was labeled with a concrete emotion, users tend to feel limited in that they will not be able to convey the subtleties of their emotions.

Ambiguity also follow from the ideas of embodiment that regard meaning as arising from social practice and use of systems – not from what designers intended originally. An open-ended ambiguous design allow for interpretation and for taking expressions into use based on individual and collective interpretations. Ambiguity in a system will also create a certain amount of mystery that perhaps will keep users interested. However, it needs to be a balance, since too much ambiguity might make it hard to understand the interaction and might make users frustrated (Höök et al. 2003).

While Gaver and colleagues want to more or less provoke people with their design so that they get into a process where they create their own meaning of the artifact we do not wish to go that far. We wish to use ambiguity to allow the user to experience flow. We aim for systems that have a little bit of mystery to them so that users can explore the interaction and find new alternative ways to interpret the results, and where they can be emotionally involved in the interaction.

2.4 NATURAL BUT DESIGNED EXPRESSIONS

To get users emotionally involved, one approach is to take inspiration from "natural"[3] emotional body language. This approach can be applied to the design of the whole interaction, including input as well as output channels and the connection of the two in the application. However, human-computer interaction and human-computer-human interaction are not and should perhaps not be the same as human-human interaction. An application is a *designed artifact* and can therefore not build solely upon natural emotional expressions. On the other hand, using mainly designed expressions bearing no relation whatsoever to the emotions people experience physically and cognitively in their everyday lives, would make it hard for the user to recognize and get affected by the expressions. We therefore argue that emotional expressions should be natural but designed.

This thesis has a greater focus on affective gestures and affective input than on cognitive feedback and affective output, although both input and output are as

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[3] By natural we in this thesis mean what is natural for our targeted user who is presented in detail in chapter four.

important for the affective loop. When studying research on gestures in computer interaction in general there are two main strands that exemplify the conflict: *designed gestures* (e g Long et al. 2000, Nishino et al. 1997) and *natural gestures* (Cassell 1998, Hummels and Stappers 1998, Kjölberg 2004). Designed gestures can be resembled to sign language. The gestures make up a language and depending upon the complexity of the language, it may take quite some effort to learn. Natural gestures, on the other hand, aim to be easier to learn as they build upon how people tend to express themselves in various situations. However, body language, posture and more conscious gestures vary between individuals, cultures and situation. Thus, designers of gesture interaction often aim for designed gestures based on the underlying dimensions giving rise to the specific movements.

To experience flow and harmony is essential to interaction overall, but perhaps more so to physical interaction (Kjölberg 2004). Using gestures to interact with computer systems can be awkward to people even though the gestures are natural but designed. Even a little disturbance can make people stop and become even less expressive than is natural to them. Moreover people use gestures and body language very differently and have differences in what they are prepared, willing and comfortable to physically express. To reach the couplings between cognitively and physically experienced emotions, gestures need to be expressive enough to affect users but not so that they inhibit people's personal boundaries to the physical expressiveness they normally use. Therefore we need to be very specific in describing what group of users we are designing for. Gestures that are too expressive for one group might not be so for another group of users.

In chapter four we will describe how we have used these four design principles in practice when designing eMoto, a mobile service for sending and receiving affective messages, but first let us provide a brief introduction to the state of art in emotion theories and affective research.

3 AFFECTIVE INTERACTION

Artificial Intelligence (AI) researchers have for a long time been interested in human resemblance and systems that can interact with humans in human ways. What they are trying to do is extremely hard but has lead to many interesting results and has also initially inspired to and influenced research areas, such as social and ubiquitous computing. Affective computing (Picard 1997) also originates from the AI community in that its aim is to infer information about users' affective state, build computational models of affect and respond accordingly.

Our approach to affective interaction differs somewhat from the goals in affective computing. Instead of automatically capturing emotions our approach is *user-centered*. Users should be allowed to actively express their emotions both cognitively and physically rather than having their emotions interpreted by the system, so that they can reflect on and get a stronger experience of their emotions.

Still, the results from affective computing are a source of inspiration. Many of the techniques for capturing human emotions and for responding to or resemble human emotions found within affective computing are also used in our more user-centered affective interaction approach. In this chapter we will present techniques for sensing emotions and for expressing emotions but also point to the differences between affective computing systems and systems build for affective interaction.

3.1 EMOTION THEORY

Knowledge about human emotions used by computer scientists originates from a wide range of disciplines such as psychology, neurology and medicine. Perhaps it is already at this stage that we can find the first clue to why it is such a complex task to build systems that relate to, arise from, or deliberately influence emotions.

There are a number of different theories of human emotions. Psychologist Scherer (2002) has summarized the most common emotion theories with respect to their focus on components and phases in the emotion process (Figure 3.1). The classic definition of the components is the emotional response triad with three components; psychological arousal, motor expression and subjective feeling (Scherer 2002). Psychological arousal manifests itself as changes in body temperature, muscle and heart activity and other physical processes, processes that under normal circumstances are hidden from other people. Motor expressions are the processes that people share with others, such as changes in facial and vocal expressions, gestures. Subjective feeling is how people consciously reflect on their emotions and the fact that they can verbally express how they feel. Scherer also explains how it more recently has been suggested that the classic definition needs to be complemented with two additional components: behavior preparation and cognitive processes. Behavior preparation implies that emotions change ongoing behavior. Cognitive processes state that emotions have a strong effect on attention
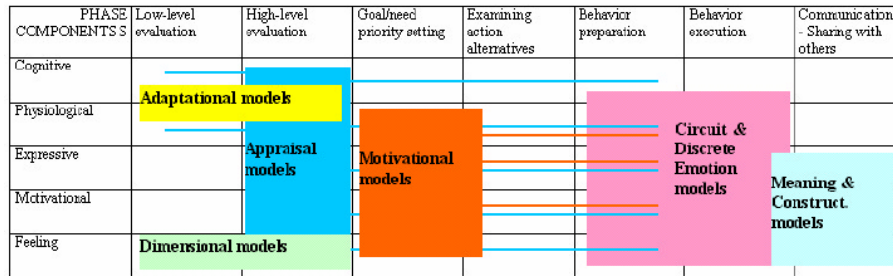
PHASE COMPONENTS	Low-level evaluation	High-level evaluation	Goal/need priority setting	Examining action alternatives	Behavior preparation	Behavior execution	Communication - Sharing with others
Cognitive							
Physiological	Adaptational models				Circuit & Discrete Emotion models		
Expressive		Appraisal models	Motivational models			Meaning & Construct. models	
Motivational							
Feeling	Dimensional models						

Figure 3.1: Comparison of major emotion theories with respect to their focus on components and phases in the emotion process (Scherer 2002)

and memory. Emotion processes are changes in these components during a set of phases, from low-level phases to communicative phases. Emotions can be evoked both cognitively and physically. Emotion stimuli can be anything from external events to internal psychological changes. The order of the phases depends on the stimuli.

In Figure 3.1 Scherer lists the major emotion theories with respect to their focus on components and phases in the emotion process evoked by external stimulus:

➢ *Adaptional models* imply that emotions emanate from what we experience in our daily life. Evolution has equipped people with a biological preparedness for stimuli that are potentially harmful, such as snakes and spiders. Emotions that we are not born with are added when experienced for the first time and are then stored in our emotional library.

➢ In *Dimensional models* each emotion has its own unique region in a multidimensional space. One example of such dimensions are arousal and valence used by Russell in his circumplex model of affect (1980). Dimensional models focus on subjective experience, in philosophy called *qualia*, in that emotions within these dimensions might not be placed exactly the same for all people.

➢ *Appraisal models* looks at emotions concerning the needs and abilities of the individual experiencing them in regards to the current context. Appraisal models not only describe the experience of an emotional state but also explain how and why an emotion is produced in that specific moment. Appraisal models cover the whole area between a stimulus and the response it creates in that specific setting.

➢ *Motivational models* are similar but grounded more to the output end of the emotional process focusing on the goals and principles of the individual and not so much her basic needs and abilities.

➢ In *discrete emotions models* psychologists defines a limited set of basic emotions that can be mixed or blended into the large variety of emotions that

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exists. Most known is Ekman and colleagues' set containing six basic emotions; anger, disgust, sadness, happiness, fear and surprise (Ekman et al. 1972). Their definition is oftentimes used for example by computer scientist interested in facial recognition.

➢ Finally, *meaning-oriented models* suggest that there are relations between semantic meaning and emotional value and that there are categories of emotions meaning nearly the same thing, like the anger category including rage, irritation, being cross etc. These theorists also argue that not all categories are used in all cultures.

Theories of emotions are not easily applicable to computer science. They should be treated as an inspiration and not as directly implementable models. After all, to quote Davidson and colleagues (2003; p. xvi):

"Much of current research, while sometimes inspired by grand theories, or more often middle-range theories and models, focus on more limited, but more precisely defined, topics within affective science."

Human beings have several characteristics that have turned out to be very hard to implement. Recognizing and understanding emotional expressions is only one of them. Still it is an extremely interesting research area and there are many creative applications that use aspects of emotions. In the following, some of these applications are presented and related to our approach of the affective loop.

3.2 A PLANE MODEL DEFINING THE AFFECTIVE LOOP

To relate our work on the affective loop to the applications presented below we developed a plane model showing two of the most important factors of an affective loop; *level of control* and *emotions as both cognitive and physical experiences* (Figure 3.2). It is a simplistic model set up to define the affective loop in relation to other ideas for design brought forward within the affective research area. The model is not mathematically correct in that the x-axis is ranging from apples to pears and in the middle there is "fruit salad" while the y-axis is ranging from a few oranges to a lot of oranges. Moreover, the x-axis should not be interpreted as the middle "fruit salad" of cognitive and physical expressions involves that there has to be less of one of them in order to make room for the other. Our aim is to allow for stronger experiences by including them both.

Control has to do with the depth of a computer-based interaction, where the two extremes are little control and much control. For users to be engaged in an affective loop it is important that they do not find the interaction too simplistic but also not totally unpredictable. A one-to-one mapping between emotions and expressions does not leave anything to explore. Neither does a system where users feel they have no influence at all on what data the system automatically captures and what interpretations it makes. Users need to be actively involved for a system to allow for an affective loop experience. Users should not feel that they can outsmart the system, there has to be some mystery there for them to work with.

This implies that we take some of the control away from the user so that we do not create a tool but instead a something for her to interpret and have fun with.

The aim of the affective loop is to put users in a state where they feel there is a communication between them and the system or between them and another user through the system. Human to human communication can also have the characteristics of an affective loop.

How much control the user feels she has in a computer-based interaction is related both to flow and to ambiguity. According to Csikszentmihalyi (1990) flow is the state people get in when they get so involved in doing something that they loose the feeling for time and place. Such a task needs to be ambiguous enough for people to feel that there continuously are new things to discover, but it should not be too complicated for them so that they feel they have no influence at all on what is happening. In our work on the affective loop we want users to experience the fuzziness, the mystery and the fascinating aspects of emotions, we want them to get involved and also experience their emotions. We want them to reach a moment of flow. For this to happen we believe that we have to include a little bit of ambiguity to allow for personality and open interpretation. We also believe that users have to experience emotions both cognitively and physically to get this strongly involved.

Below our idea of an affective loop is related to other systems built within the research area. To describe state of art in affective research, we have chosen to describe applications that we find representative for their genre; however, we do not say that this is the complete list of systems within the research area or that there will not be more techniques to come. Moreover, we have not personally tested all systems that we mention and we do not always know so much of the designers' intentions, therefore we can only speculate about how much control users feel they
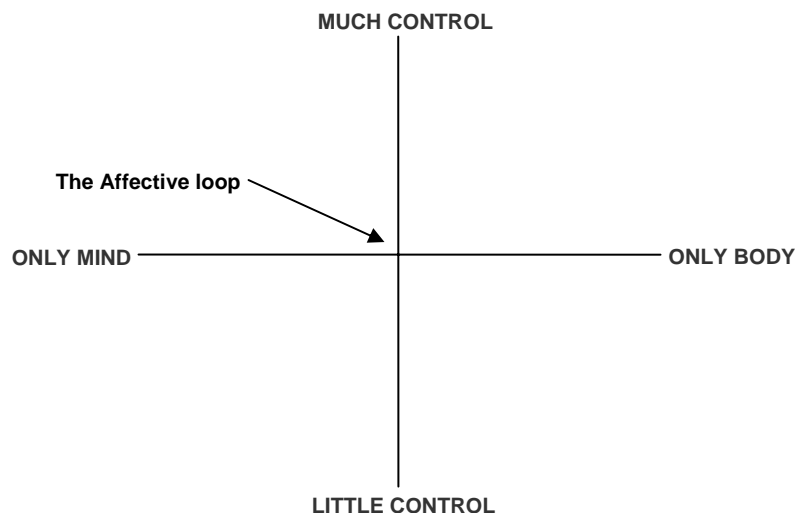

Figure 3.2: A plane model defining the affective loop

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have when using these systems. It is easier to say something of how much control we instead can infer that they actually have, although this is not always the same thing as how much control users *feel* they have, which in our case is the more important issue.

3.3 TECHNIQUES FOR SENSING EMOTIONS

People have a number of ways to express emotions, some they are in more control of than others. First of all, people use words to express how they feel, "I'm so happy today" for example. A cheerful tone of voice can express the same thing. Body posture and gestures are also clues to what emotions people might have. Less controllable expressions are physical reactions to emotions, such as an increase in blood pressure or a decrease in skin conductivity. Physiological changes are normally hidden and not something that people under normal circumstances are used to relate to. To use these signals in computer based communication we believe that we first of all have to find ways for people to relate to data such as own and other users' temperature or electrocardiogram.

Sensing and interpreting users emotions is a large area of interest. In here we have divided research on techniques and methods for inferring users' emotions into six categories; *cognitive-based affective user modeling*, *emotions explicitly stated by the user*, *speech recognition*, *facial affect analysis*, *affective gestures* and *bio sensors*. How much control users feel they have varies within all categories. We have therefore chosen to present the techniques following the x-axis of the plane model presented in Figure 3.2, from techniques affecting only cognitive parts to techniques affecting mostly bodily aspects of emotions.

COGNITIVE-BASED AFFECTIVE USER MODELING

Cognitive-based affective user modeling was first proposed by Elliott and colleagues (1999) in their learning environment Design-A-Plant. This method for inferring with users' emotions builds on the appraisal models briefly introduced above. A set of goals and principles are set up for the user and based on cognitive theory of emotions the user's emotional state is decided from how those goals and principles are fulfilled. Design-A-Plant is set up from the notion that students' learning capabilities improve if they continuously get feedback and encouragement on their performance.

In Design-A-Plant a pedagogical agent, called Herman, is designed to motivate students to learn about botanical anatomy and physiology. Herman is a caring helper sensitive to students' emotions. Students, in turn, are expected to want to do well on every task, to be entertained, and want to learn the material. If they then fail on a task Herman will think that they are disappointed with themselves and will therefore give them support. When they succeed Herman will think that they are happy with themselves and will then be there to encourage them. Thus, the emotional state of the student is inferred from a rule-based way of describing the relationship between cognitive state and emotional state. The student

is not modeled from his/her physical reactions, but from what the cognitive state implies.

Another example of a system using cognitive-based affective user modeling is Teatrix, a collaborative virtual environment for story telling developed by Martinho and colleagues (2000). Teatrix is designed to help young children dramatize familiar situations. Each child gets to be a character in the story and the basic idea is that when a child selects which character she wants to be she is also implicitly defining her goals and needs. The aim is for the child to develop an empathic relationship to her character and her emotional state is dependent of what happens to the character in the story. The goals and principles of the character become the goals and principles of the child, and this is in turn used to model the child's emotional state. Martinho and colleagues argue that children enjoy taking sides; if someone hurts their character in the game they will be sad with their character and angry with the character that hurt them. If their character wins something they will be proud with their character and so on. Thus, in Teatrix, the user model is inferred from the child's cognitive experience.

A problem with cognitive-based affective user modeling in Teatrix is that there is a difference between current goals and final goals of the characters in a story. An achievement in the game might at that point look very positive for the character but later it can be revealed that overall it was not so good after all. Winning a battle can imply that the character has to face an even more dreadful monster. When a child plays with the game for the first time she only knows of her current goals but as an experienced user she will also be aware of what affect her actions have later in the story and then there is a contradiction between current achievements and achievements overall.

Cognitive-based affective user modeling is also used in systems designed for communication between people. One such system is EmpathyByddy (Liu et al. 2003). EmpathyBuddy is an email agent that looks at each sentence the user writes and uses cognitive-based affective user modeling to extract the emotional value of each sentence. EmpathyBuddy uses a common-sense filter to decide the goals and needs of the writer. Crashing a brand new car is one example of something that the writer most likely does not want to do. Figure 3.3 shows a user scenario of a user writing to tell his mum about his new car.

A game that uses cognitive-based affective user modeling somewhat differently is Kaktus developed by Laaksolahti and colleagues (2001). Kaktus is a game where the user plays one of three teenage girls and the computer controls the other two. Together the three are about to organize a party and the user has to make socially complex decisions that have an emotional effect on the other two characters. The user has to maintain social relationships to succeed in the game and therefore she has to use her emotional skills to get the other characters into the right mood. The overall idea of Kaktus is to make cognitive-based affective user modeling into something that the user has to reflect upon to steer the interactive narrative. It is not the user's emotions or the emotions of her character that is

Figure 3.3: A user scenario of EmpathyBuddy (Liu et al. 2003)

important here. Instead the focus is on the common-sense filter that people use in their real life contacts with other people. The user has to use what she knows of the goals and needs of the other two characters and from that pick actions that will keep them in a happy and positive mood for them to help her in organizing the party. Having the girl, whose parents' house is going to be the place of the party, pissed off, is not a good idea. Thus, in a sense, it is the user and not the system who performs cognitive-based affective user modeling.

In relation to the affective loop there is very little physical experience of emotions in all four systems. In Teatrix the user also has very little control of how her emotions are captured and interpreted. Teatrix is also not designed to have the user explicitly reflect on how the system emotionally influences her. Kaktus is not a good example of affective input since it is not so much the user's emotions that are being reflected upon but it is a good example of a system using the fuzziness, the mystery and the fascinating aspects of emotions. It is an implicit usage of cognitive-based affective user modeling as the cognitive models of emotions are really used to control the behavior of the two computer-controlled characters in the story.

EMOTIONS EXPLICITLY STATED BY THE USER

Having users explicitly express their emotional state is perhaps the simplest method to infer end user's emotions. It might sound like a rather boring and very controlled approach but there are researchers that have managed to design and implement some fun and engaging applications using this method.

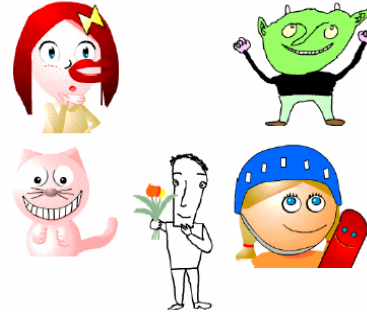**Figure 3.4: Acting in Virtual Reality (Mel Slater et al. 2000)**

Figure 3.5: Avatars in ExMS (Persson 2003)

Mel Slater and colleagues (2000) have designed a system, Acting in Virtual Reality[4], where the user expresses her emotions by changing the characteristics of a drawn face (Figure 3.4). The user can influence the eye brows and the mouth of that face. The mouth can express happy, neutral and sad, while the eye brows can express surprised, neutral and angry. By interacting with both the mouth and the eye brows at the same time the user can create more complex expressions. It is also possible for the user to affect some body parts of her avatar. The emotions are carried out by the user's avatar in a virtual rehearsal system. The system was set up to be used by actors to see if they could rehearse a play in virtual reality that in the end was going to be performed on a real stage. The actors who were not previously familiar with each other met in the virtual reality four times for a one hour rehearsal each time. Then they met a fifth time for a live performance in front of an audience. Even though the actors did not think the system could replace real rehearsal they all learnt to master the program and to use its qualities. One of the actors compared it to talking on the telephone which is not like a real life meeting but still very effective and interesting.

ExMS is another system where the user explicitly states her emotions (Persson 2003). ExMS is an avatar-based messaging system where users can create short pieces of animated film to send to each other. The idea is that each user chooses an avatar that she can identify herself with (Figure 3.5) and by using the library of animated expressions specific to her character she can express feelings, reactions and moods in the messages she sends to her friends. One disadvantage with ExMS was that the avatars had so much character in themselves so that it sometimes was hard for people to see themselves and their own expressions represented through their avatars[5].

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[4] No name of this system has been found. In this thesis we use Acting in Virtual Reality, which is the name of the article we reference to, also as the name of the system.

[5] Personal conversation with one of the users from a user study of ExMS.

Another communicational system where users explicitly state the emotion they want to communicate is used in CHATAKO, a speech synthesis system developed to assist people with communication problems (Iida et al. 2000). In CHATAKO the user writes what she wants to say and then chooses if she wants to say it with a female or a male voice and what emotional value she wants that voice to have. The prototype has three emotions to choose from; joy, anger and sadness.

All three systems are examples of applications that support emotional communication. The first two are creative and fun and CHATAKO is an important solution for people with speech problems. However, they do not fulfill the physicality and ambiguity of an affective loop that we want to create. Even if the expressivity in Acting in Virtual Realty and CHATAKO was to be extended on there were other problems with personality and open interpretation experienced in ExMS where there were more expressions to choose from. Even though Acting in Virtual Reality opens up for more complex emotional expressions and ExMS had the flexibility to add words to the expressions, none of the systems really addressed emotions as the processes that blend into one another that we want to address.

SPEECH RECOGNITION

A lot of researchers work on extracting emotional content from human voice as another technique for affective input. Speech recognition is a difficult problem in itself. There are problems with surrounding and disturbing sounds, problems with dialects and personality in the human voice. And if all that is solved there are also problems with understanding the actual meaning of what is being said. The same word can mean so many different things depending on its context and how it is being said. Researchers have come so far that they can work with a defined set of words in a relatively quiet environment. The emotional value of what is said and how it is said is yet another problem to researchers. There are not yet any fully developed prototypes using this method for affective input. Before that happens researchers will have to work on the problem of defining the characteristics of emotional states expressed in speech. Cowie and colleagues point out the importance of working with naturally expressed emotions and not acted data which is the most common approach (Cowie and Cornelius 2003, Douglas-Cowie et al. 2003). They have noted several characteristics not previously defined such as impaired communication and articulation. Acted data is most often based on monologue whereas spoken emotional reactions are more common when interacting with another part. Breakdowns and disarticulation are two examples that may not occur in acted data. Cowie and colleagues have also noted some patterns in pitch, volume and timing, which are descriptors already established as important for extracting emotions from speech.

In our point of view we believe that speech recognition could be used in applications that would allow for an affective loop experience. It would have to work better but users could for example play with their vocal expression to control the affective expressions of an avatar representing them in some virtual

environment. With a high pitch voice users could make their avatar aroused and happy while a low pitch voice would calm him down with.

FACIAL AFFECT ANALYSIS

People's facial expressions are very reliable signs of their emotional reaction to various stimuli. Ekman found six basic facial expressions that people use to express emotions (Ekman et al. 1972). These expressions are highly used within facial affect analysis but there are also applications that use more personality and openness in how users are allowed to express themselves.

Facial Action Coding System (FACS) is the most common approach to facial affect analysis. All the muscle movements of the face have been classified and grouped according to their emotional meaning. Using FACS in a computer system that recognizes user's emotions, often entails making the user wear dots in her face in order to more clearly be able to infer the facial muscle movements (see Figure 3.6). The relative positions of these dots are captured by a camera and interpreted, most often according to Ekman's six basic emotions.

Kapoor and colleagues (2003) have looked at the problem of having dots attached to the face when using FACS. This technique is of course quite disturbing to an end user. Instead they have developed a technique that detects the pupils using an infrared sensitive camera equipped with infrared LEDs. The technique is perhaps more known as the red-eye effect. From detecting the pupils they can to this point localize the eyes and the eyebrows of the user. Using this technique they can cover more subtle facial actions such as an eye-squint or a frown and the user can move her head a lot more in front of the camera than when using dots. Still there has to be proportionally quite a lot of hardware involved when using facial expressions as affective input.

FAIM is an example of a system using FACS (El Kaliouby and Robinson 2004). FAIM is a system for instant messaging where each user is represented by an emotive character that changes its expression due to the user's facial expression while she is interacting with the system. This is, in our point of view, an example of a system where the user has less control of the emotions she communicates.
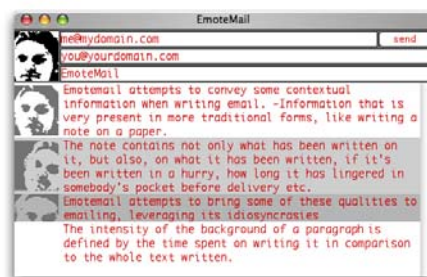

Figure 3.6: FACS (Kaiser et al. 1998)

Figure 3.7: EmoteMail (Ängeslevä et al. 2004)

When a user gets involved in conversation it is very hard to also think of her facial expressions. Since the media is in real time it might be that she communicates emotions that were not intended for the receiver to see. Another difficulty with this system is that the expressions are narrowed down to a set of expressions and therefore it is harder to communicate more complex emotions. This is easier if the receiver gets too see a photo of the real expression as in EmoteMail (Ängesleva et al. 2004).

EmoteMail is an email client that automatically takes a photo of the user each time she writes a new paragraph. The receiver will see an email that has these photos in the margin and indicates through color which paragraphs that took the longest time to write (Figure 3.7). EmoteMail opens up for peoples' personal expressions and even though they are automatically captured, users will understand how and when that is done and probably learn to make use of the medium.

Kaiser and colleagues (1998) performed studies of facial expressions in interactive settings and point to problems that EmoteMail also suffers from: that facial expressions do not communicate pure emotions but processes, and that facial expressions also communicate signs of cognitive processes that are not always part of an emotional reaction, which implies that people smile to show that they are part of a conversation or frown to show that they do not understand. In FAIM this process is limited only to a few expressions but also in EmoteMail only a few photos are taken and the receiver only gets to see a part of the emotional process.

AFFECTIVE GESTURES

Since research in psychology and neurology shows that both body and mind are involved when experiencing emotions it should be possible to design for stronger affective involvement by making users physically engaged in the interaction. Important though, is that the physical involvement resembles the gestures and movements people would normally do for various emotions. Otherwise, the movements would not affect the components of physiological arousal and motor expression that can act as a physical stimulus to emotions. To design physical interaction from how people act, learn and create knowledge in their everyday life, personality is essential. While some extroverts in real life might jump of joy some other introverts might just allow themselves to smile. To exceed people's physical limits is more critical that to exceed their cognitive limits in that physical expressions are not so easy to keep private. However, to emotionally affect people through physical stimuli it is crucial that movements also are expressive enough.

One way to have users physically engaged is to use artifacts to allow for tangible interaction (Ishii and Ullmer 1997), since it can be more comfortable for users to have something to interact with than to gesture without anything to hold on to. Using this method it is necessary that the gestures are done with the artifact and not to the artifact. Heidegger refers to this as *ready-to-hand* and *present-at-hand* (Heidegger according to Dourish 2001). If the artifact in itself requires too much attention the movements are done *to* it and not *with* it. Dourish uses the example of

how the mouse that is connected to the computer is used for interaction. As long as the mouse acts as an extension of the hand and the interaction is done *with* the mouse, the interaction is ready-at-hand. This lasts as long as the movements are kept within the mouse pad. If the mouse is moved outside the mouse pad the mouse will instead be present-at-hand, since the user will have to shift her attention from the screen to the mouse itself. In the context of the emotional experience movements have to involve the user in order to act as emotional stimulus; tangible interaction for this purpose have to be ready-at-hand and not present-at-hand. For this to happen it seems like a perfect combination of size and character of artifacts is important.

Let us discuss two examples of interaction with plush toys. In the first the plush toy is large and has little character in itself, which implies that the user has to move with the plush toy (Figure 3.8). The second is an example of a system using too depictive and very small plush toys and where the user instead of moving herself tends to move the dolls around which does not involve her so much (Figure 3.9).

SenToy (Figure 3.8) is a forty centimeters tall plush toy used to interact with FantasyA, a computer game where the user plays the character of an apprentice wizard who has to fight battles with various opponents (Paiva et al. 2003). The user affects her character through acting out various emotional gestures with the plush toy. Depending on the character's current emotional state, the emotional state of the opponent and the emotion expressed by the user the character will either defend itself or attack the opponent. There are six gestures for the user to choose from and most of them also involve the user. For example the user can express happy by moving SenToy quickly up and down and sad by bending SenToy slumping forwards into a sad posture. Since SenToy is relatively large the user gets to wave her arms up and down when she expresses happy, which are movements that easily can get also the user in a happy state, and to express sad the easiest way is to lean forward with SenToy in her lap, into a position where it is rather hard to laugh. The problem with this application, however, is how these gestures affect the game plot. In a user study of FantasyA and SenToy users felt that they had a hard time understanding how their gestures affected the result of the battles (Höök et al.

Figure 3.8: SenToy
(Paiva et al. 2003)

Figure 3.9: Voodoo dolls
(Lew 2003)

2003). It was also hard for the users to see what emotions had to do with the event in the game. In our point of view, FantasyA and SenToy could have been a perfect affective loop application but this confusion disturbed flow since users were not given the "right" level of control.

The second example is the plush toys used in Office Voodoo (Lew 2003). Office Voodoo is a huge box that two users enter to see a film of Frank and Nancy at their office. The box has a bench where users can sit and from where they will see the film presented on a large screen. There are also two voodoo dolls, one for each character in the film. The users interact with the story about Frank and Nancy by interacting with these dolls. The emotional model of Office Voodoo is similar to Russell's circumplex model of affect (1980). Through shaking and squeezing the two voodoo dolls of Frank and Nancy (Figure 3.9) the user can affect the arousal and valence of the two office workers and see what happens on the screen for example when Nancy is depressed and Frank is flirtatious. The application is very much an affective loop but the voodoo dolls are relatively small and has very much character in them which implies that the shaking and squeezing is more done to the dolls than with the dolls. The interaction is very focused on the dolls and what they do. In our judgment, the dolls are very much present-at-hand instead of being ready-to-hand. It is more the movements of the dolls that are the center of attention than the movements of the users.

But artifacts used for tangible interaction can also be other things than dolls. Wensveen and colleagues (2000) have designed an alarm clock that senses how the user sets the alarm and from that decides the mood of the user (Figure 3.10). The Alarm Clock[6] has twelve sliders that add time when they are pushed forwards and subtract time when they are pushed in the other direction. The pattern of how the user sets the time decides her mood and also the sound that she is going to hear when the alarm sets of. The Alarm Clock is designed to get the user frustrated or annoyed and it allows the user to be quite careless with it. However, in our point of view the interaction is secondary to setting the time which makes the interaction more present-at-hand than ready-to-hand. Furthermore, the timing between input and output, in this case when the alarm sets of, is too long for the interaction to allow for an affective loop.

On the same theme of affective domestic furniture Gaver and colleagues has designed a table that is to be placed in the hallway of someone's home[7]. The idea is that people will put their keys on that table and that they will do that differently depending on what mood they are in. How hard the keys are put on the table influences the movement of a painting in the home. If someone throws her keys on the table the painting will swing wildly. Gaver and colleagues strive for ambiguity that provokes people. They want people to reflect and interpret what they think is

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[6] No name of this application has been found. In this thesis we simply call it the Alarm Clock.

[7] http://www.interaction.rca.ac.uk/equator/weight_furniture.html (9-Dec-04)

**Figure 3.10: The Alarm Clock
(Wensveen et al. 2000)**

**Figure 3.11: Ghost in the Cave
(Rinman et al. 2003)**

the meaning of his systems. This intention in general does not go hand in hand with the idea of an affective loop where systems that are too hard to comprehend do not get most users into a state of flow. The key table more specifically however, might create a short moment of a communicative affective loop between the user, the system and the other people in the home. Since the interaction is performed with the keys to the table this is also a good example of a tangible that will have the user express anger and not just interacting with the artifact. Even though this is a very creative and new way to express oneself to the other people in the house it is a very limited and short termed expressivity that is allowed.

Another communicative usage of affective gestures is explored in LumiTouch a system developed by Chang and colleagues (2001). LumiTouch builds on the notion that closely related people often have a picture of each other. When a user is in front of her LumiTouch the frame of the corresponding LumiTouch lights up to tell her friend or loved one that she is there looking at his/her picture. Squeezing or hugging the frame turns on another light. The ways of expressing oneself is limited and perhaps it is more an indication of awareness than an emotional expression but the application is still worth mentioning as a more subtle approach to emotional communication. The main problem with LumiTouch though, is that it is not ergonomically designed for the interaction to be ready-to-hand.

If artifacts are designed to be ready-to-hand they are perhaps the easiest way to have users physically involved in the interaction. Since they make use of people's everyday knowledge of how to handle physical objects they can be very straightforward for people to interact with. Having an object to interact with can also let users be less self-conscious and more at ease with this new more physical form of interaction. However, Rinman and colleagues (2003) have shown that given the right context it is possible to have users extremely physical and at ease with that movement even without an object to hold on to. Their computer game, Ghost in the Cave, is a game where two teams use expressive gestures in either voice or body movements to compete (Figure 3.11). To get points in the game each

team has to navigate a fish avatar into a cave and there act out the emotional expression of the ghost living in that cave.

What is inspiring with Ghost in the Cave is how the players get to act out emotional expressions together as a group. Emotional expressions, and especially physical expressions, are often contagious and better experienced in a social context. If one person in a group starts laughing it is quite possible that that will cheer up also other people in the group. In this case the users influence each other to jump up and down, or slow down their movements, and in this process they all become more and more expressive which also seem to give them all a stronger game experience. The game is developed for teenagers but has been demonstrated at scientific conferences where even the people that started to look at the interaction from a distance soon came and joined in with the people who were playing.

The technique used to capture the emotional expressions in Ghost in the Cave is developed by Camurri and colleagues (2000, 2003, 2004). They have developed a gesture recognition platform, EyesWeb, where they use video input, motion segmentation and Laban Movement Analysis (LMA) to extract emotions from body movements (Davies 2001, Laban and Lawrence 1974).

BIO SENSORS

The prevailing paradigm of affective computing does not see users as actively involved in the interpretation of their own emotions. Instead emotions are seen as states or processes that the system "read" off the user. The most common approach is to capture internal physiological changes by the use of biosensors. Mostly known within this research area is the Affective Computing Research Group at the Massachusetts Institute of Technology (MIT) Media Laboratory directed by Rosalind Picard. Using pattern recognition of physiology, Picard and her group have achieved recognition rates of 81% accuracy of emotional states (Vyzas and Picard according to Picard 2002). However, the results were for a single user and were obtained from a forced selection of one of eight emotions; neutral, hatred, anger, romantic love, platonic love, joy and reverence. In a study of twelve Boston drivers they have managed to measure stress with up to 96% accuracy, using sensors for electrocardiogram (EKG), electromyogram (EMG), galvanic skin response (GSR) and respiration through chest cavity expansion (Healy according to Picard 2002). Such good results are possible to get in very isolated scenarios but the technique is very sensitive to personal differences and technicalities, such as correct placement of sensors and surrounding noise and frequencies. In addition, quite a lot of hardware is required.

To hide all this hardware, one of the main research areas of the Affective Computing Research Group is to build *affective wearables* which are wearable systems equipped with sensors and tools to recognize the wearer's affective state, for example an earring measuring blood volume pressure (BVP) or a shoe with sensors for skin conductivity (Picard and Healey 1997). Another wearable is the

Galvactivator, a glove that senses the wearer's skin conductivity and maps its values to a bright light emitting diode display (Picard and Scheirer 2001).

Affective Medicine is one of the usage areas that Picard (2002) sees for her research. Stress is today an increasingly recognized medical problem. Picard wants to teach computers to recognize stress and frustration so that they can do a better job of serving people. However, it is not only the problem of measuring stress correctly, perhaps the biggest issue is how computers are to respond. One user might be even more annoyed if faced with help in the middle of her session while that would be exactly what another user whishes for. To complicate the scenario even more, the two users might have shifted roles during a session. It is extremely hard to know what the stress symptoms depend on since users not only are influenced by what happens on the computer screen but also from a range of other sources, such as people around us and our own thoughts about current and previous events.

Affective Learning is another domain where Picard and her group believe that affective computing can be applicable (Kort et al. 2001). It is well known that students' results can be improved with the right encouragement and support. Kort and colleagues propose an emotion model built on Russell's circumplex model of affect relating phases of learning. The idea is to build a learning companion that keeps track of what emotional state the student is in and from that decide what help she needs. Another application they have worked on is a leap chair with pressure sensors (Mota et al. 2003). The chair classifies nine postures a student can have. The postures are related to affective states associated with a student's interest level.

In relation to our work on the affective loop the work conducted by Picard and colleagues is not so much aiming for emotional experience as for helping people in various tasks, where they strive for automatic solutions. A research problem that not only concerns how to capture users' emotions correctly, but also what help different people want, need and are open for in various situations.

3.4 TECHNIQUES FOR AFFECTIVE EXPRESSIONS

To this point we have focused on techniques for sensing emotions, as this is the main focus of this thesis. However, in the definition of the affective loop we emphasize the importance of relevant response to the emotions that are being communicated. Not all systems described in this thesis include both input and output of the kind we are looking for, but some do and we have already given a few such examples. Below we will give a more structured presentation of the techniques used explicitly for affective output: human expressions, colors, shapes and animations, affective music, and haptics. To date it seems like most research within affective interaction has a greater focus on emotion sensing than on affective expressions. However, it is a research area highly inspired by film, music and graphic design and there will most likely soon be more categories to add to this list.
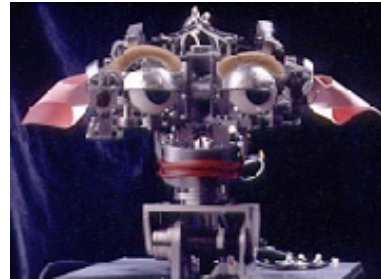
**Figure 3.11: Kaktus
(Laaksolahti et al. 2001)**

**Figure 3.12: Kismet (Breazeal
and Velasquez 1998)**

HUMAN EXPRESSIONS

The means people use to express emotions, like tone of voice, facial expressions, gestures, and body posture, are also used for affective output. We have already mentioned several systems using such techniques; in EmpathyBuddy smilies or emoticons are used to show facial expressions of various emotions, in Acting in Virtual Reality users can affect the facial expression and the body posture of their avatar, in CHATAKO tone of voice is used as an indicator of emotion, in ExMS and FAIM characters having various emotional expressions are used to express emotions, and in Office Voodoo there are actors that express emotions.

Smilies, small icons representing the facial expressions people use for various emotions, are perhaps the simplest approach to human expressions (Figure 3.3). A more advanced approach is to use Embodied Conversational Agents, ECAs (e g Cassell et al. 1994). ECAs naturally include audible and visual speech, emotions deployed by the face and voice, and gestures conveyed by the eyes, head and body. ECAs are for example used in Kaktus (Figure 3.11) representing the teenage girls that organize a party together.

Humanoid robots are the most advanced usage of human expressions. Kismet developed by Brezazeal and colleagues (1998) is one example of such a robot. Kismet is like an infant whose learning is assisted by its caretaker. Kismet can tell if it is bored, happy, scared or a number of other emotions (Figure 3.12). The robot uses emotional expressions to influence its caretaker to play with it or to stop doing something that it finds boring etc. Kismet is equipped with visual and auditory sensors and it also has vocalizations, facial expressions, and motor capabilities to adjust the gaze direction of the eyes and the orientation of the head.

COLORS, SHAPES AND ANIMATIONS

Colors, shapes and animation are other modalities through which we can visualize emotions. For example, colors are often used to express arousal, where red represents emotions with high arousal and blue is calm and peaceful (Itten according to paper A and B). By the use of shapes and animations it is also
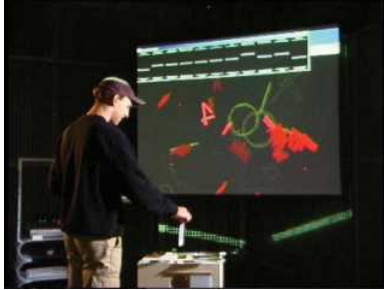
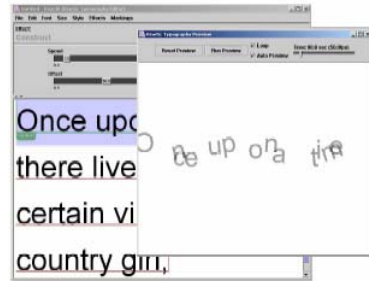**Figure 3.13: The Influencing Machine (Sengers et al. 2002)**

Figure 3.14: Kinedit (Forlizzi et al 2003)

possible to create visual effects of various emotions, like smaller and faster moving objects for emotions with high arousal while larger more billowing objects better represent emotions with less energy. This technique is used by Sengers and colleagues (2002) in their work on the Influencing machine. The Influencing machine explores the relationship between users and affective computers. Users are told to put postcards with various illustrations into a box situated in front of a large screen where the machine answers in child like drawings representing different emotional states (Figure 3.13). The results from a first evaluation of the Influencing Machine showed that users saw little connection between their actions and what was happening on the screen (Höök et al. 2003). Sengers and colleagues did not explicitly increase users' control; instead they made the interaction faster and after a second evaluation it seemed like some users experienced parts of a cognitive affective loop. People are used to look for patterns and if they believe they have found one they feel more in control even if that might not be true in theory. Regarding the Influencing machine, more data to analyze and to find patterns in might have been the reason why some users felt more in control even if that was not the case.

Another way of using animations and visual effects is explored by Forlizzi and colleagues (2003) in their usage of kinetic typography in a system they call Kinedit. Kinetic typography is successfully used in advertising and graphic design but in Kinedit it is used for expressive communication between users (Figure 3.14). Techniques previously used in animated film, such as slow-in slow-out movement, squash and stretch, anticipation, follow-through and secondary action, is in Kinedit added to the text a user wants to send. The user can herself combine the effects in a way that suits the emotional value she wants to communicate. This way she can include the whole emotional process into her message and also combine effects to create a more complex expression. However, the system requires users to be quite familiar with graphic design.

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AFFECTIVE MUSIC

Another technique that also is highly exploited within the film industry is how music or sound is used to create moods or emotional states with the audience. Researchers have looked at how it is possible to express emotions in music so that they are recognizable to users. Bresin and Friberg (2000) have worked on cue profiles that they use to identify emotions in short pieces of music. One of their findings is that irregular tempo and low sound level are used to express fear, while little variability in tempo and high sound level is used to express happiness. Kim and André (2004) have conducted studies where they use bio sensors on people who listen to music. They have found that disquiet can be separated from relaxed by the GSR pattern, and pleasant or unpleasant can be judged from the EMG value. Applications where affective music is used are Ghost in the Cave and the Influencing Machine presented above.

HAPTICS

A few researchers have also worked on haptics and investigated how sensory output can be used to strengthen the experience of various emotions. Short programmed force patterns called hapticons are used to communicate a basic notion in a similar manner as ordinary icons are used in graphical user interfaces. Enriquez and MacLean (2003) have constructed a knob associated with a graphical user interface where users themselves can record and edit their hapticons. Rovers and van Essen (2004) have used the results of Enriquez and MacLean when constricting HIM, a system for instant messaging where users can choose between special input devices such as a glove or an egg.

The Palpable Machines Group at Media Lab Europe has also looked at haptics but not with an explicit focus on emotions. Their focus is to enrich the experience of interacting with the digital world by focusing on the capabilities of human sensory systems. An example is their system Touching Tales[8]. It is a system built for kids that allows them to listen, hear and also feel the story that is told. One example is a story about a cowboy and his horse where the children by holding their fingers on a sensor can feel when the cowboy throws his lasso or when the horse eats his hay.

3.5 SUMMARY

We have now provided a brief overview of the affective computing/interacting research area mainly focused on techniques for sensing and expressing emotions in a digital context. We have described a few systems in more detail in order to exemplify our categorization, but also to position our work on the affective loop in relation to state of art within affective research. In Figure 3.15 we can now place these application systems into our previously presented plane model to summarize

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[8] http://www.medialabeurope.org/~ian/tales/textonly.shtml (Dec. 9, 04)

MUCH CONTROL

CHATAKO

Acting in virtual reality

ExMS   LumiTouch   The Alarm Clock

Kismet   Key table

The Affective loop

Ghost in the cave

ONLY MIND   ONLY BODY

Kaktus   Office Voodoo   eMoto

Influencing Machine   HIM

Kinedit   EmoteMail

EmpathyBuddy

FantasyA/SenToy

FAIM

Teatrix

Design-A-Plant   Affective learning

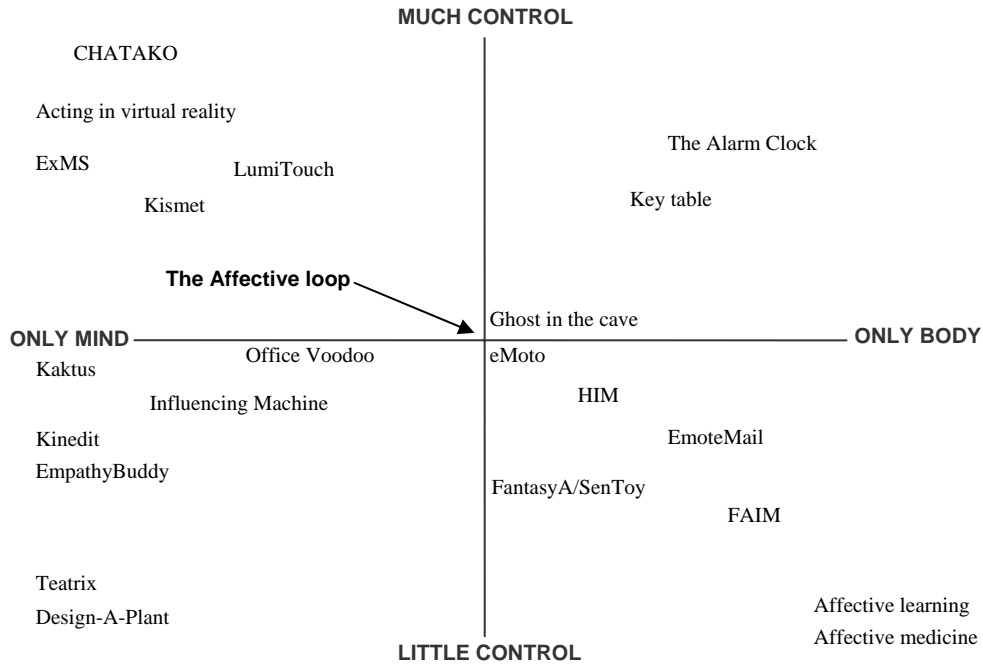Affective medicine

LITTLE CONTROL

Figure 3.15: State of art in relation to the affective loop

this presentation. Applications that we have placed close to the middle are in our point of view applications that let users experience both cognitive and physical aspects of emotions. With this summary we will also contribute with a graphical analysis of the research area. Obviously, this description does not include all systems within the research area. Moreover, we believe that also the categorization will expand in the close future, due to apparent connections to other affective media, such as film, music and graphic design.

Nevertheless, according to the presentation above a combination of affective gestures and colors, shapes and animations, music and haptics are good candidate modalities through which we can design applications that will fulfill the aims of involving end-users in an affective loop. In the next chapter we will present our system eMoto, a mobile messaging system using this combination.

4 DESIGNING FOR AN AFFECTIVE LOOP EXPERIENCE

Our aim is to explore whether it is possible to design systems from an affective loop design perspective. To better understand whether and how it is possible to create an affective loop application for communication purposes, we have designed, implemented and evaluated a mobile service named *eMoto* (Figure 4.1) – the prototype embodies our design ideas, and serves as a research vehicle to test our ideas.

We have designed eMoto from the four design principles presented in chapter two; embodiment (Dourish 2001) as a means to address how people communicate emotions in real life, flow (Csikszentmihalyi 1990) to reach a state of involvement that goes further than the current context, ambiguity of the designed expressions (Gaver et al. 2003) to allow for open-ended interpretation by the end-users instead of simplistic, one-emotion one-expression pairs and natural but designed expressions to address people's natural couplings between cognitively and physically experienced emotions. In this chapter we present the design process in more details to reveal some of our methodological perspective.

But first a presentation of eMoto: eMoto is a mobile messaging service for sending and receiving affective messages. The idea of eMoto is to extend on both the input and output channels when sending text messages between mobile phones. The aim is to convey more of the emotional content through the very narrow channel that a text message provides. Emotions are addressed as both physical and cognitive processes. The user expresses her emotions by the use of affective gestures and the system responds to those gestures using colors, shapes and animations combined as affective expressions in the background of her text message. The intention is to have the user engaged in a personal affective loop where she gets a strong experience of her own emotions. The expression she in the end chooses is then communicated to the receiver as a background to her text message.

The process of determining the meaning of a sent/received message with some emotional expression is, similar to any human communication, best characterized as a negotiation process. The message is understood from its context; who the sender is, her personality, the relationship between sender and receiver, and their mutual previous history. Over time this is the foundation of a communicative affective loop with the people we send messages to and receive messages from.

4.1 BRAINSTORMING

The intention with our prototype-driven approach was not to design a product but a prototype acting as a research vehicle for exploring the idea of the affective loop. However, for us to say something of how we have succeeded the scenario for such prototype needed to be as realistic as possible, almost as if we were to design a

Figure 4.1: eMoto

Figure 4.2: The persona

product. Therefore we used a set of established design and brainstorming methods and aimed to find a suitable scenario. We asked two other design teams to help us in this process; one team including people from the Swedish Institute of Computer Science and the Department of Computer and System Sciences and one team from the Future Application Lab at the Victoria Institute in Gothenburg. We used *Random Words* and *Six Thinking Hats* (de Bono 1985); two well established brainstorming methods.

Random Words is used to come up with novel, inspiring, thought-provoking combinations of words from specified categories, in our case *emotions*, *techniques for sensing emotions* and *places*. The team then brainstorms around what an application using that specific combination of words could be for a few minutes before going on to the next combination of words. We worked with each design team separately and each time we used Random Words to come up with a range of ideas.

Thereafter we used Six Thinking Hats, a method for evaluating and developing already existing application ideas. In this method each idea is reflected upon from five different viewpoints represented by five differently colored hats that the participants "put on": *facts and information* (white), *optimism* (yellow), *opinions and thinking* (red), *cautiousness* (black) and *creativity* (green). These viewpoints represent five of the different hats. The last hat (blue) is given to the person who regulates the process. The design team takes turns in taking on the hats to work on, modify, and evaluate the given design ideas (in our case taken from the random words-session).

We also sent a questionnaire to 80 potential users with questions about their personality, computer and mobile phone usage and how they today use emotions in digital communication. The results of this questionnaire helped us to set up a *persona* to be used in the design process (Cooper 1999).

The Persona method is a different way of working with end-users developed by Cooper (1999). The idea is to design for a more specific group of users instead of trying to please all users at the same time. Cooper talks about the Persona method as the opposite of designing for "the elastic user" that tends to have the user adapt to the software and not as intended where the software has to be adjusted to the user. However, using the Persona method one never refers to 'the user' since the imprecision of such a reference to an unknown user makes it unusable; instead all team members of the design team refer to a very specific individual: a persona. A persona is not a real person but a representative set up from real user data, in our case from the results of the questionnaire. The intention is to be as specific as possible therefore the persona is given a name, a picture and a precise description of her goals and needs.

The persona set up for the eMoto service is named Sandra (Figure 4.2). In short she is a confident 29 year old woman who likes to spend time with her friends and family. She works as a trainee at a city planning office in Stockholm. Sandra does not care about how things work technically, but she likes new cool technological features and she is very happy with her new mobile phone that has a camera and MMS functionality.

The persona is used all along the design process but at this point it helped us to choose between all the ideas we had generated in the brainstorming. The persona at this point also helped to improve and modify the idea of a mobile messaging service using affective gestures as input and cognitive graphical expressions as output.

4.2 AN ANALYSIS OF EMOTIONAL BODY LANGUAGE

Both gestures and emotional expressions used in eMoto are developed from an analysis of emotional body language. Our aim is to address the couplings between cognitively and physically experienced emotions, therefore both input and output need to affect the user emotionally. We want users to *feel* emotional not just express emotions through some iconic expressions like a thumb up, emoticons or smilies. Both input and output should have characteristics of natural emotional expressions – not be abstracted representations of those emotions.

To find such characteristics of emotional body language we invited Erik Mattsson[9], an actor, who works with counseling and education in human rhetoric. We asked him to express nine different emotional processes in body language, while we videotaped him. The nine emotions were picked from the results of the questionnaire concerning what emotions people most wanted to be able to express in SMS: *excitement, anger, surprise-afraid, sulkiness, surprise-interested, pride, satisfaction, sadness* and *being in love*.

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[9] http://www.ordrum.com/erik.html (9-Dec-04)

The most common approach to a computational model of human body language is McNeil's approach used primarily to implement Embodied Conversational Agents, ECAs (e g Cassell et al. 1994). McNeil has defined five categories for human communicative arm gestures (McNeil as described by Chi et al. 2000):

➢ *Iconics* are used to represent some physicality of a subject, like its shape or size

➢ *Metaphorics* represent some abstract feature of a subject, like the fact that it is exchangeable or emerging

➢ *Deictics* indicate a point in space, the most common gesture for this is probably the gesture of pointing at something

➢ *Beats* are used to structure the conversation, like counting gestures or gestures for turn-taking

➢ *Emblems* are stereotypical gestures like the ok-sign or a thumb up

McNeil's approach does not describe how various gestures feel when performed and nor does it describe emotional gestures. According to Chi and colleagues (2000) this approach will render unnatural, robotic movements when implemented in ECAs.

Our aim was to look further than categories of gestures and instead aim to find the underlying experience dimensions of movement. We therefore decided to use *Laban Movement Analysis* (LMA) to extract the *shape* and *effort* of movements (Davies 2001, Laban and Lawrence 1974). The same analysis has been used by Chi and colleagues (2000) for their work on EMOTE, a 3D character animation system, and Camurri and colleagues (2000, 2003, 2004) in EyesWeb, a system developed for real-time analysis of body movement and gestures. In particular, Camurri and colleagues have had a similar focus to ours on what emotions specific body movements communicate.

LABAN MOVEMENT ANALYSIS

Laban, a choreographer and movement analyzer, and his disciples have defined five underlying dimensions of movement; Body, Space, Shape, Effort and Relationship (Laban and Lawrence 1974, Davis 2001). In our work we have focused on shape and effort. Shape describes the changing forms that the body makes in space, while effort involves the dynamic qualities of the movement and the inner attitude towards use of energy.

The Laban-notation is presented in more detail in paper A, but in short, shape is described in terms of movement in three different planes: the table plane (horizontal), the door plane (vertical) and the wheel plane, which describes sagittal movements. Horizontal movement can be somewhere in-between spreading and enclosing, vertical movement are presented on a scale from rising to descending, and sagittal movement go between advancing and retiring.

The second dimension in the Laban formalism is effort, comprised of four motions factors: space, weight, time and flow. Each factor is a continuum between two extremes; direct or flexible for space, light or strong for weight, quick or sustained for time and bound or fluent for flow.

All of the emotions the actor was asked to perform may of course give rise to a whole range of different body movements depending on the setting, the background and previous experience of the person, personality, culture and various other factors. This act is only one way that these emotions can be expressed. Even though the actor was asked to perform nine distinct emotions, his way of acting out those emotions was more like a process working on the concept of each given emotion, going from starting the expression to *feeling* it more and more, expressing it stronger, and then varying it using various alternative interpretations of when this emotion would arise. The LMA was performed on the whole sequence of expressions for each given emotion, although summarized into one effort graph for every emotional process.

Camurri and colleagues have used LMA to classify dance gestures in terms of basic emotions; anger, fear, grief and joy. Table 4.1 presents a comparison between our LMA of emotional body language and the notation used by Camurri and colleagues (2003). There were, however, only three emotions that were used in

	Our analysis	Camurri and colleagues'
Anger	Time - Quick Flow - Fluent Space - Flexible Shape - Somewhat spreading, rising and advancing Weight - Strong	Time - Short duration of time Time/Flow - Frequent tempo changes, short stops between changes Space/Shape - Movements, reaching out from body centre Weight - Dynamic and high tension in the movement; tension builds up and then explodes
Fear	Time - Quick Flow - Fluent Space - Flexible Shape - Enclosing, somewhat descending and retiring movements Weight - Strong	Time/Flow - Frequent tempo changes, long stops between changes Space/Shape - Movements kept close to body centre Weight - Sustained high tension in movements
Joy	Time - Quick Flow - Fluent Space - Flexible Shape - Extremely spreading, rising and advancing movements Weight - Strong	Time/Flow - Frequent tempo changes, longer stops between changes Space/Shape - Movements reaching out from body centre Weight - Dynamic tension in movements; changes between high and low tension

Table 4.1: A comparison between our LMA and the one conducted by Camurri and colleagues (2003), however, only three emotions overlapped.

both studies; anger, fear and joy. As can be seen in Table 4.1, the similarities are apparent, but Camurri and colleagues have better managed to keep the dynamics of movement. In his notation Laban does not suggest that a process of movements such as the emotional process shall be narrowed down to one effort graph, as we did in our analysis, instead he uses a set of effort graphs for movements that changes over time. Our set of one effort graph for each emotional process had us in the position where we could not differ between all emotions. A few emotions such as excitement, anger and afraid had the same characteristics at this point. Thus we needed another variable to get a more varied picture of emotions.

RUSSELL'S CIRCUMPLEX MODEL OF AFFECT

In addition to the dimensions of shape and effort, we looked for an emotion theory specifically focused on how emotions are experienced. As discussed above, according to Scherer (2002), *dimensional models* cover the feeling of emotional experience both on a low level (as in the limbic parts of the brain and in the body), and on a higher, cognitive, level. One such dimensional model is Psychologist Russell's *circumplex model of affect* (1980) where emotions are seen as combinations of *arousal* and *valence* (Figure 4.3). Since a high degree of effort brings a high degree of arousal and vice versa Russell's analysis of emotions concurs nicely with Laban's theories of movements. In Russell's circumplex model of affect, emotions are distributed in a system of coordinates where the y-axis is the degree of arousal and the x-axis measures the valence, from negative to positive emotions.

While Camurri and colleagues used their LMA in combination with a discrete emotion model (see section 3.1 about emotion theories) we combined our LMA with Russell's circumplex model of affect and that way we extended the results of our LMA to cover more emotions than the initial nine, and also allowed for personal and more complex emotions. Moreover, we have included the whole
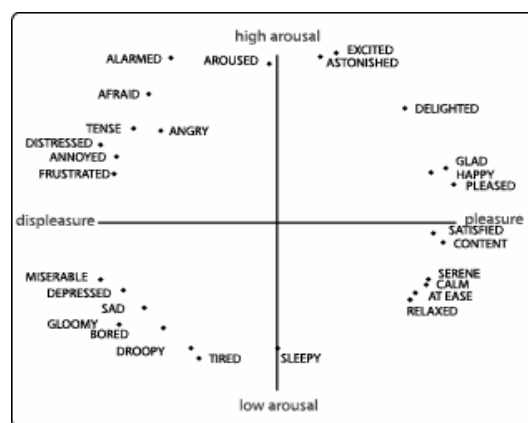

Figure 4.3: Russell's circumplex model of affect
(Russell 1980)

emotional map of both positive and negative emotions. Many systems designed to connect remote lovers or friends, such as LumiTouch (Chang et al. 2001), presented in chapter three, or Gaver's work on provocative awareness (Gaver 2002), seem to miss the notion of also including negative emotions. According to the results of our questionnaire there is a need also to express emotions such as sulkiness, sadness and anger. People are not only sweet and loving; people are more complex than that. Quite often we like to say that we were pissed at something or we want our loved ones to suffer a while when we have been fighting with them.

4.3 DESIGN AND IMPLEMENTATION

Both gestures and graphical expressions used in eMoto are designed from the analysis of emotional body language presented above. The user first writes an SMS and then finds a suitable affective expression to add to the background of her text message. The user navigates the affective background by the use of affective gestures. Since both gestures and background expression are designed from the same LMA, they will, in a sense, mirror one-another in terms of movement even if they are not exact isomorphic representations of each other. This also implies that the receiver of an affective message formed in eMoto will know what gestures the sender must have done to create such message, which in turn gives also the receiver some form of physical experience.

AFFECTIVE GESTURES

From the analysis of emotional body language it became apparent that even though negative and positive emotions not always differ in terms of effort, most negative emotions have more tense expressions. Therefore the affective gestures in eMoto are set up as combinations of valence in terms of pressure and effort communicated through movement; see Figure 4.4, which describes the four extreme gestures. However, in between those extremes there can be a whole range of combinations of movement and pressure.

Since eMoto is a mobile service that is going to be used in a public environment the gestures had to be fairly discrete, however, since the persona set up for the eMoto service is a relatively expressive woman the gestures had to be designed expressive enough to affect the couplings of such user. An obvious mistake we did that might have affected both the design of the gestures as well as the design of the background circle was that we invited a male actor rather than someone who would be similar to Sandra. We could also have decided to study emotional body language conducted naturally by people similar to our persona rather than using an actor. However, to what extent this affected the final design is hard to say.
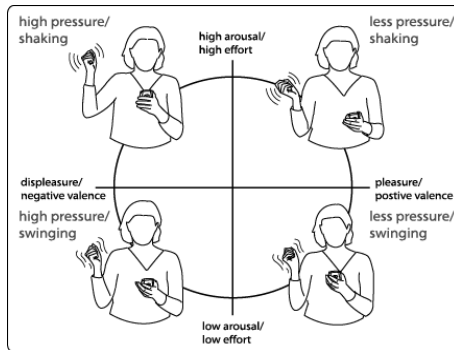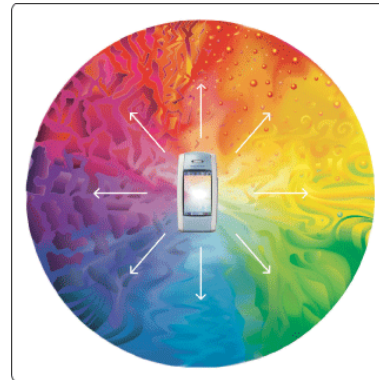
Figure 4.4: The affective gestures

Figure 4.5: The affective background circle (the animations can be seen on www.sics.se/~petra/animations)

AFFECTIVE GRAPHICAL EXPRESSIONS

Similar to the gestures the affective expressions are designed from the analysis of the actor's behaviors. The expressions are non-symbolic and constructed from what is known about the effects of colors, shapes and animations (Figure 4.5). The purpose of the affective expressions is to give feedback to the user's gestures and therefore they are both designed from the same emotional model, described above. They are also to be used as backgrounds in text messages. However, to allow for personality and open interpretation there is no indication of what emotions various expressions were designed from, that is up to the user to decide.

However, the affective graphical expressions are not the focus of this thesis but instead of a forthcoming licentiate thesis to be written by Anna Ståhl.

TECHNICAL DESIGN

eMoto is built in Personal Java and runs on the P800 and the P900 series of Sony Ericsson's Symbian mobile phones. These mobile phones all come with a stylus to be used with their touch-sensitive screens. We have extended this stylus with an accelerometer capturing the shape of movements and a pressure sensor capturing the effort. The stylus is now connected to the serial port of a stationary computer which in turn communicates with the mobile phone (Figure 4.6), but we are working on a technical design using Bluetooth where the stylus will be connected directly to the mobile phone (Tränk forthcoming).

When constructing a new message the user always starts in the middle of the background circle. The background picture is a hundred times larger than the screen of the mobile phone. Thus only a small proportion can be seen at a time (Figure 4.5). The data captured from the two sensors is reflected in how she moves from that initial position. Moving in the circle is done through combining pressure
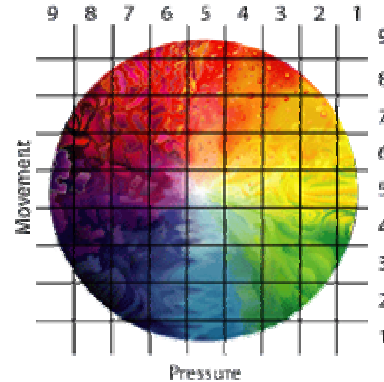
| Figure 4.6: The prototype | Figure 4.7: Technical design |

and movement as captured by the two sensors in the stylus. The movement in the circle is animated as a fairly slow gliding change.

As users can navigate freely around the entire circle and decide to stop anywhere, there is a large amount of expressions to choose from. Both the pressure and the movements are measured in nine levels where the fifth level implies that the user will move towards the middle of the circle (Figure 4.7). A softer pressure than "five" will make the system move right on the background picture, while a harder pressure implies a movement to the left. The harder or softer a user presses the more sections she can reach. The same applies for how she can move vertically in the picture using faster or slower movements. Slower movements than "five" will make the system go to the lower parts of the circle while a more increased shaking will render expressions placed in the top of the picture. To reach the borders along this scale, the user will have to either nearly not shake the stylus at all or shake it violently, as presented in Figure 4.4.

The user can both press and shake at the same time; however, the two gestures affect her movements in the background picture independently, nine level for pressure and nine levels for movement. These levels together form squares and not circles. If the levels were set up as circles there would be dependency between the two sensors. However, she can never leave the outer border of the circle which implies that when she is out in the outer regions of the circle there is dependency between the two gestures.

4.4 SEVERAL USER STUDIES AND REDESIGN

The evaluation process of eMoto follows Höök's *two-tiered evaluation method* (Höök 2004), which implies that each part of an affective interaction system must be evaluated on its own before combined into an overall design and evaluated against its purpose. It might be that an idea of an affective interaction system is really good but unless the expressions used in each part of that system are

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understood by the end-user, the overall idea will fail anyway. After each part has been evaluated on its own there should be a final evaluation conducted in a natural setting and on "real" usage. Not much can be said about real usage of for example a mobile system if it is only evaluated in a lab environment.

Thus far, two user studies have been conducted on eMoto. We first did a user study of the colors, shapes and animations[10] before they were combined and, in a second study, evaluated together with the affective gestures (as described in paper C). The first affective expressions study was performed by subjects in pairs in front of a laptop in a lab environment. Six pairs took part in this user study. In short summary, the subjects chose expressions from approximately the same area of the background circle to express the same emotions. The results confirmed that our aim to let people express themselves differently was possible and viable – without becoming completely random and confusing.

The user study of the affective gestures was a qualitative study capturing whether users got emotionally involved in an affective loop. 18 subjects took part in this user study which also was conducted in a lab environment, this time as individual sessions. The study indicates from an analysis of facial expressions and the users own reports that 12 out of 18 subjects got both physically and emotionally involved in the interaction. The combination of gesture, affective expression in color, shapes and animations, and the intended emotion overall seems to be for the most part working, even if minor adjustments are needed. Subjects did for the most part the same kinds of gestures (according to our LMA) and they picked background expressions in approximately the same area to express the emotions. Important to remember here, is our aim of creating ambiguous, open-ended expressions that allows different users to pick different expressions – something that we seem to have succeeded in doing. This is not a task-based interface where the same task always should render the same output. The subjects were also able to interpret some faked messages from other users and assign different emotional messages to the same textual message. The results of this user study are presented in further detail in paper C. Below follows a more technical description of what changes that needs to be made before a final evaluation of eMoto in a natural setting can be conducted.

FUNCTIONALITY TO BE REDESIGNED

This second user study of eMoto indicated three main areas for redesign, *timing*, *the emotional model* and *initial pressure*.

With timing we mean the relationship between the gestures performed by the user and the feedback given by the system. For the graphical expressions to change the user now has to continue with the gestures until she gets to an expression she likes. The results shows that some emotional expressions, like the gestures for low

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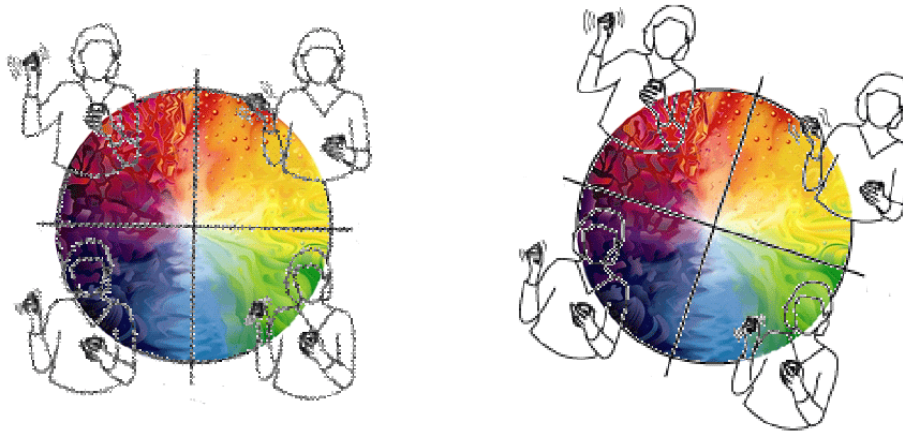[10] To be published elsewhere, mainly the work by Anna Ståhl.

Figure 4.8: A shifted emotional model

arousal and negative valence, are suited to be sustained while other expressions, like the expressions for high arousal and positive valence need to be quick and performed in intervals. In the current implementation, there is a one-to-one mapping between the gestures and the changes on the screen and this need to be change to a one-to-five or one-to-ten interval so that the user performs her gestures and then studies the screen for a while before she stops or continues with more gestures. It is important to find the natural length of various emotional expressions for users to experience flow.

Furthermore, the mapping between how the gestures are constructed form Russell's circumplex model of affect and how the graphical expressions are constructed needs to be shifted (Figure 4.8). Extreme positive arousal requires some pressure while the most calm but negative emotions are loser than we had designed for.

A final issue for redesign is the initial pressure. To save battery an initial pressure is now used to turn on the sensors. Because of this, pressure tends to dominate movement as there can not be any gestures without pressure but there can be gestures without movement. As the eMoto-pen does not provide any feedback on when the initial pressure is high enough so that the user's gestures are communicated, the user can not know if the graphical expressions are not changing because her gestures have taken her to the most extreme those gestures can bring her or if her gestures are not communicated because she has a pressure that is lower than the required initial pressure to start the system. Instead of an initial pressure we therefore want to redesign the stylus to more resemble a thick pen where the user has to press a button to be able to write with the pen and to press that button again when she wants to use it for gestures.

When these three aspects have been redesigned it is time for eMoto to be evaluated in a real user scenario, in a natural setting and for "real" usage. We now know that the designed openness and ambiguity of the expressions, was appreciated and understood by our subjects, and that users got both physically and emotionally involved in the interaction, but it will be interesting to see if users will react in a similar manner in a mobile and public environment outside the lab.

5 SUMMARY OF PAPERS

The authors of the three papers of this thesis have to a large extent conducted the work together; however, Anna Ståhl has had the main responsibility for the design of the colors, shapes and animations used as affective expressions in eMoto. My own main focus has been on the design of gestures for input and the overall design of eMoto as a communication channel. I have also implemented the service. Kristina Höök has been the supervisor and has given valuable input all along the process. eMoto is also using some hardware that Martin Nilsson at The Swedish Institute of Computer Science (SICS) and a design firm, About Design AB, have helped to construct and cast the hard pen-shell in which the sensors are placed.

Below, we give a summary of the three papers included in this thesis. Important to note is that the work has developed from when we wrote paper A to where we are today. Initially, in paper A, we started with a set of design principles where the affective loop was regarded as one of the principles and user-centered design was the overall goal. The design process has taken us to the point where we are now, where user-centered design is the overall goal but where we have focused on the affective loop and where we have listed embodiment, flow, ambiguity and natural but designed expressions as the principles needed to allow for such experience.

5.1 AN ANALYSIS OF EMOTIONAL BODY LANGUAGE

In paper A we have studied the problem of finding a set of affective gestures. Based on previous work in movement analysis and emotion theory and a study of an actor expressing emotional states in body movements, we have identified three underlying dimensions of movements and emotions: shape, effort and valence. From these dimensions we have created a new affective interaction model, which we name *the affective gestural plane model*. In this paper we also gave a very early description of eMoto which then included a sensor capturing the user's pulse, a functionality that never came to be included in the final design.

5.2 EMOTO

eMoto, a mobile text messaging service, has been presented before in this thesis but is in detail presented as a design sketch in paper B. The interaction designed from the above analysis of emotional body language is presented in both textual and graphical form. The goal of eMoto is to provide users with means to emotionally enhance their SMS. The user first writes the textual content of the message and then adjusts the affective background to fit the emotional expression she wants to achieve. The adjustments are done through affective gestures that will render an animated background acting as an emotional expression to the user's text message.

5.3 A User Study of the Affective Loops in eMoto

Paper C presents a user study of eMoto where 12 out of 18 subjects got both physically and emotionally involved in the interaction. The study also shows that the designed openness and ambiguity of the expressions, was appreciated and understood by our subjects. The user study was set up in a lab environment and contributes mostly to the personal affective loop. However, the results also give valuable information to eMoto as a mobile service including also a communicative affective loop, that under normal circumstances occur over time, best described as a negotiation process between users.

6 DISCUSSION

We have introduced and attempted to define the idea of creating applications that involve end-users in affective loop experiences. To better understand whether and how it was possible to create systems that allow for an affective loop involvement we have taken theoretical inspiration from recognized ideas within the field of HCI and from that extracted four, interrelated design principles that we have modified to the particular motives and needs of our design situation; embodiment, flow, ambiguity and natural but designed expressions. To exemplify and test the affective loop idea we have designed, implemented and evaluated eMoto, a mobile service for sending affective messages to others, with the explicit aim of addressing both cognitive and physical senses of human emotions. Through combining affective gestures for input with affective expressions that make use of colors, shapes and animations for the background of messages, the interaction "pulls" the user into an affective loop.

The design principles we set up turned out to be useful, however, in the user study described in paper C and from the analysis of the research area presented in chapter three, we encountered a few problematic issues that need to be further explored; the extent to which users' *feel in control* of the interaction, *harmony and coherence* between cognitive and physical expressions*, timing* of expressions and feedback in a communicational setting, and effects of users' *personality* on their emotional expressions and experiences of the interaction.

6.1 CONTROL

For users to be engaged in affective loops it is essential that they feel they are a part of the interaction. It is also important that the interaction is somewhat mysterious and open for interpretation. There has to be several levels to the interaction for the user to explore. Central is to find the "right" level of control. Interacting with systems where the interaction is too simplistic does not capture and continue to keep users' interest, and if the interaction is too complicated for users to understand they will not even start to get interested.

EmpathyBuddy (Liu et al. 2003) and EmoteMail (Ängeslevä et al. 2004), two systems presented in chapter three, seem to allow the user very little control of what emotions she communicates but there is an openness in both these systems that allow the user to go deeper and begin to elaborate with how her emotions are captured, interpreted and communicated. In EmpathyBuddy each sentence a user writes is attached with a smilie. A first look at this system indicates that the user takes a relatively passive role in how the emotional value of her sentences is interpreted, but because of the openness she will probably soon understand some of how the system works. By elaborating with words the user can start to explore the emotional model implemented in EmpathyBuddy and thereby gain some control. EmoteMail does not allow for a rich communication with the system. In

EmoteMail email a user writes are combined with photos of her. There is an openness in that she eventually will learn when the photos are taken, and since the photos are kept as they are and not narrowed down to a set of expressions she can use this knowledge to communicate all the expressions she can think of. By this she can start to elaborate with the interaction between her and the people she send emails to.

In our user study of eMoto, presented in paper C, it seems as we for some users have found the "right" level of control, while other users felt it was more random and therefore were not as interested and did not seem to enjoy themselves as much.

6.2 HARMONY AND COHERENCE

The importance of harmony and coherence between cognitive and physical expressions is another key aspect of the affective loop that we have discovered from comparing eMoto with systems presented in chapter three. In FantasyA the user affected the emotions of her avatar by acting out emotional gestures together with a large plush doll called SenToy (Paiva et al. 2003). The avatar answered by acting out the same emotions but it did not always use the same gestures as the player did. In the evaluation of SenToy it became apparent that players often imitated the avatars' expressions, and when that expression was nothing like the initial expression performed by the user there was no second iteration in the affective loop. In eMoto, on the other hand, the graphical expressions were designed having the same characteristics as the gestures. Hence, imitation, if it occurred, had the user further engaged in an affective loop. However, physical expressions and graphical cognitive feedback are two very different modalities with different properties, which was also the case in eMoto. In eMoto the two media were connected by Russell's circumplex model of affect (1980) and then the characteristics found in the Laban Movement Analysis (presented above and in paper A) of emotional body language were used in both the design of the gestures as well as in the design of the graphical expressions. This we believe was a viable path for achieving harmony and coherence between the two modalities experienced in eMoto.

6.3 TIMING

Timing of expressions and feedback in a communicational setting was another problem with SenToy as well as with the Influencing Machine (Höök 2004) which also turned out to be a problem in eMoto, however, in a slightly different manner. In SenToy (similar to the Alarm Clock (Wensveen et al. 2000)), the time between expression and feedback is too long for users to stay in a state of flow and involved in an affective loop. In SenToy the user first expresses her emotions and then she has to wait to see how that affects her avatar. Her avatar after that takes some action towards the opponent, and the user has to wait until the opponent has

answered to that action before it is time for her to affect her avatar with new gestures. When interacting with the Alarm Clock that waiting time is even longer, the user has to wait until the next morning or to the time when the alarm sets of before she gets feedback on her expressions. From the evaluation of eMoto it also became apparent that emotions have different length as to how long it is possible to have users engaged in an affective loop in a very physical, interactive sense. Emotions with high arousal, such as extreme happiness or anger, seem to have very short time span while emotions with low arousal and negative valence, such as sad, seem to be longer lasting emotional states. One solution to this can be to separate moods from emotions.

6.4 PERSONALITY

The relationship between the success of the interaction and users' personality was another interesting aspect found in the evaluation of eMoto. Users' personality also seemed to play a role when interacting with the Influencing Machine (Sengers et al. 2002), presented in chapter three as one of the applications designed to have emotional expressions. In both the evaluation of eMoto as well as in the second evaluation of the Influencing Machine it became clear that both systems were more appealing to a subset of the users. Regarding eMoto this user group was very similar to the persona set up for the eMoto service, which in turn, has to be admitted, had characteristics of people within the design team. Höök and colleagues (2003) refer to Oudshoorn's definition of the I-methodology, which implies that designers subconsciously design systems that they themselves are attracted to.

In eMoto differences in users' personality affected especially the tangible design of eMoto. Users who seemed to be more extrovert in their personality were more comfortable with the physical and expressive gestures than users who seemed to be more introverted in their personality. Using gestures to express emotions is something very natural to most people. It is not so much something we are consciously aware of as something we just do in conversation. However, what gestures people use are highly personal and probably also culturally dependent. Some people are said to be more physically expressive than others. There is a difference in what people can, want to and dare to physically express to other people. To make gestures the modality for interaction is not an easy task. To reach the couplings between cognitively and physically experienced emotions, gestures need to be enough expressive to affect users but not so that they inhibit their personal boundaries to the physical expressiveness they normally use. When designing for physical interaction it is therefore essential to know who the targeted user is, perhaps more important to know this than when designing for more common keyboard modalities.

Gesture interaction has many similarities to voice interaction. Neither gestures nor voice can be kept personal in a public environment as for example keyboard interaction. The social norms for what is accepted in a public

environment need to be extended on if people shall be comfortable with these new interaction forms. Mobile phones have shown that that is possible at least for voice interaction. As long as it is clear to the surrounding that a person is talking in a mobile phone, it is at least in Sweden ok with people talking out in the air in public. People in a mobile phone conversation physically turn away and make sure they not have eye contact with people around them to show that they are talking to someone that is not there (Murtagh 2001). If people do not understand that it is a mobile phone conversation they might think the person is talking to herself, which is not something that is socially accepted. To act out gestures in public without a conversational partner entails the same. We have not yet evaluated eMoto in a natural setting and it will be very interesting to see how the users who have characteristics of the persona, experience the affective gestures in eMoto in a mobile and public environment.

6.5 FUTURE WORK

First of all, we will redesign eMoto from the knowledge we have gained so far about the affective loop. Then we will conduct a user study in a natural setting, where a few users will be given the service to use in their every day life. However, to verify this knowledge and the design method that has been defined we also need to take a second turn in the process of exploring the affective loop – not only with eMoto but also with at least yet another example prototype. Thus, we need to design, implement and evaluate a second prototype, where the extent to which users' feel in control of the interaction, harmony and coherence between cognitive and physical expressions, timing of expressions and feedback in a communicational setting, and effects of users' personality on their emotional expressions and experiences of the interaction, are areas that are given more focus.

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PAPER A

Fagerberg, P., Ståhl, A., Höök., K.
Designing gestures for affective input: an analysis of shape, effort and valence

Designing Gestures for Affective Input: An Analysis of Shape, Effort and Valence

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Abstract

We discuss a user-centered approach to incorporating affective expressions in interactive applications, and argue for a design that addresses both body and mind. In particular, we have studied the problem of finding a set of affective gestures. Based on previous work in movement analysis and emotion theory [Davies, Laban and Lawrence, Russell], and a study of an actor expressing emotional states in body movements, we have identified three underlying dimensions of movements and emotions: *shape, effort* and *valence*. From these dimensions we have created a new affective interaction model, which we name *the affective gestural plane model*. We applied this model to the design of gestural affective input to a mobile service for affective messages.

Keywords: Affective interaction, gestures, user-centered design, mobile service

1   Introduction

By addressing human emotions explicitly in the design of interactive applications, the hope is to achieve both better and more pleasurable and expressive systems. The work presented in here is inspired by the field of *affective computing* [Paiva, Picard], even if our aim is to take a slightly different stance towards how to design for affect than normally taken in that field – a more user-centered approach.

Affective computing, as discussed in the literature, is computing that relates to, arises from, or deliberately influences emotions [Picard]. The most discussed and spread approach in the design of affective computing applications is to construct an individual cognitive model of affect from first principles and implement it in a system that attempts to recognize users' emotional states through measuring biosignals. Based on the recognized emotional state of the user, the aim is to achieve an as life-like or human-like interaction as possible, seamlessly adapting to the user's emotional state and influencing it through the use of various affective expressions [e g Ark et al., Fernandez et al.]. This model has its limitations [Höök], both in its basic need for simplification of human emotion in order to model it, and its difficult approach into how to infer the end-users emotional states through various readings of biosignals.

To get the users involved in a more active manner we would, instead, like to propose the user-centered approach to affective computing. Our aim is to have users consciously expressing their emotions rather than having their emotions interpreted or influenced by the system, while still maintaining the mystery and open interpretation of emotional interaction and expression. Inspired by the results of our previous work [Paiva et al.] we arrived at a set of four design principles, outlined in detail below: *embodiment* as a means to address physical and cognitive concepts in the interaction with the application [Dourish], *natural but designed expressions* as a means to communicate affect instead of aiming for complete naturalness, an *affective loop* to reach emotional involvement with both body and mind, and *ambiguity* of the designed expressions [Gaver et al.] to allow for open-ended interpretation by the end-users instead of simplistic, one-emotion one-expression pairs.

Our specific focus in this paper is to describe the process of finding affective gestures for interacting with a mobile service. Our idea is that gestures will address the body-part of emotions in people. When placed in an interaction that also speaks to our mind, the result may be an increased sense of actually communicating affect. Based on previous work in movement analysis [Davies, Laban and Lawrence], emotion theory building upon people's everyday understanding of emotion states [Russell], and a study of an actor expressing emotional states in body movements, we identified three underlying dimensions of movements and emotion: *shape, effort* and *valence*.

To exemplify our design principles and our ideas of affective gestures, we approached the design of an application for a mobile setting, an affective messaging service. An important part of telephone communication is its usage to maintain intimate and close relationships between people [Castelfranchi]. In mobile phones this is done both through phone conversations but also through text messaging (e g SMS[1] and MMS[2]) [e g Grinter and Eldridge]. In the messaging interaction, the affective bandwidth is narrow, and most of the richness of the emotional content is lost. This also has a negative impact on the communicative bandwidth.

The designed affective message application makes use of a combination of gestures and a pulse sensor as affective input, and uses emotional expressions in graphics (color, shape, animation) as output. An important goal is to mirror form and content of the gesture input in the emotional expressions added to the message.

Below we first describe our design principles in more detail, before we turn to the specific problem of designing the affective gestures. We describe our affective interaction model, which we name *the affective gestural plane model*. The mobile service for

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[1] SMS: Short Message Service, used to send text messages between mobile phones.
[2] MMS: Multi-Media Messaging Service, used to send multi-media between mobile phones.

affective messaging, which we describe last, exemplifies how our design framework and the affective gestural plane model might be applied.

2 Designing for affect

While early theories on emotions regarded emotions as discrete states [Ortony et al., Roseman et al.], later work has seen emotions more as processes and appraisal functions that regulate behavior [Paiva], not on or off singular states. As discussed by Castelfranchi, [Castelfranchi], emotions are subjectively experienced states, and we all react differently depending on our background, our previous experience, our mental and physical state and other individual factors. Depending on the social setting we may also express our emotions differently. Expressing happiness during a football game will be quite different from expressing happiness at a business meeting. Thus, recognizing emotional states from biosignals or other physical or external signals is an extremely difficult task – especially in a mobile scenario with its ever-changing psychical and social contexts.

Therefore, emotions as part of human communication is better seen as a human, rich, enigmatic, complex, and ill-defined *experience*. This experience does not solely sit in the brain as part of a rational, cognitive reasoning process. Instead, body and mind are intimately connected [Davies, Dourish, Ekman, Laban and Lawrence, Picard], and *emotions* cannot be seen solely as a mental state but also a physical, bodily, state [Ekman, Picard]. Emotions can be generated through someone's imagination without physical interaction, but they can also be generated from body movements [Ekman]. Try moving as if you are extremely happy and you will probably also experience a warm feeling that slowly grows inside you. It is quite hard to feel sad while jumping up and down and smiling.

In order to design for subjective affective experiences with a user-centered perspective that addresses both body and mind, we extracted four, interrelated design principles that we adjusted to the particular motives and needs of our design situation.

2.1 Embodiment

Dourish [Dourish], defines embodiment as "the creation, manipulation, and sharing of meaning through engaged interaction with artifacts". By artifacts he does not only mean physical objects, but also social practice. Rather than embedding fixed notions of meaning within technologies, embodied interaction is based on the understanding that users create and communicate meaning through their interaction with the system and with each other through the system. The concept of embodiment allows Dourish to combine two trends from the human-computer interaction area; *tangible interaction* where interaction is distributed over the abstract digital world and objects in the physical world [Ishii and Ullmer], and *social computing* where social practice and the construction of meaning through social interaction is core in design [e g Bannon].

Designing for embodied affective interaction thus entails both looking for the physical artifact embodiment of abstract emotion concepts, as well as allowing for social practice and interpretation of meaning of the emotional expressions. The physical embodiment concurs nicely with the strong connection between body and emotion, as discussed above.

2.2 Natural but designed expressions

To get users physically involved, one approach is to build the interaction upon our previous physical and cognitive experiences of emotional processes. This approach can be applied to the design of the whole interaction, including both input and as well as output channels and the connection of the two in the application.

Human-computer interaction and human-computer-human interaction are not and should perhaps not be the same as human-human interaction. An application is a *designed artifact* and can therefore not build solely upon (whatever is meant by) "natural" emotional expressions. On the other hand, using mainly designed expressions bearing no relation whatsoever to the emotional experiences people have physically and cognitively in their everyday lives, would make it hard for the user to recognize and get affected by the expressions. Therefore we argue that emotional expressions should be aiming to be *natural but designed expressions*.

The specific focus of this paper is how to design for affective gestures. When studying the research done on gestures in computer interaction in general there are two main strands that exemplify the conflict: *designed gestures* [e g Long et al., Nishino et al.] and *natural gestures* [Cassell, Hummels and Stappers]. Designed gestures can, for example, be resembled to sign language. The gestures make up a language and depending upon the complexity of the language, it may take quite some effort to learn. Natural gestures, on the other hand, aim to be easier to learn as they build upon how people tend to express themselves in various situations. Body language, posture and more conscious gestures, however, vary between individuals, cultures and situation. Thus, designers of gesture interaction often aim for designed gestures based on natural behavior, looking for the underlying dimensions giving rise to the specific movements.

2.3 Affective loop

The aim of the affective loop idea, is to couple the affective channels of users closely to those of interactive applications, so that the user's emotions are influenced by those emotions expressed by or through the application, and vice versa. Through designing for physical expressions of the end-user (e g body posture, gestures, tangible input through toys, speech) that makes sense with regards to the design of the overall interaction or narrative or the system they interact with, we try to make users involved both physically and cognitively. By having users express their emotions in interacting with the system, they can be engaged in an affective loop, where their emotions are either affected or increased in intensity, either by the modality by which the emotions are submitted or as a response to output.

An example of a system that inspired and explored the affective loop idea is SenToy [Paiva et al.]. SenToy is a doll, which is used as an input device to a game. The end user interacts by acting out various emotions through movements with the doll. For example, to express anger, the user needs to shake the doll back and forth. The idea was that these body movements, together with the resulting activities appearing in the game progression would also influence users emotionally, both their body and mind.

The other part of the affective loop, the emotional output, concerns how the system in turn expresses its response to the user input. Some modalities, such as color and shape [Itten], movement, and music stand a better chance to address our physical experience. For example, according to Ryberg [Ryberg] humans have the same first instinctive reaction to colors. In movies music is used to put us in different emotional states [Bordwell and Thompson]. Bresin and colleagues [Bresin and Friberg] have produced a system, which given a piece of music can replay it to express different emotions.

2.4 Ambiguity

Most designers would probably see ambiguity as a dilemma for design. Gaver, however, looks upon it as "a resource for design that can be used to encourage close personal engagement" [Gaver et al.]. He argues that in an ambiguous situation people are forced to get involved and decide upon their own interpretation of what is happening. As affective interaction oftentimes is an invented, on-going process inside ourselves or between partners and close friends, taking on different shades and expressions in each relationship we have with others, ambiguity of the designed expressions will allow for interpretation that is personal to our needs. For example, if a system was to have buttons where each was labeled with a concrete emotion, users might feel extremely limited since they would not be able to convey the subtleties of their emotional communication to others.

Ambiguity may also follow from the ideas of embodiment, that sees meaning as arising from social practice and use of systems – not from what designers intended originally. An open-ended ambiguous design might allow for interpretation and for taking expressions into use based on individual and collective interpretations – both by sender and receiver of affective messages. Ambiguity in a system will perhaps also create a certain amount of mystery that will keep users interested. However, there needs to be a balance, since too much ambiguity might make it hard to understand the interaction and might make users frustrated [Höök et al.].

3   A model of affective gestures

While any service that attempts to instantiate the design ideas outlined above should be concerned with the whole interaction and not only one part of it, this paper will be focused mainly on the affective input side. As discussed above, we wanted to involve users physically with the application and our idea from the SenToy-work was that natural but designed gestures for affective expressions could be an interesting design alternative.

In order to find affective gestures that can express emotion, we turned to the work by Laban and his colleagues [Davies]. Laban was a famous dance choreographer, movement analyzer and inventor of a language for describing the *shape* and *effort*[3] of different movements. His work will not lend itself to turning emotional expressions into a table with one-to-one mappings of movements to emotions – but his theories of movement can be used to understand the underlying dimensions of affective body behaviors.

To map emotional body behavior to Laban's dimensions of movements, we invited Erik Mattsson[4], an actor, who works with counseling and education in human communication. We asked the actor to express nine different emotional processes in body language, while we videotaped him. In a questionnaire distributed to 80 SMS-users in Sweden we found the emotions they mostly wanted to communicate in mobile messages: *excitement, anger, surprise-afraid, sulkiness, surprise-interested, pride, satisfaction, sadness* and *being in love*.

Before we turn to the analysis of the movements, we need to introduce Laban's formalism for describing movements and

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[3] Laban's theory oftentimes referred to as LMA (Laban's Movement Analysis) is composed of five major components: body, space, effort, shape and relationship. The focus in our analysis is on effort and shape as these best describe the emotion expression contained in gestures.
[4] http://www.ordrum.com/erik.html

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theories about shape and effort, at least at a shallow level, in order to understand the analysis of the actor's expressions.

3.1 Shape and Effort according to Laban

Shape describes the changing forms that the body makes in space, while *effort* involve the "dynamic" qualities of the movement and the inner attitude towards use of energy [Zhao].

Motion factor	Dimensions	Examples
Space attention to the surroundings	**Indirect (flexible)**: spiraling, deviating, flexible, wandering, multiple focus	Waving away bugs, surveying a crowd of people, scanning a room for misplaced keys
	Direct: straight, undeviating, channeled, single focus	Threading a needle, pointing to a particular spot, describing the exact outline of an object
Weight attitude to the movement impact	**Light**: buoyant, weightless, easily overcoming gravity, marked by decreasing pressure	Dabbing paint on a canvas, pulling out a splinter, describing the movement of a feather
	Strong: powerful, forceful, vigorous, having an impact, increasing pressure into the movement	Punching, pushing a heavy object, wringing a towel, expressing a firmly held opinion
Time lack or sense of urgency	**Sustained**: leisurely, lingering, indulging in time	Stretching to yawn, striking a pet
	Sudden (quick): hurried, urgent, quick, fleeting	Swatting a fly, lunging to catch a ball, grabbing a child form the path of danger, making a snap move
Flow amount of control and bodily tension	**Free (fluent)**: uncontrolled, abandoned, unable to stop in the course of the movement	Waving wildly, shaking off water, flinging a rock into a pond
	Bound: controlled, restrained, rigid	Moving in slow motion, tai chi, fighting back tears, carrying a cup of hot tea

Table 1: The dimensions of effort according to Laban as described by Zhao [Zhao].

Shape can be described in terms of movement in three different planes: the *table plane* (horizontal), the *door plane* (vertical) and the *wheel plane*, which describes sagittal movements. Horizontal moments can be somewhere in-between spreading and enclosing, vertical movements are presented on a scale from rising to descending, and sagittal movements go between advancing and retiring (Figure 1).

Effort comprises four motions factors: space, weight, time and flow. Each motion factor is a continuum between two extremes (Table 1).
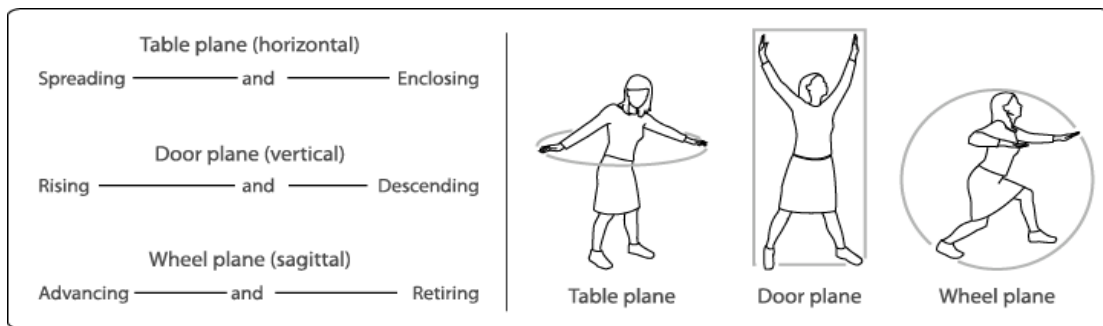
Figure 1: The three different planes of shape, adapted from Davies [Davies].
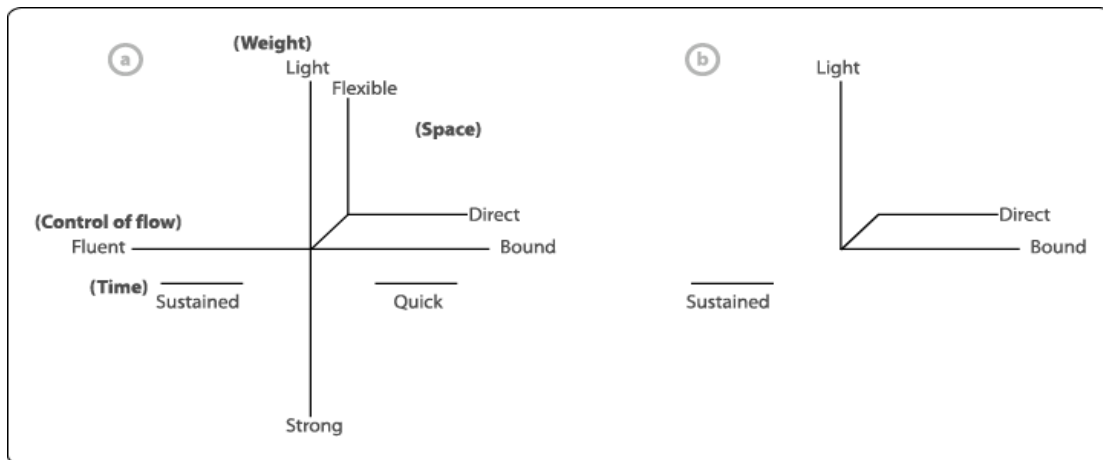

Figure 2: (a) Laban's effort graph, (b) an example effort graph of inserting a light bulb. [Laban and Lawrence]

In figure 2a we depict the graphs Laban uses to express effort. As an example, figure 2b presents an effort graph of the movement of inserting a light bulb where the movement is direct in space, light in weight, sustained in time and bound in control.

3.2 Analysis of emotional expressions in body movements

All of the emotions that the actor was asked to perform may of course give rise to a whole range of different body movements depending on the setting, the background and previous experience of the person, personality, culture and various other factors. This act is only one way that these emotions can be expressed.

Even though, the actor was asked to perform nine distinct emotions, his act was more like a process working on the concept of each given emotion, going from starting the expression to "feeling" it more and more, expressing it stronger, and then varying it using various alternative interpretations of when this emotion would arise. In figure 3, an example of the actor's expression of each emotion is depicted. The analysis, however, was performed on the whole sequence of expressions for each given emotion. Two independent persons (two of the authors) did the same analysis of the videotape, after which notes were compared and discussed.

3.2.1 Shape and effort

Using Laban's theories of shape the actor's interpretation can be described as follow:

- Excitement – extremely spreading, rising and advancing movements.

- Anger – somewhat spreading, rising and advancing movements.
- Surprise-afraid – enclosing, somewhat descending and retiring movements.
- Sulkiness – enclosing, somewhat rising and retiring movements.
- Surprise-interested – somewhat spreading, neutral in the vertical plane and advancing movements.
- Pride – somewhat spreading, rising and somewhat advancing movements.
- Satisfaction – neutral in all planes of movements.
- Sadness – enclosing, descending and retiring movements.
- Being in love – somewhat spreading, somewhat rising and somewhat advancing movements.

Figure 4 presents the corresponding effort graphs using Laban's notation.

From looking at our analysis of emotional body language the nine emotions, presented in figure 4, can be divided into three groups with different effort levels, starting with the one with highest effort:

1) Excitement, anger, surprised-afraid
2) Sulkiness, surprised-interested, pride, satisfaction
3) Sadness, being in love

This far we had worked with two variables, shape and effort, but the different emotions are still clustered, for example excitement and anger have nearly the same shape descriptions and exactly the same effort graphs (Figure 4). Therefore, we looked for a third variable, which we found in Russell's "circumplex model of affect" [Russell].
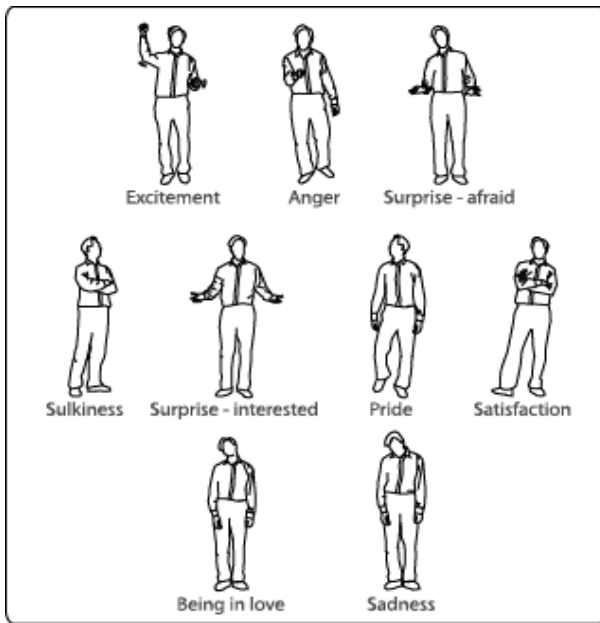
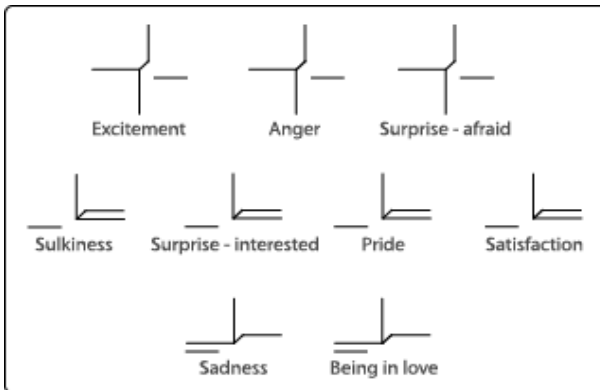**Figure 3:** Emotional body language expressed by the actor.

Figure 4: Emotional body language expressed in effort graphs.

3.2.2 Valence

In the "circumplex model of affect" psychologist Russell looks at emotions in terms of *pleasure* and *displeasure* (here named *valence*) and *arousal*. Since a high degree of effort brings a high degree of arousal and vice versa Russell's analysis of emotions concurs nicely with Laban's theories of movements. Thus, *valence* is our third variable. In a series of studies Russell established that people have the same mental map of how emotions are distributed in a system of coordinates where the y-axis is the degree of arousal and the x-axis is the valence (Figure 5). The subjects, for example, placed angry and delighted on the same arousal level but with different valence.

3.3 Designing emotional expressions with a basis in shape, effort and valence

To conclude the above analysis it is necessary to set up a combination of shape, effort and valence to create an affective interaction were it is possible to express all kinds of emotional states without resorting to a one-to-one mapping. It is not necessary, however, to incorporate all dimensions: shape, effort and valence, into a new modality. It can likewise be a combination of the modality and emotional expressions in the interface. We will show an example of the latter in the next section.
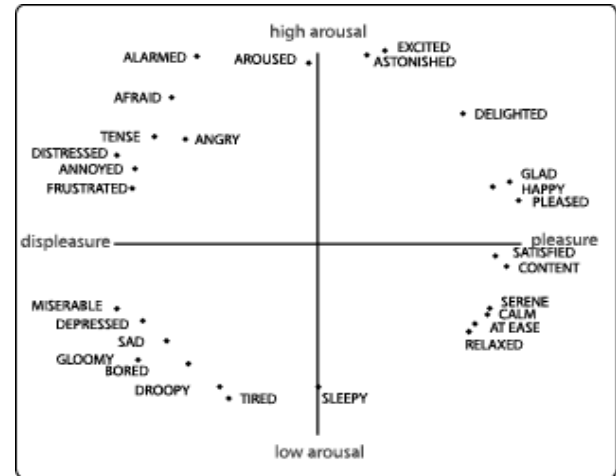

Figure 5: Russell's "circumplex model of affect" [Russell].

4 A mobile service for affective messaging

The goal of the affective message service is to provide users with a means to enhance their messages with emotional expressions. With today's technology, such as MMS, users can add photos, colors, sound or animations to messages, but it is quite time-consuming, difficult to create on the fly and to get the right expression of such a messages. Instead, our idea is to build an interactive service on top of the MMS-technology that expands on the expressive power while still allowing for ambiguity and open interpretation of the affective content.

In the questionnaire (mentioned briefly above) the answers indicated that most users feel limited or alien to expressions such as smilies as a means to express emotions in text messages. Not only is the emotional content restricted but also the emotional interaction with the other party. In a phone conversation, the voice itself can be a bearer of emotional content that complements what is being said. Thus, both parties in the conversation receive too little emotional feedback and are provided with too little emotional expressive power when composing or receiving text-messages. The users in our questionnaire expressed a need for a richer medium.

Below follows a description of the mobile service and thereafter we will explain how shape, effort, valence and the four design principles are incorporated.

Our design example is an emotional text messaging service built on top of a SonyEricsson P800 mobile terminal, where the user can write a text message and then adjust it to fit the emotional expression they want to achieve. The adjustments are mainly done through affective gestures, but with a little mystery added through obscuring the input through mixing it with measurements of the users' pulse. The affective gestures performed with the stylus used with the P800 terminal, together with the pulse will render an animated background with an emotional expression to the user's text message. Figure 6 shows a usage scenario.
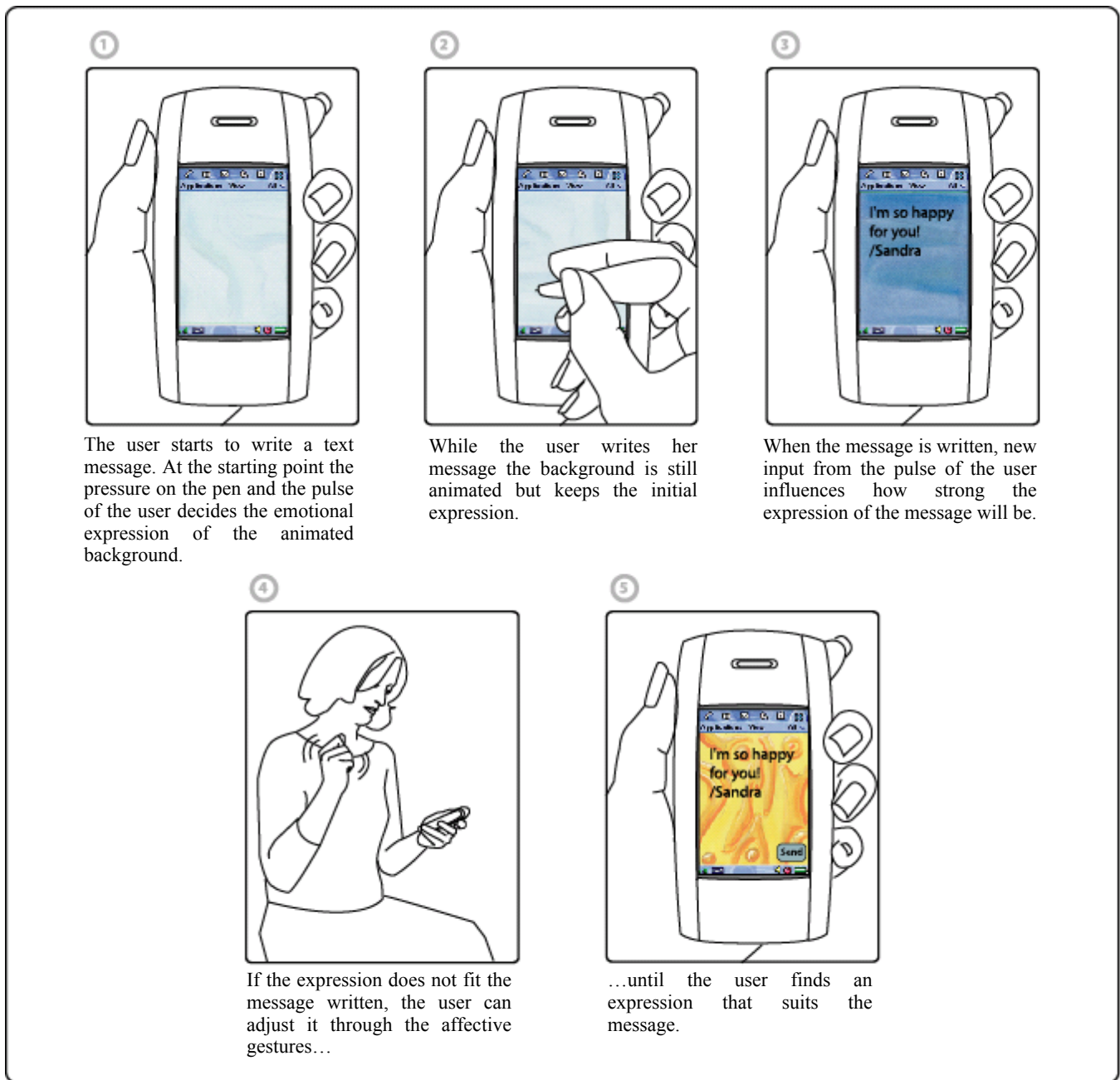
The user starts to write a text message. At the starting point the pressure on the pen and the pulse of the user decides the emotional expression of the animated background.	While the user writes her message the background is still animated but keeps the initial expression.	When the message is written, new input from the pulse of the user influences how strong the expression of the message will be.

If the expression does not fit the message written, the user can adjust it through the affective gestures…	…until the user finds an expression that suits the message.

Figure 6. A usage scenario

4.1 Shape, effort and valence in the interaction

We use Russell's "circumplex model of affect" (Figure 5), as the basis for the interaction. The user will be moving around in the circular space of emotions expressing effort and valence of their emotional state through combinations of two basic movements that when combined can render an infinite amount of gestures. We call these combinations of the two movements the *circumplex affective gestures* (Figure 7):

- Moving along the valence scale towards displeasure is done through increasing the pressure on the stylus, decreasing the pressure on the pen results in higher pleasure on the valence scale.

- Shaking and making faster movements, with the hand holding the pen, requires more effort and therefore result in higher arousal, while more swinging, not so direct movements result in lower arousal.

The circumplex affective gestures are inspired by the shape, effort and valence analysis. Emotions with negative valence are associated with strain and tension, while positive emotions often involve less pressure and strain. Emotions with high effort are stronger in weight, more flexible in space and quicker in time, while emotions with less effort are less controlled, lighter and smaller in space. While the user is performing the circumplex affective gestures, the system is responding through showing the emotional expressions in color, shape and animations as indicated in figure 8. The emotional expression works like an animation in
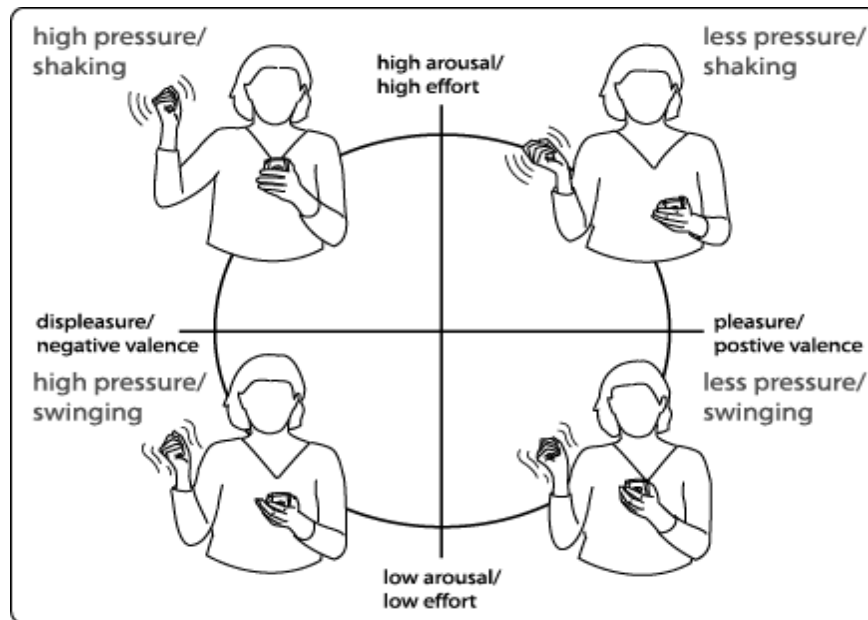
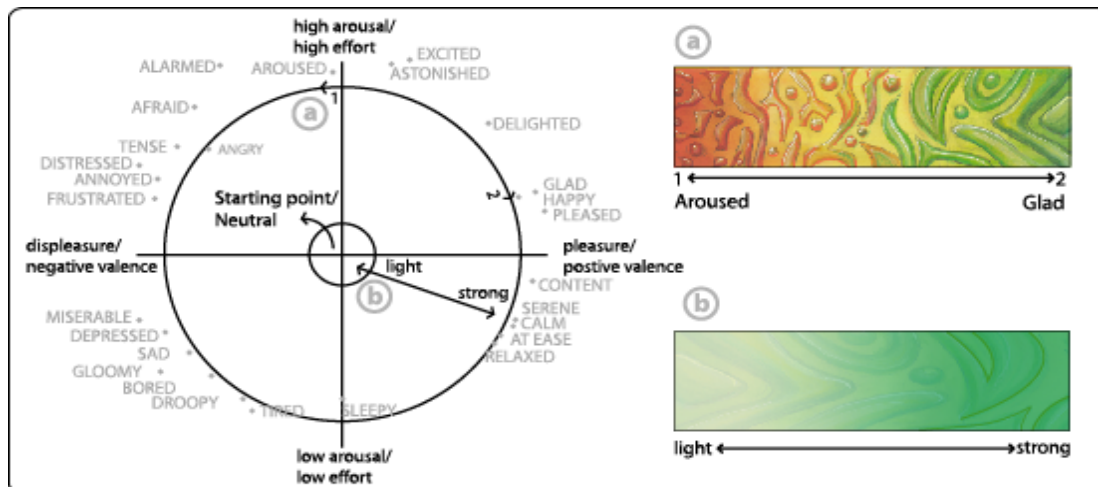**Figure 7:** The circumplex affective gestures.

Figure 8: The affective gestural plane, a. showing how the output is expressed when interacting and b. showing how the pulse decides the width of this plane, presented in light to strong colors.

the background of the message, giving the writer immediate feedback on the appearance of the message (Figure 8a). The user activates this input by holding in a button on the pen. Once the user finds the expression she wants, the button on the pen is released and the expression is thereby chosen.

The animations allows the different emotions to float into each other similar to how Russell argues that emotions blend into one another and do not have any defined borders. Still, the characteristics of each emotion found in the analysis of body movements are clearly represented through the choice of colors, shapes and movements. Most of the emotions, or their position in Russell's circular model, can be expressed through colors. Red represents, according to Ryberg, the most powerful and strong emotions. Moving along a color scale ending with blue would be moving towards calm and peaceful emotions. The strength of an emotional state could then be expressed in terms of deepening the color. In this example we are not working with the actual text in the message, neither with sound, but it is something that can be added in future work. Much can be done with different typefaces,

sizes and animations of text, [Forlizzi et al.], sound and music can also convey emotional content [Bresin och Friberg].

As an example, the characteristics of the emotion *excited* entail much energy, it is high in effort, and the movements are extremely spreading, rising and advancing. This can be used to create an animation and coloring as in figure 9 (where the animation cannot be shown in this paper).

The circumplex affective gestures would probably render a predictable and thereby less interesting interaction. We therefore decided to add the pulse sensor, which is integrated in the pen, measuring the user's pulse while writing.

The model combining pulse with the pressure on the pen, as shown in the usage scenario, decides where in the circular space of emotions the user initially starts:

- If your pulse is high and you are holding the pen firmly, you will start where there is high effort and negative valence
- With high pulse and a lighter grip around the pen you will end up where there is high effort and positive valence

- Low pulse and a firm grip will put you where there is low effort and negative valence
- Low pulse and a lighter grip will put you where there is low effort and positive valence

Figure 9: How "excited" is expressed in the message

The user always starts the message with a light emotional expression. When the user has finished writing her text, the pulse decides the width of the circular space of emotions, which is presented as the strength of the emotional expression – varying from light to strong (Figure 8b). This combination of circumplex affective gestures and the pulse sensor we named the *affective gestural plane model*. The intention is to achieve a kaleidoscopic effect, so that e g "sad" always has the characteristics of sadness but never takes on exactly the same expression. This will hopefully maintain the user's interest.

If the pulse signal were the only way for the user to provide input to the system, the user would not be in control of the interaction at all, which in turn would be both frustrating and probably render erratic interpretation of users' affective states most of the time. But since the circumplex affective gestures allows the user to move around the circle of the affective gestural plane, the user is still allowed most of the control.

4.1.1 The interaction device

Designing for emotional input requires a coherency between the actual product's physical design and the task performed. In this case, the stylus has to be designed in such a way that it appeals to our emotional sensing. You are probably more likely to hug and pat, for example, a teddy bear than a laptop.
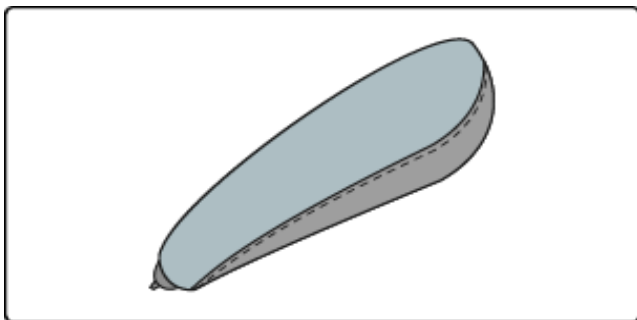

Figure 10: A design example of the interaction device.

On the other hand, it is also important that the interaction device does not take on any personality or emotional state in itself. It must not look like some character or carry a specific expression [Andersson et al.], but instead be bland enough to carry users' intentions. Making a pen that is quite characterless, but still emotionally appealing will provide a suitable artifact for affective computing but still keep the user focused on the interaction. Figure 10 shows a design example.

4.2 Incorporation of design principles

The design principles introduced above, all played an important role in the design of the affective message service. *Embodiment* is realized both in terms of the actual physical interaction with the extended stylus, as well as through how the user will experience the circumplex affective gestures as such. The two taken together, embody and aid users to externalize the internal emotional states they want to convey.

The principle of *Natural but designed expressions* is incorporated through the circumplex affective gestures and the interactive feedback that are designed to resemble the shape, effort and valence of natural emotional movements.

Since the design is trying to address both body and mind the emotional state of the user is reinforced not only through the gestures, but also through the response that the system generates, and therefore the interaction will involve the user in an *affective loop*. While not discussed in this paper, the interaction with the receiver of the affective message will also constitute another affective loop interaction.

Ambiguity is achieved in the affective gestural plane model as well as in the interactive feedback. The pulse sensor creates a small proportion of mystery in the interaction, thus keeps the user interested in exploring their emotional expressions further. By using circumplex affective gestures to navigate the affective gestural plane, we avoided that one gesture corresponds to one emotion, and instead created an interaction where users can create their own language and make their own interpretations of the interactive feedback.

5   Summary

We have shown how to go from a user-centered perspective, involving both body and mind, via theory of movements and emotional expressions, a study of an actor and his emotional expressions, to a specific design of a set of *circumplex affective gestures* for expressing emotion to a mobile messaging service.

We are aware of that this work is somewhat cultural dependent, however, we find this piece of work valid and interesting as input even if not entirely possible to generalize irrespective of culture and personality.

In particular, we have identified three underlying dimensions of bodily emotional expressions: *shape*, *effort* and *valence* that we have incorporated in the design of our mobile service both in the *affective gestural plane model* as well as in the interactive feedback. This frees us from design solutions that assume that users will be in discrete, well-defined emotional states, where one gesture (or input signal) corresponds to one emotion. Instead our specific design approach allows for an interpretative, interactive cycle with the emotional output that will place users, and their interpretation of emotional expressions and needs for how to express themselves, at core. This diverts from the existing trends in affective computing, where the focus is not on the emotional *experience* as such but on recognizing and adjusting to what the system believes that the user is feeling.

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PAPER B

Fagerberg, P., Ståhl, A., Höök., K.
eMoto – Emotionally Engaging Interaction
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DESIGN SKETCH

Petra Fagerberg · Anna Ståhl · Kristina Höök

eMoto: emotionally engaging interaction

Through the *eMoto* design, we intend to emotionally engage users both cognitively and physically using a tangible interface, allowing for affective gestures that are mirrored in the expressions produced by the system. A questionnaire sent to 66 potential users showed a need for richer emotional expressiveness in text messaging in mobile phones than what is available today. Emotions are expressed not only through what is said, but also through body gestures and tone of voice—mediums not available in this context.

eMoto is an emotional text messaging service built on top of a SonyEricsson P900 mobile terminal. The goal of this service is to provide users with means to emotionally enhance their SMS messages. The user first writes the textual content of the message and then adjusts the affective background to fit the emotional expression she wants to achieve. The adjustments are done through affective gestures (Fig. 1) that will render an animated background acting as an emotional expression to the user's text message (Figs. 2, 3, 4, 5 and 6). The P900 terminal is used with a stylus pen. We have equipped this pen with two sensors that will recognize the affective gestures: an accelerometer and a pressure sensor. In a first prototype, the extended stylus is connected to the serial port of a stationary PC, which in turn communicates with the P900 terminal—in the final prototype, this will be a direct wireless communication channel between the stylus and P900 terminal.

In this specific design, our aim is to let users consciously express their emotions. This should not entail a simple one-to-one mapping of emotions to specific expressions. Instead, we build the interaction on the fact that emotions should not be seen as singular, discrete states, but instead as processes that blend into one another. Through creating the interaction model based on

Russell's circumplex model of affect [3] (Fig. 7), we could create a system that allows users to choose emotional expressions that best suit their messages. Without explicitly naming each emotion in the interaction, we maintain open interpretations of emotional expressions. In Russell's model, emotions are seen as a combination of *arousal* and *valence*. By combining two basic movements that together can render an infinite amount of affective gestures (Fig. 8), the user will move around in this circumplex plane. Technically, we have made the plane 100 times larger than the screen of the mobile phone (Fig. 9). This, in combination with the affective gestures, will have the user experience a kaleidoscopic effect when choosing between the vast amounts of emotional expressions. We call this *the affective gestural plane model*. The two basic movements for construction of affective gestures are *natural but designed expressions*, extracted from an analysis of body movements [1]. The arousal of emotions is communicated through movement, where intense shaking of the stylus will increase arousal and a more swinging movement will imply lower arousal (Fig. 8). To navigate to emotions with negative valence, the user has to increase the pressure on the stylus, while less pressure will transfer the user to emotions with positive valence (Fig. 8).

The affective gestures are closely connected to the affective feedback that the user receives as visual output. The characteristics of emotional expressions found in the analysis of body movements are represented through colours, shapes and animations in the design of the affective feedback. Colours are used to express arousal, where red represents emotions with high arousal and blue is calm and peaceful [2]. The shapes of the animated objects in the areas containing high arousal are small and can, therefore, render animations and patterns that are energetic, quick and spreading. Moving around the circle towards less energy and calmer expression, the shapes get bigger and more connected, rendering slower and more billowing animations. Shapes placed on the positive side of the circle are softer and more round, while shapes placed on the negative side are more

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Fig. 1 The tangible interface; interacting through affective gestures using the stylus

Fig. 4 One way of expressing a little excited, through a red/orange background and a few, small, round objects with fast movements in the background

Fig. 2 One way of expressing quite relaxed, through a green/yellow colour and animated objects that are quite big and connected in their shapes

Fig. 5 One way of expressing more excited than in Fig. 4, through a deeper red colour in the background and with even larger and more animated objects

Fig. 3 One way of expressing more relaxed than in Fig. 2, through deeper green colours that are closer to one another and larger animated shapes

Fig. 6 One way of expressing tired/bored through dark blue colours, big, connected shapes and slow animations
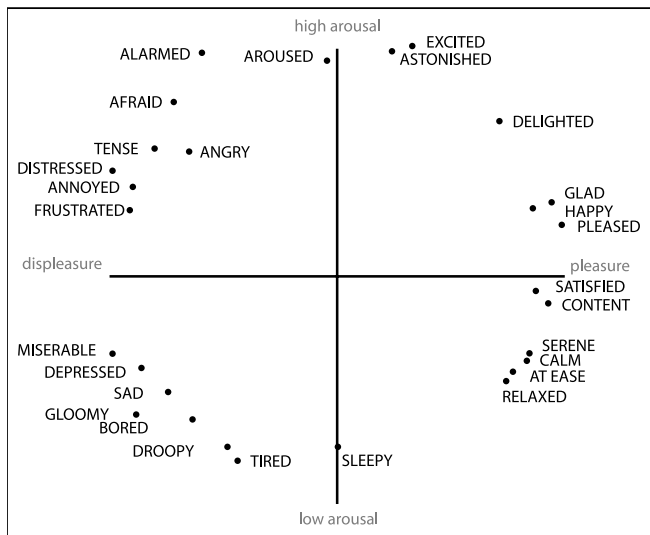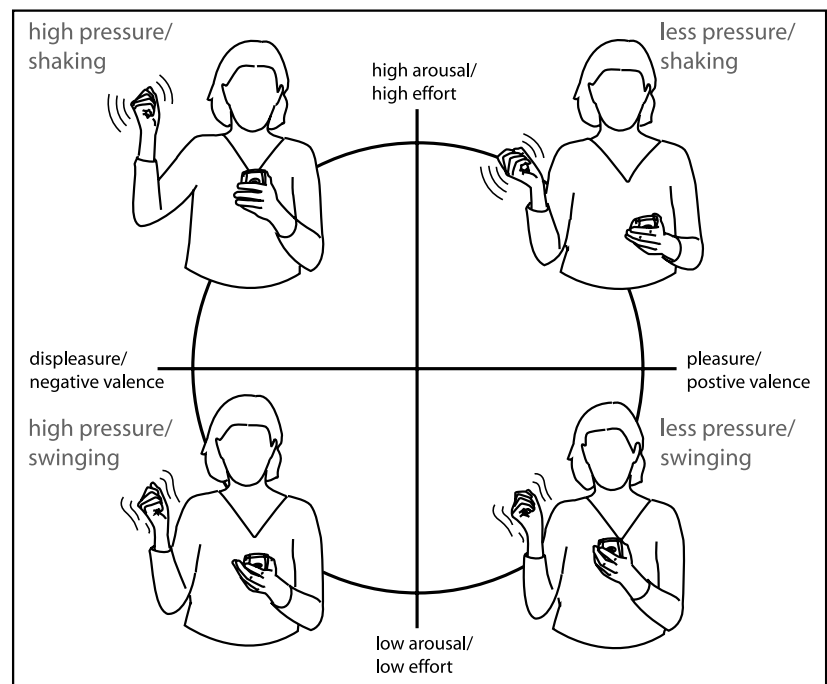
Fig. 7 Russell's circumplex model of affect [3]

Fig. 8 The affective gestural plane model

angular and sharp. The emotional expressions are stronger along the outer border of the circle while weaker towards the middle; this is represented through less depth in colours and fewer animated elements (Fig. 10).

A user study of the affective output has just been completed. A few expressions need to be redesigned, for example, negative emotions with high arousal were rendered in too bright colours and some of the shapes were too depictive and thereby hindered users from reading their own interpretation into them. The big picture, however, showed a great interest in this new way of communicating emotions and that users perceived most expressions as intended.

Fig. 9 The kaleidoscopic effect of the interactive feedback when navigating the affective background circle
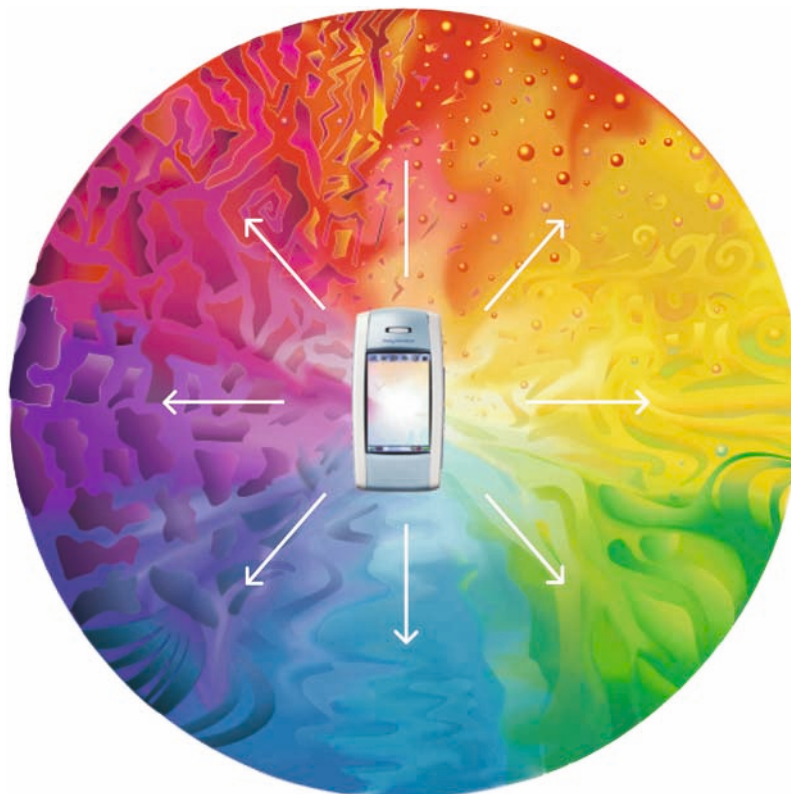
Fig. 10 The affective background circle, showing how the colours, shapes and sizes of objects vary together with Russell's circumplex model of affect
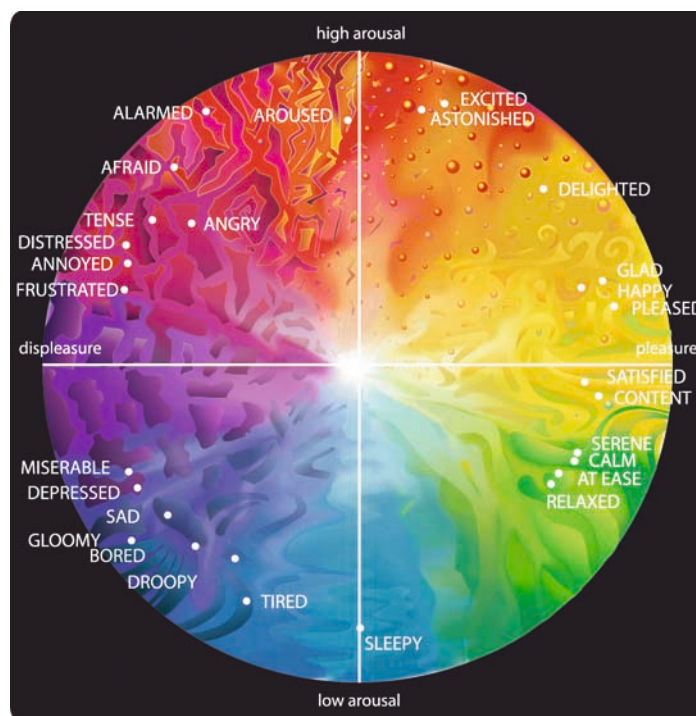
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PAPER C

eMoto – Affectively Involving both Body and Mind

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ABSTRACT

It is known that emotions are experienced by both body and mind. Oftentimes, they are evoked by sub-symbolic stimuli, such as colors, shapes, gestures, or music. We have built eMoto, a mobile service for sending affective messages to others, with the explicit aim of addressing such sensing. Through combining affective gestures for input with affective expressions that make use of colors, shapes and animations for the background of messages, the interaction pulls the user into an embodied 'affective loop'. The design builds on a Laban-analysis of shape and effort together with emotional valence. We present a user study of eMoto where 12 out of 18 subjects got both physically and emotionally involved in the interaction. The study also shows that the designed 'openness' and ambiguity of the expressions, was appreciated and understood by our subjects.

Author Keywords

Affective interaction, gestured based interaction, user-centered design, embodiment, ambiguity

ACM Classification Keywords

H.5.2 [**Information Systems**]: User interfaces – *graphical user interfaces (GUI), interaction styles, screen design, user-centered design.*

INTRODUCTION

Research in psychology and neurology shows that both body and mind are involved when experiencing emotions [3,4]. Emotions influence somatic signals, hormones, heart rate, and body movements, and sometimes emotions become reinforced or even initiated by such bodily signals [5]. Thus, it should be possible to design for stronger affective involvement with artifacts through addressing physical, bodily interaction modalities. Tangible interaction [14], gesture-based interaction [1,12], and interaction through plush toys and other artifacts [16], are all examples of such physical modalities.

The feedback from the system, in turn, may also make use of a range of sub-symbolic expressions addressing our sensual emotional experience. Instead of focusing on expressing emotions through 'labels' of emotions or facial expressions of interactive characters, we can make use of colors, shapes, animations, sounds, or haptics.

Our approach to affective interaction differs somewhat from the goals in affective computing [17]. Instead of inferring information about users' affective state, building computational models of affect and responding accordingly, our approach is user centered. Users should be allowed to consciously express their emotions both cognitively and physically rather than having their emotions interpreted by the system. We want to explore whether we can create a rich, somewhat ambiguous and open-ended design of affective expressions. After all, to quote Sengers et al [20]:

"Rather than experience as something to be poured into passive users, we argue that users actively and individually construct meaningful human experiences around technology."

We have summarized our design aims into what we name an *affective loop*. In an affective loop, users may consciously express an emotion to a system that they may or may not feel at that point in time, but since they convey the emotion through their physical, bodily, behavior, they will get more and more involved. If the system, in turn, responds through appropriate feedback conveyed in sensual modalities, the user might get even more involved. Thus, step by step in the interaction cycle, the user is 'pulled' into an affective loop.

Our aim is to create affective loop applications for communication between people. The process of determining the meaning of a message with some emotional expression is, similar to any human communication, best characterized as a negotiation process. The message is understood from its context, who the sender is, his/her personality, the relationship between sender and receiver, and their mutual previous history.

To better understand whether and how it is possible to create a user-centered affective loop for communication purposes, we have designed, implemented and evaluated a mobile service named *eMoto*. eMoto is a mobile messaging service for sending and receiving affective messages [10].

In here, we present the design and a user study of eMoto as example of an affective loop application. The user study shows that we managed to create an interaction that involves most users emotionally both cognitively and physically. We show how users were able to express themselves through our open-ended emotional expressions in a personal meaningful way.

DESIGNING EMOTO

eMoto extends on both the input and output channels when sending SMS[1] between mobile phones. The aim is to convey more of the emotional content through the very narrow channel that an SMS provides. Emotional communication between people meeting physically in the 'real world' make use of many different channels, such as facial expression, body posture, gestures, or tone of voice. Much of our knowledge of the meaning of these lies in the everyday meetings between us, in the actual physical enactment of expressions – we understand through knowing each other and through acting and feeling ourselves. Emotional communication is a process, not just a matter of sending a signal for others to interpret.

Embodiment of interaction as discussed by Dourish [7] suggests that design of interactive artifacts should be based upon how we act, learn and create knowledge in our everyday life – through social and physical interactions with the world as it unfolds in our daily activities. In eMoto, we wanted to create an embodied representation engaging some of the physicality of our emotional experiences. Inspired by bodily expressions, we have created affective gestures to be used as input to eMoto.

As we aim to make the user emotionally involved in a physical sense, it is also important that the gestures we pick are not singular, iconic or symbolic gestures, but gestures that give rise to a physical experience that harmonizes with what the user is trying to express. An angry gesture should feel angry when performed. It needs to be sustained for a certain period of time, not too long, nor too short, in order to be experienced.

This first step in the interaction with eMoto, using gestures to find an appropriate SMS background, we call the *personal affective loop*. In it we aim to avoid creating a one-to-one mapping between emotion, gesture and expression. Instead, there is a certain level of ambiguity which allows people to express themselves in their own personal way. This is inspired by the work by Gaver et al. [11]. But where Gaver and colleagues define and make use of ambiguity to provoke users, make them reflect on and appropriate technology, our aim is just to create some space for individual interpretation of the expressions.

The second interaction step in eMoto, the *communicative affective loop*, occurs when the message is sent and then

Figure 1: The extended stylus and a P900 running eMoto

subsequently received by someone else. The sender will have used the affective gestures to alter the background of the SMS so that it now has expressive colors, shapes and animations.

Targeted user group

We started by sending a questionnaire to 80 potential users, in our targeted user group: women between 25 and 35. The questions concerned how well they felt that they could express emotions through SMS. The results revealed a need for richer expressions and also a frustration with current means. For example, some indicated that they made use of smilies, but that there were too few smilies that they could be sure that the other party would understand. They also felt that smilies were not really appropriate to their user group but rather to teenagers.

The questionnaire results were used to create a *persona* [2]. A persona is a precise description of a hypothetical person, which in the design process, makes it easier to talk about the targeted user group as one user and steer the design process. The persona set up for the eMoto service is named Sandra. In short she is a confident 29 year old woman who likes to spend time with her friends and family. She works as a trainee at a city planning office in Stockholm. Sandra does not care about how things work technically, but she likes new cool technological features and she is very happy with her new mobile phone that has a camera and MMS[2] functionality.

eMoto

eMoto is built in Personal Java and runs on P800 and P900 mobile phones, two of Sony Ericsson's Symbian phones, see Figure 1. The user first writes an SMS and then finds a suitable affective expression to add to the background of her text message. The user navigates the affective background by using the affective gestures described above. Both the P800 and P900 mobile phones come with a stylus to be used with their touch-sensitive screens. We have extended this stylus with an accelerometer and a pressure sensor to capture the gestures, see Figure 2.

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[1] SMS: Short Message Service, mobile text messaging.

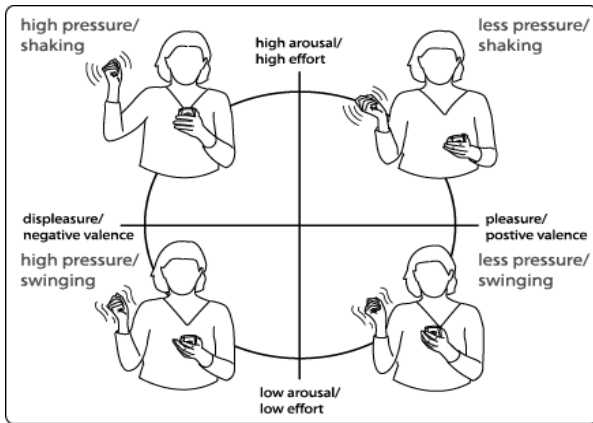[2] MMS: Multi-Media Messaging Service.

Figure 2: The Affective Gestures

Affective gestures

In order to find a set of affective gestures that can express emotion and that harmonize with our inner experience of the emotion, we turned to the work by Laban and his colleagues [6]. Laban was a famous dance choreographer, movement analyzer and inventor of a language for describing the *shape* and *effort*[3] of different movements – Laban-notation. His work does not lend itself to turning emotional expressions into a simple table with one-to-one mappings of movements to emotions – but his theories of movement can be used to understand the underlying dimensions of affective body behaviors.

In Laban-notation, shape is described in terms of movement in three different planes: the table plane (horizontal), the door plane (vertical) and the wheel plane, which describes sagittal movements. Horizontal movement can be somewhere in-between spreading and enclosing, vertical movement are presented on a scale from rising to descending, and sagittal movement go between advancing and retiring.

The second dimension in the Laban formalism is effort, comprised of four motions factors: space, weight, time and flow. Each factor is a continuum between two extremes; direct or flexible for space, light or strong for weight, quick or sustained for time and bound or fluent for flow.

In addition to the dimensions of shape and effort, we looked for an emotion theory specifically focused on how emotions are experienced. According to Scherer [19], *dimensional models* cover the feeling of emotional experience both on a low level (as in the limbic parts of the brain and in the body), and on a higher, cognitive, level. One such dimensional model is Russell's circumplex model of affect where emotions are seen as combinations of arousal and *valence*

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[3] Laban's theory, oftentimes referred to as LMA (Laban's Movement Analysis), is composed of five major components: body, space, effort, shape and relationship. The focus in our analysis is on effort and shape as these best describe the emotion expression contained in gestures.

Quadrant	Gesture	Effort
Upper left	Hard pressure Much shaking	Strong, bound, flexible and sustained
Upper right	Soft pressure Much shaking	Light, fluent, flexible and sustained
Lower left	Hard pressure No shaking	Strong, bound, direct and sustained
Lower right	Soft pressure No shaking	Light, fluent, direct and sustained

Table 1: The 4 extremes of the affective gestures

[18]. Since a high degree of effort brings a high degree of arousal and vice versa Russell's analysis of emotions concurs nicely with Laban's theories of movements. In Russell's circumplex model of affect, emotions are distributed in a system of coordinates where the y-axis is the degree of arousal and the x-axis measures the valence, from negative to positive emotions.

We recorded the body movements and behaviors of an actor expressing nine different emotions, and extracted the shape and effort of each [8]. From the analysis it became apparent that even though negative and positive emotions not always differ in terms of effort, most negative emotions have more tense expressions. Therefore the affective gestures in eMoto are set up as combinations of valence in terms of pressure and effort communicated through movement, see Figure 2.

A description of the extreme gestures in terms of effort according to Laban-notation is presented in Table 1. However, inbetween those extremes there can be a whole range of combinations of movement and pressure.

Affective expressions

Similar to the gestures the affective expressions in the background of the text-SMS builds on the Laban-analysis of the actor's behaviors. The expressions are non-symbolic and designed from what is known about the effects of colors, shapes and animations. For example, colors are often used to express arousal, where red represents emotions with high arousal and blue is calm and peaceful [15].

On top of the colors, we added objects of different shapes and sizes that are animated in different ways. Smaller

Figure 3: The Affective expressions (the animations can be seen on www.sics.se/~petra/animations)

Scenarios	
The racist doorman	You write to tell a friend that you and your other friend could not get into the bar because of a racist doorman.
The perfect job	You write to tell your boyfriend that you got the job you applied for even though there were over a thousand other applicants.
The ex-boyfriend	You write to tell a friend that your boyfriend who you love so much has dumped you.
The hammock	You write to a friend who is at work telling her that you are relaxing in the hammock.

Table 2: Scenarios used in task 4

shapes move quicker and with less control in areas with high arousal. As we move around the circle, see Figure 3, towards less energy and calmer expression, the shapes get bigger and more connected, rendering slower and more billowing animations. Shapes placed on the positive side of the circle are softer and more round, while shapes placed on the negative side are more angular and sharp. The affective expressions are stronger along the outer border of the circle, and weaker towards the middle; this is represented through less depth in colors and fewer animated elements.

The resulting colorful circle is a hundred times larger than the screens of the P800/P900 mobile phones. Thus only a small proportion can be seen at a time. As users can navigate freely around the entire circle and decide to stop anywhere, there is a large amount of expressions to choose from.

Validating the affective expressions

We first did a user study of the colors, shapes and animations before they were combined and evaluated together with the affective gestures. The affective expressions study was performed by subjects in pairs in front of a laptop in a lab environment. Six pairs took part in this user study. In short summary, the subjects chose expressions from the same area of the background circle to express the same emotions. The results confirmed that our aim to let people express themselves differently was possible and viable – without becoming completely random and confusing.

The study showed that some objects were too depictive and that users would start interpreting them in a too literal, symbolic way. For example, one of he shapes looked like a rose, which made users think of romance, but the intent was only to create an angry, angular shape. Second, the subjects asked for darker and more depressed colors in the negative parts of the background circle. This led to redesign of some parts of the circle, and the new version was subsequently used in the next study – described below.

USER STUDY

The user study of eMoto as an affective loop application is a qualitative study capturing whether users get emotionally involved in an affective loop.

Subjects

We recruited the subjects through putting up notes around Kista, a working area outside Stockholm, asking for female subjects between 25 and 35 who were frequent mobile phone and SMS users. 18 women signed up for the user study; six master students, two PhD students, four working with PR and marketing, five software developers and one journalist, $24 < 28,6 < 35$ years old. 12 subjects had mobile phones with MMS functionality and 7 subjects had a camera on their mobile phone. Each was given two movie tickets in reward for the one hour they spent in the study.

Goal

We wanted to see if our subjects got emotionally involved in the personal affective loop and we also wanted feedback on eMoto as a communicative mobile service. We wanted the subjects to experience somewhat of both the sender and receiver role in the communicative affective loop (even if the study was done with one subject at a time).

Procedure and tasks

The study started with a questionnaire to determine their similarity to the Persona discussed above. The questions concerned their mobile phone and computer usage, and their personality. We then discussed what sensors are and how they work in order to make sure all subjects had some intuitions about what sensors can do.

The tasks given to subjects ranged from being very open-ended where the experimenter provided very little information, to more and more realistic scenarios where they were told more of how the system works. Thereby we hoped to see their first intuitive ideas of how to interact so that we could validate our gesture model, before they got too influenced by our implementation choices. The tasks were:

Task 1: Users were asked to perform gestures holding the modified stylus expressing the emotions angry, excited, satisfied and sad. The system did not give any feedback at this point.

Task 2: Users were told that the gestures were supposed to be combinations of pressure on and movements with the stylus. With this new knowledge users were asked if they would like to adjust their gestures from task 1. However, the users were never told exactly how to combine pressure and movement for navigating to various parts of the circle.

Task 3: Subjects were then introduced to the affective background circle. It was displayed in its whole, although in a decreased version, on a laptop. The subjects got some practice time where they could move a square around on this background picture by using the extended stylus.

Task 4: Users were asked to move to and continue to interact with the real prototype running on a P900 mobile phone. They got four scenarios, presented in short summary in Table 2, to which they were asked to find suitable affective expressions.

Emotion	#	Most common gesture	Effort
Angry	6	Repeated hard striking	Strong, bound, flexible and quick
	6	A pressure so hard that it became impossible to hold the arm still	Strong, bound, direct and quick
Excited	12	Wavy movement high up in the air	Medium strong, fluent, flexible and quick
Sad	11	An immobile hanging arm	Light, bound, direct and quick
Satisfied	11	Just holding the stylus gently	Light, bound, direct and quick

Table 3: Most common gestures used by the subjects in task 1. The second column shows how many of the 18 subjects that used that gesture.

Scenario	#	Most common gesture	Effort
The racist doorman	15	Hard shaking	Strong, bound, flexible and sustained
The perfect job	12	Wavy moments high up in the air	Medium strong, fluent, flexible and sustained
The ex-boyfriend	13	Holding it still with a medium hard pressure	Medium strong, bound, direct and sustained
The hammock	8	Lose swinging movements	Light, fluent, direct and sustained
	5	Just holding the stylus gently	Light, bound, direct and sustained

Table 4: Most common gestures used by the subjects in task 4. The second column shows how many of the 18 subjects that used that gesture.

Task 5: Users were asked to look at four messages as depicted in Figure 7 below and discuss what the sender may have wanted to convey.

Finally, subjects filled in a questionnaire about their general impression of eMoto as a mobile communication service.

RESULTS

The results are structured into three parts. First we discuss the success of the emotional gestures as such. Second, we present the results that have to do with the *personal affective loop*, that is the subjects' emotional involvement when combining the gestures with the affective expressions. It is however, a difficult task to measure this emotional involvement. We have used the Laban formalism and the subjects own responses from the final questionnaire, but also our interpretation of their facial and bodily involvement has contributed to answer this question. Finally, we present the results concerning the *communicative affective loop*, the communication between sender and receiver.

Affective gestures

If we compare the Laban-characteristics of the movements implemented in eMoto (see Table 1 above) the gestures have nearly the same Laban-characteristics as most subjects 'naturally' came up with when asked to improvise in task 1, see Table 3. Thus, our initial Laban-analysis seems to have led us in the right direction and the interpretation of gestures vis-à-vis the actual artifact (the extended stylus) was able to carry the same kinds of behavior.

For task 4, all subjects interpreted the scenarios, 'the racist doorman', 'the perfect job', 'the ex boyfriend' and 'the hammock', as emotions very similar to respectively angry, happy, sad and content. Users got more emotionally involved with this task, probably because they were imagining actually being in that scenario. Thus, in one sense, those gestures might be considered to be even more 'natural' than the gestures from task 1. On the other hand, for this task,

they had to adjust their gestures to our design in order to navigate in the circle; otherwise they would not arrive at the expression that they wanted. Our Laban-analysis of the gestures used in task 4 is presented in Table 4.

The difference between the gestures, as described in Table 3 and 4, is that all gestures in the latter are 'sustained'. That is, subjects had to keep on doing the same gesture over and over in order to get the system to continue to move in the circle towards the expression they wanted. As discussed in the introduction, if users have to keep on doing a gesture for too long, we risk loosing their emotional involvement. On the other hand, the gesture must not be too fast, especially not for emotions with less arousal, such as sadness. Thus, our timing needs to be slightly altered to better capture different emotional experiences. Some users even said they wanted another expression than what they picked but found it too hard to continue gesturing to get there:

"Perhaps it should have been more orange up there (pointing to the top of the expression she had chosen), but it was too exhausting for me to continue"[4]

If we compare our intended design (in Table 1) with the gestures done for the different scenarios (in Table 4) we also note that the pressure level is too high for sad and too low for extremely happy. This could easily be adjusted through rotating the axes for the gestures relative to the axes for the affective expressions in the circle slightly forward clockwise. Moreover, the prototype required an initial pressure to get the sensors started and this pressure was set too high.

Figure 4 shows that the users not only got emotionally engaged with the gestures, but also that their whole appearance changed, in particular their facial expression. The first picture shows a subject engaged with 'the racist doorman'

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[4] All citations are translated from Swedish by the authors.

Figure 4: Subjects interacting with the 4 scenarious; 'the racist doorman', 'the perfect job', 'the ex-boyfriend', and 'the hammock'

scenario. She not only had a stern facial expression and bit her teeth together really hard, but she also uttered:

"Now I'm really pissed and it's night time and we were gonna have fun together and..."

The second picture shows a subject engaged with 'the perfect job' scenario. This subject waved her hand in the air and smiled. In the third picture a subject engaged in 'the ex boyfriend' scenario expressed depression both in her face and in how she just hang her arm down with a very loose grip on the stylus. Finally, in the last picture the subject was neutral and she just held the stylus in her hand for 'the hammock' scenario.

The prototype did not have any sensors for registering how high up in the air or how low down in their lap the subjects were holding the stylus. Still 14 subjects held the stylus high up in the air for excited emotions and 9 subjects held the stylus lower, often in their lap, for sadness (which can be seen in Figure 4). One subject commented on this:

"Up high for emotions that goes up and low down for emotions that go down. Angry is more straight."

Affective gestures and expressions

After each scenario subjects were asked if they thought the gestures they had done and the expressions they had chosen suited the emotion they interpreted from the scenario. The results presented in Table 5 show that most users during all scenarios were satisfied with the affective expressions. Concerning the gestures, it seems as if we were most successful with the gestures used for 'the racist doorman' and 'the ex boyfriend' scenarios. Those gestures were experi-

enced as very suitable for the emotions angry and sad. Even though the gestures for 'the perfect job' and 'the hammock' scenarios were not as successful they were still experienced as suitable by more than half of the subjects.

The personal affective loop

The aim of the personal affective loop is to make subjects emotionally involved when expressing themselves and choosing affective expressions. It was obvious that most of the subjects got more relaxed and found the study more enjoyable when they got to do the gestures in a context such as together with the background circle or in the scenarios. Figure 5 shows a girl who had the following interaction in task 3:

"But now it moves, now I feel... Yes, it's rolling and it goes... Ok, if I'm really happy and, Ohhhhh, Ohhhhh... Where do I go then? How shall I get up? Here I have to press more to get up. This will be fun for you to look at. Where do I go now? Here, ehhhrrrrm ehhhrrrm, come on! How do I get to? If I shake a bottle of champange or something. Ok, then I get there. ..."

When this subject came to the scenario-task she got very involved. She sang and leant back with her arms behind her head when she was acting out 'the hammock' scenario.

A group of subjects (6 subjects) on the other hand, got more confused when they got to task 3 where the affective expressions were introduced. These subjects found the task of moving the square in the circle through the stylus interaction to be very hard. Most of them got more involved once the scenarios were introduced in task 4. At that point even the six subjects who earlier had experienced interaction problems forgot about them – at least for the duration of one scenario.

Scenario	Gesture suited the emotion	Expression suited the emotion	Both suited the emotion
The racist doorman	13	15	10
The perfect job	10	14	7
The ex-boyfriend	14	12	10
The ham-mock	9	15	7

Table 5: The 18 subjects' own thoughts of their interaction in task 4

Figure 5: A subject physically involved during task 3

Figure 6: Affective expressions the users picked in task 4 for the 4 scenarious; 'the racist doorman', 'the perfect job', 'the ex-boyfriend', and 'the hammock'

Based on our subjects differing behaviors in the scenario-task, we divided them into four categories for each scenario:

The successful subjects whose initial gestures were truly emotional and who also found expressions they wanted.

The frustrated subjects are the subjects who performed truly emotional gestures but became frustrated when those gestures did not take them to the affective expression they wanted. These subjects then gave up and did not attempt any alternative gesture.

The focused subjects are the subjects that focused mainly on finding the right expression and who did not really get very involved with the gestures that took them there.

The less engaged subjects only did what they were told to do and they stopped when they thought they had pretended to try long enough.

The results of the video analysis are shown in Table 6. This video analysis was our interpretation of the subjects' usage, their facial expression and their general appearance. All of the successful interactions were done by the same group of subjects that previously had happily played with and not felt confused during their interaction with the affective expressions displayed on a laptop in task 3. These subjects got emotionally involved both physically and verbally during the successful interactions. So did the subjects regarded as frustrated, and the subjects who were concentrated It was only the subjects under the label less engaged who still

Scenario	Succes-sful	Frus-trated	Focused	Less engaged
The racist doorman	3	3	6	6
The perfect job	4	2	9	1
The ex-boyfriend	3	2	9	2
The ham-mock	4	1	11	0

Table 6: The result of the video analysis of the 18 subjects' interaction in task 4

were bored and quickly wanted to give their answers and quit, see Table 6. Two subjects, although not the same two subjects throughout all scenarios, wanted to keep the initial expression in the middle of the circle where eMoto starts during the three last scenarios. These subjects are not included in Table 6.

In the final questionnaire the first question was about using gestures to express emotions. When comparing the answers to this question with the results from the video analysis it became even more apparent that there were two groups of users. 12 subjects felt relaxed when using their body language:

"Cool! It really feels like I'm communicating the emotions I've got without being aware of them."

"I think that's really good, especially if you have had a hard time to express yourself in words. It can also be a fun complement to other ways of expressing yourself."

"A superb idea since one is so used to gestures when talking to people."

Six subjects were very uncomfortable in doing so:

"Hard! Partly because you have so different strength and partly because it's basically hard."

"I think it would be easier to gesticulate in front of a camera and do small movements. That would feel better in an environment with a lot of people."

The communicative affective loop

In the communicative affective loop users are thinking of and getting involved with the fact that their message is sent to/from someone. Figure 6 shows which expressions subjects said they were satisfied with for the different scenarios in task 4. A minority of subjects[5] did not get to where they wanted or did not find an expression they found suitable and are therefore not represented in Figure 6. Either these subjects stopped because the pressure or the repetition of gestures needed prevented them from reaching an expres-

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[5] Three subjects for 'the racist doorman' scenario, four for 'the perfect job' scenario, eight for 'the ex boyfriend' scenario and three for 'the hammock' scenario.

Figure 7: The messages used for interpretation in task 5

sion they wanted or they did not think that any part of the circle would be suitable for the emotion they wanted to communicate. Still, from Figure 6 it is apparent that subjects picked expressions from approximately the same areas of the circle.

In the final task, task 5, subjects were given four messages that already had an affective expression. For all four messages the text is the same but there are different backgrounds in each, see Figure 7. The four backgrounds were chosen to be extreme expressions: the first, leftmost, represents minimal arousal and neutral valence, the second, represents negative valance and medium arousal, the third represents positive valence and medium arousal, and the fourth represents maximum arousal and negative valence. The subjects were asked to interpret the emotional content of each message and also elaborate on what could be the reason for constructing such a message. All subjects interpreted the first message as sad. 14 said that the second message communicated anger while 4 said it was more positive than the first message. 15 subjects marked the third message as happy while 3 said it communicated love. The last message was more confusing; 8 subjects marked it as love, 5 with hate while four said it was a mixture of love and hate. One subject said it was stormy but positive. As an example of the complexity one subject said the following about the last message:

"It depends on who of my friends that have picked this color. Some would think it was 'We've had phone sex and everything is fantastic' while some would say it was 'He's gonna dump me to-morrow'"

A few subjects, like the subject above, indicated the aspect of personality that we had whished to design for: that the messages can have different meaning depending on who the sender is. Another subject expressed it as follows:

"It would be easier to interpret them if I knew who sent them to me."

The citations together with the fact that so many subjects interpreted the message in a similar way indicate that we had managed to design for personal but not completely random expressions.

eMoto as a mobile service

Even though the user study was set up in a lab environment several subjects touched upon eMoto's capabilities of being a mobile service in a public environment. Mainly they questioned the gestures set up for positive and extremely energetic emotions that are so visible that it would be hard to hide from others in public settings.

"These gestures are a bit too much. One often does this in the underground or something."

"If this is one of these things for writing SMS, with a thing that you're supposed to hold in your hand, and then you're supposed to write an SMS and express an emotion, then you wouldn't shake your hand in the air if you were in public. That is the problem with being happy."

However, the subjects also saw that the gestures had to be in a certain way to be emotionally engaging:

"Then you just want to jump and squeeze it really hard"

Despite their worry about the potentially privacy-intrusiveness, ten subjects stated in the final questionnaire that they were positive to using gestures in a mobile setting:

"More expressive than just words!"

"I use smilies today so this would be like the next step."

Six subjects were a bit hesitant:

"Yes, but if they weren't so large or so sustained."

"Perhaps, you wouldn't like to wave your arm on the bus, on the other hand it's fun with something special and original."

Only two subjects were entirely negative to gestures in a public setting:

"Only if I didn't have to pay more for it!"

"If it was more efficient than writing the expression or to symbolize them in some other way, then the answer is yes otherwise no!"

In the final questionnaire some subjects noted that the problem of privacy might be solved in a longer perspective where everyone uses eMoto:

"eMoto would need to be established so that I wouldn't feel so stupid"

Personalities

As can be seen from the data eMoto was more appealing to 12 of the 18 subjects. As we were curious about why, we extracted four variables from the questionnaires and from watching the videos that could differentiate the two groups. The variables were appearance, interest in technology, and openness to new services. Appearance was determined subjectively from their clothes, facial expressions, body language, etc. Interest in technology was judged on their answers to the initial questionnaire about their computer and mobile usage (even if subjects that came to the test must be regarded as fairly technically interested in general). Openness to new services was judged from their answers about eMoto in a mobile setting, in the final questionnaire. We then checked the variables against the Sandra profile, the persona initially set up for the design, and found that the 12 subjects differed from the other 6 subjects in that their personalities were very close to 'Sandra'. These were also the subjects who felt more relaxed and enjoyed themselves more in task 3 and 4.

DISCUSSION OF RESULTS

Coming back to the issues discussed in the introduction – is it possible to design for an affective loop? – the study of eMoto shows that it is indeed possible to become physically and cognitively involved with emotional messaging even on a small device such as mobile phones. Let us divide the discussion into issues concerning the *personal affective loop*, that is the experience for the individual user when interaction with eMoto, and issues concerning the *communicative affective loop*, that is the interaction between users through eMoto.

Involvement with the personal affective loop

The study indicates from the analysis of facial expressions and the users own reports that most of the time they got both physically and emotionally involved. Adjustments should be made to the need for an initial pressure on the stylus to get it started, the gesture axes needs to be slightly rotated vis-à-vis the expression circle, and we might add an extra sensor to detect whether the gesture is done above the head, in the lap or hanging down. More interesting is probably the need to work further on the duration for each gesture. Some emotions seem to require a fairly long, sustained, gesture, while others are better expressed in a quick gesture done once.

In previous studies of affective interfaces, the timing of events and the level of control handed to the end-user have been shown to be crucial to the success of the system [13]. When an emotion is displayed to the user it has to come at the right point in time, and last for an appropriate length. If an affective response from the user is the aim, then the interaction has to be carefully paced so that the user can follow it without being bored or puzzled. Similarly, it seems from our study of eMoto, it is crucial that users are allowed to express emotions for an appropriate length that allows them to become involved but not bored with the physical movement.

Throughout the study we used four emotions to test eMoto. We noticed that for three of them, the gestures seem to work much better. The fourth, satisfied, is harder to express. Our hypothesis is that human body language is more attuned to expressing 'basic emotions' [8] than to expressing complex and subtle emotions such as satisfied. However, this requires further studies.

Not all of our subjects did get involved with the gestures and affective expressions. The Persona analysis revealed that this can partly be explained as a mismatch between their personality and the targeted user group for eMoto. In general, some users might be more open to physical, bodily expressions than others. A study by Öhman and collegues has shown that some users are more sensitive to their somatic and bodily emotional reactions than others [21]. Again, further studies are needed to disentangle whether this is the reason behind this difference.

The combination of gesture, affective expression in color, shapes and animations, and the intended emotion overall seems to be for the most part working, even if minor adjustments are needed. Subjects did for the most part the same kinds of gestures (according to our Laban-analysis) and they picked background expressions in approximately the same area to express the emotions. Important to remember here, is our aim of creating ambiguous, open-ended expressions that allows different users to pick different expressions – something that we seem to have succeeded in doing. This is not a task-based interface where the same task always should render the same output.

Involvement with the communicative affective loop

Our subjects succeeded in choosing expressions for the scenarios for the most part. In those cases where they were unhappy with the expression they ended up with, it seemed more to do with the timing of the gestures; that they did not want to repeat the gestures as long as our design required.

The subjects were also able to interpret the faked messages from other users and assign different emotional messages to the same textual message. Obviously, they felt that they would have been better able to determine the emotional content if they had known the person sending the message. Again pointing to the importance of seeing emotional communication as a negotiation process.

We believe that the communicative affective loop could be made even more physical. When you receive a message it could arrive not only with text and a colorful background. It could also have haptic feedback or sound effects. On the other hand, when you receive an eMoto-message from someone you know that the sender has been performing gestures to produce it and you will probably interpret the message with this in mind.

CONCLUSIONS

The physicality of emotional experiences is an intriguing complex process, expressed in both somatic reactions not visible from the outside, and in body posture, movements, facial expressions and tone of voice. The inner experience of emotions is related to these bodily reactions as well as to our cognitive, reflective processing of events and their consequences. Social emotional processes, in turn, are even more complex. The relationships we have to others are fragile, fluid ever-changing states that require quite some attention to be maintained. It is crucial that we can express ourselves and also understand our own emotional reactions when we communicate. As shown from the study presented here, a user-centered, ambiguously defined, affective loop can make users both more involved and also more expressive in subtle ways.

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