Dealing with Stress:

Studying experiences of a real-time biofeedback system

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This thesis corresponds to 20 weeks of full-time work.

Summary. To deal with stress, in a positive way, one can benefit from increased self-reflection in order to better understand the individual experiences and how they affect your health and well-being. This way the person can become increasingly empowered over him/herself yourself.

There is a lack of tools and devices to support people to be empowered to take control over their everyday behaviors and balance their stress levels. We are creating a mobile service, Affective Health, where we aim to provide a holistic approach towards health, enabling users to make a connection between their daily activities, as reflected by a representation on the mobile phone (which is constructed from values picked up, by biosensors, from some of their bodily reactions) and their own memories and subjective experiences.

This issue entailed figuring out how to provide real-time feedback without making them even more stressed and making sure that the representation empowered rather than controlled them.

In a Wizard of Oz study, testing two different visualizations on the mobile, we got some useful design feedback. In short, we found that the design needs to: feel alive, allow for interpretative openness, include short term history, allow for scrolling back into the past, and be updated in real-time.

We also found that the interaction did not, according to their feedback, increase our participants stress reactions. They also claimed that the setting was successful in recreating a real-life “feeling”.

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Contents

List of Figures

1

Introduction

1.1 Introduction

LeDoux once wrote that *"everyone knows what [emotion] is until they are asked to define it."* (LeDoux 1998). The same statement could be made regarding *stress*, a concept constantly thrown around in media and conversation, often portrayed as a negative condition, but arguably less understood than used.

It is common to associate several medical conditions to stress such as depression or *"burnout"*. Organizations such as the World Health Organization (WHO) are increasingly concerned with stress related disorders, as can be seen in publications from WHO (Leka et al. 2003). Their approach is mostly connected to work productivity, in the sense that not only the worker as a person is affected but also the organization in which this individual is active. The resulting conclusion is that employers should be alert to this issue as they can face the consequences of ignoring it. WHO goes as far as to consider it one of the major occupational health concerns alongside with *"unemployment and exposure to physical, chemical and biological hazards"* (Leka et al. 2003).

Similar concerns are echoed throughout the world as we reflect more and more on the relationship between work and private life. The central bureau of statistics in Sweden, to provide a local example, reports increased stress-related diseases, such as sleep problems, associated with increased overtime work, since the mid-nineties (SCB 2005).

Whatever one's motivation is, be it the improvement of productivity, well-being, or the quest for a more subjective, personal perspective on life, stress is arguably having a major impact on our quality of life. What we know that stress is any physiological change occurring whenever the body needs to adapt to external stimuli. This reaction, often referred to as "fight-or-flight", is indispensable as a survival mechanism and is in no way negative in itself. It is the cognitive perception of the situations that can determine the positive or negative outcome. The way we perceive the stress stimuli and the hope, or not, to be able to deal with it positively are fundamental for the short term effects as well as long term on our physical well-being.

The cognitive aspect of the stress phenomena has led us to try to address this issue in a more personal and individualized fashion. Self-reflection has been explored as a method for dealing with stress (Wicks 2007) in that it invites people to better connect with their internal perceptions and emotions, addressing them rather than failing to do so.

In computer science, Affective Computing (Picard 1997) has emerged in an attempt to shatter traditional views on emotions as distinct from rationality and bodies as a machine separate from mind, the control center. We know that in a "regular" functioning human these work together, indissociably, and only by understanding the connection between them we can better understand and reflect upon our own emotions. The Affective Computing field, however, is strongly informational in that research often tries to map emotions to discrete states. Affective Interaction (Boehner et al. 2005) research on the other side, using interdisciplinary knowledge from fields such as psychology, neurology and affective computing, tries to develop systems that, instead of inferring emotional states, help users in getting better insight on themselves and increase their self-awareness.

The current technological approaches often aim at guided behavior change, where the digital systems will typically warn the user of potential problems, "fostering" them into changing their behavior. Here we take a slightly different stance to the problem. We want to empower users to make sense of their experiences, providing them with tools that can open up their own reflections. In this thesis we to address this complex issue in a more interdisciplinary and holistic manner, providing new insights.

1.2 Problem description

We are developing a system to help users deal with stress. The system, named "Affective Health" is intended to be used as a lifestyle application and not as a medical tool. What this means is that it should integrate with the users' lives as seamlessly as possible. It is not meant to provide any diagnosis of stress, but instead, a means to reflect on bodily feedback, to empower users and allow for self-reflection.

In our attempt to empower users, we wish to endow our system with certain characteristics. One of them is that the bodily data we obtain from the biosensors should be open to users' own interpretation and meaning-making processes. We want the users to construct their meaning through self-reflection as opposed to the system doing the interpretation for them. The design aspects are thus of fundamental importance, since that is the perception users will have over the data. Another property of our system is that it should provide real-time feedback, so that users can look at the system whenever they feel the need to, and get up-to-date information concerning them.

This thesis is situated in the domain of Affective Interaction (Boehner et al. 2005). It is neither concerned with mapping emotions to discrete states nor is it a design study in the strict sense of the term. The final goal is to obtain design input for the system we are trying to develop. The first and main question is:

> *"Is it possible to provide an open-ended representation of the biodata that the end-users can make sense of and benefit from?"*

The system under development makes use of sensors that capture biometrical data from the individuals in order to be able to create a representation that is, in turn, feedback to the user in real-time. Medical professionals in stress treatment, that we had the opportunity to meet and converse with several times, raised issues concerning the real-time nature of the biofeedback. They suggested that we risked stressing the users even more by providing them with the real-time feedback of their physical stress reactions. And so a second question is:

> *"How do users experience real-time biofeedback, as stressful in itself or helpful?"*

And if the experience, as was suggested, entails negative effects for the user:

> *"What can we make better?"*

These represent the main motivations for the user study presented in this thesis. Studying user experience is, however, a complex problem in itself. And so some collateral questions had to be addressed in order to conduct the study we are about to present: *How can we set up a controlled situation in which the user experiences the system as if it was a real life usage situation?*, then: *How can our study participants share their experiences of the system with us?* and finally: *How can we evaluate the data collected in order to get some valuable feedback on the design?*. These are all questions that intrigue us and motivate our work. Traditional methods for analysing user interaction with systems are aimed at usability issues. We try to drift away from this type of analysis which, we believe, often fails to capture important aspects of the interaction and experience, particularly on an emotional level. To achieve this we try to get other types of feedback that we believe can be more relevant to the design problem at hand.

In summary, the goal of this thesis is to inform the design and construction of the Affective Health system before it is fully designed and constructed. This meant that we let the users try a preliminary version of the system to get as much useful feedback from them as possible.

1.3 Methodology

As mentioned in the previous section, evaluating user experience of interacting with a system is a step in the design cycle. This thesis addresses this problem. The goal is to shape the design of the final system using a user-centred approach.

The particular method we will be using is a Wizard of Oz method (Dahlbäck et al. 1993). This method has been used in a wide variety of fields, including human machine interaction studies, natural language processing and intelligent agents.

The underlying idea, inspired by the manipulative character from the book "The wonderful wizard of Oz" by Lyman Frank Baum, has a "wizard", which is a person responsible for impersonating the system that is to be used. This system can be partially built or in some extreme cases totally simulated by this wizard.

The reasons for the popularity of this method are many, the main being the reduced cost to test systems that are not fully functional yet. This is the reason that motivated us to employ the method. We have to deal with technical limitations in order to build the final system. Before the effort of doing so, we wanted to be sure that we are building something meaningful for users, instead of spending time, effort and money in building something to later realize that it is not adequate and does not fit our purposes.

1.4 Contributions

The goal of this thesis is to inform the final design of the affective health system, helping to "get it right". Building such a system is expensive, consuming time, money as well as human resources, reasons which should be strong enough to motivate testing prior to investing exponentially more on a fully functional, but potentially irrelevant one. It is an exploratory study into a design space where much is unknown. Steering the process to stay on track is therefore crucial for our project.

The non-resource-related reason is that we intend to build a coherent and useful lifestyle application. For this we cannot use traditional usability analysis methods as they are intended to provide feedback on how users are able to accomplish tasks. This system is not task oriented, it is in some ways a mirror to your body and mind. Instead we want to know what the quality of the interaction will be.

Another effect we hope to have is to try and go a little further in analysing human experiences of interacting with machines. By not using conventional methods, such as statistical analysis of data, but instead provoking users into, themselves, telling us what they make of the system.

The main contribution of this thesis, however, is the results we got from the study and the design implications that from there emerge, allowing us to better understand what people want from a system like the affective health, and how we can continue developing it.

1.5 Outline

The work we describe here started with a literature survey, presented in section 2, into what stress is, methods for dealing with stress problems, and the relationship between everyday behaviours and stress reactions.

After providing a brief summary of that review, we will, in the following chapter, discuss what has already been done in the fields of affective computing and affective interaction that can be used as inspiration for stress management systems: systems relating emotions, everyday behaviours, social context and physiological data to behavioural change. We will therefore introduce these fields and then go through some systems, developed for similar purposes, breaking down what we do not feel is useful for our system and what we were inspired by.

We will then follow to the next chapter where we will present a brief history of the Affective Health project, so that we can explain where it is coming from, the driving forces behind it and where we want to take it next.

After setting up our goals we will see how the Wizard of Oz study was staged in detail.

The results obtained will be then presented and discussed, finally leading to the set of conclusions we draw and that we will use as design and technical guidance for the next version of the system.

1.6 Project context

To contextualize the reader in the project development, it is necessary to place this work in its context.

When I entered the project, the goals of the Affective Health project had been set, although no decision had been made on the actual design. This initial work had been done through various meetings including: Professor Kristina Höök, the project leader, Markus Bylund and Stina Nylander, researchers within SICS contributing with experience, knowledge and motivated by the research topic as well Anna Ståhl and Malin Mäki, designers working at SICS.

At the time, a designer, Malin Mäki, had started to create a set of conceptual designs to represent stress experiences to a mobile interface. Previous work by Rafael Romero had mapped out possible user groups through a persona method.

My own task, together with my colleague, Pedro Sanches, initially was to identify features that would be relevant to map onto to the graphical representations created.

Later on, his task became mainly to determine which were the appropriate sensors to use for our application.

All the discussions were only theoretical, and technical reasons of various nature delayed the execution of the project. At some point it became necessary to test some of the goals we had set out, test the adequateness of the system and, in particular, the quality of the designs. This was my task and it is the work presented here, testing the preliminary version of the system and in particular the designs, in order to get input on the design qualities in order to pursue development.

2

Background on Stress

Digital systems and methods to monitor, prevent, help to deal with or even cure stress, have been developed. However, stress is a hot topic of research and many questions are yet unresolved. The urge to address the issue has led to the development of solutions, in terms of digital systems, that are still insufficient and often misleading. One of the reasons for this is that stress is often ill-defined and the approaches undertaken to address its negative aspects are usually on a superficial level. In this section we will go through the notion of stress, origins and current conceptions, and then show some of the digital systems currently available and why we believe they are insufficient.

2.1 Origins and first conceptions

After observing the reaction of rats to cold, heat and other external stressors, Selye (Selye 1936) observed that, in general, organisms tend to react to the conditions to which they are exposed. To this phenomenon he gave the name of *stress*. His work was largely influenced by the works of Walter Cannon. Cannon wrote about physiological changes occurring whenever we encounter a potential danger or threat situation (Cannon 1914). When situations like these present themselves we can either avoid or confront them. Cannon called this a *fight or flight situation*. It was clear at this point that this was an essential survival mechanism and in no way negative in itself.

Following on these and other results Selye went on to develop his General Adaptation Syndrome (GAS) theory (Selye 1946). He based his theory on Cannon's concept of *homeostasis* (Cannon 1914). *Homeostasis* finds its root on the Greek words *homeo*, meaning "same" and *stasis* which can be translated as "stable" or "stability". *Homeostasis* was thus illustrating the concept of "stability achieved by remaining the same". Selye argues that there are ideal values for some of our internal parameters. Heart rate, blood pressure, body temperature or any other balance that exists in our body has, according to Selye, an ideal value that the body tries to maintain. In this sense, any external stimuli that might attempt to alter this equilibrium is responded to with an opposite force.

What limits this apparent perfect mode of functioning? Well, Selye writes about *adaptation energy*, and according to him this is a finite resource constituting the limiting factor of the homeostatic adjustment. He argues that prolonged exposure to stress could drain this energy, thus leading to health problems. This is when and how stress first started to be looked upon as a potential source of illness.

For the sake of coherence and comprehension let us define some terms to describe stress-related phenomena. When some external source of perturbation is present it is commonly called the *stressor* and it represents the *stress stimuli*. The *stress response* is the way your body responds to the stressor and the *stress experience* is your cognitive experience of the episode. These are the most commonly accepted definitions, although loosely defined here.

We now know that the Autonomous Nervous System (ANS), which is composed by the Sympathetic Nervous System (SNS) and the Parasympathetic Nervous System (PNS) is responsible for our internal balance as well as for our reaction to extraordinary events (Jänig 2003). The PNS dominates in times when our body is functioning in an ordinary way. It is responsible for maintaining the bodily functions, such as breathing, heart beat, brain activity, etc., working regularly. Whenever extra demand is put on our bodies the SNS assumes a dominant role, allowing us to react with increased capacities. The SNS, when constantly put to effort, starts deteriorating leading to lesser capacity to reaction. This latter phenomena is what Selye was hinting to as *adaptation energy*.

2.2 The mind-body connection

Up to this point, in research, the cognitive perception, or emotional experience, of the stress experience had been left unaccounted for. The focus had been given purely to the physiological aspects of stress while individual psychological attitudes were not taken into consideration. Later, Lazarus and Folkman, proposed a transactional model of stress (Lazarus & Folkman 1984) in which they set forth the concepts of primary and secondary appraisal. These represent, respectively, the perceived demand and perceived ability to cope with a given stressor. By considering individual *perception* of the stress experience, both in demand and coping, they present us with an important step forward in this field. We now know that the impact of the stressor to one's health is not determined by the stress stimuli or stress response alone, but by a relationship between both at a cognitive level.

Later, Sterling and Eyer (Sterling & Eyer 1988) extended the concept of regulation to "allostasis", "allo", from Greek, meaning "change", which can be translated to "stability through variability". The main difference is that it sees the body as a whole instead of individual organs aiming at consistency, and it includes the principle of predictive regulation. This way, the individual optimal values are subjected to change and the goal is for the whole system (body and brain) to be at its utmost efficiency. In addition, the concept of "allostatic load" (McEwen & Stellar 1993) appears to account for the exhaustion of the allostatic mechanism.

What this means, is that the way the stressor is perceived, as well as the way the person feels it can cope with it, can be either aggravating or attenuating factors for the potential impact on oneself. Despite a general disagreement over the definition of psychological stress (Dahlgren 2006) there are a few generally accepted situations that may lead to chronic stress (McEwen & Seeman 1999):

- Frequent exposure;
- Failure to habituate to exposures of the same kind of stressor;
- Inability to shut off stress response even though stress exposure has terminated;
- Situations that cause regulatory disturbances of the stress system.

Later, the Cognitive Activation Theory of Stress (CATS) (Ursin & Eriksen 2004), was developed to extend the Interaction model proposed by Lazarus and Folkman. In this theory, the expectancy for the outcome of the stress exposure is fundamental. If there is not a cognitive hope that the stressor can be handled positively (coping), the exposure to the stressor can lead to states of helplessness or hopelessness. Both of these two latter states involve lack of control. The former implies the incapacity of choice in a given situation whereas the latter arises when the possibility of choice exists but all possible outcomes are perceived with negative expectancy. The ways in which these states can be avoided is through proper coping strategies that include support at all levels, be it social, financial, moral or other. It becomes apparent then, that focus should be given to proper coping with stress. This is because stress is not good or bad, what can potentially cause damage are the frequency, lack of habituation or failure to 'unwind' and/or cope. And since these are strongly subjective, self-reflection and self-awareness are key in addressing such issues.

2.3 Heart Rate Variability

In this section we will go through, briefly, the concept of Heart Rate Variability (HRV). The idea is not to delve in this issue as it is outside the scope of this thesis and medically too complex. The reasons we will address this are twofold. First to understand the functioning of one of the stress monitoring systems that we will present and, later on, to provide an explanation on the path leading to the affective health system's interface.

HRV, described shortly is the measure of the intervals between successive heart beats (Malik et al. 1996). It is currently the focus on many medical research efforts for its, yet not fully understood, potential. Many methods of analysis have been used to try and derive new information from this type of data, ranging from frequency analysis, entropy analysis to multifractal and monofractal analysis, among many others (Malik et al. 1996). The influence of ANS on the heart is a well documented (e.g. Jänig 2003, Levy 1994, Grassi et al. 1998), and this is the reason why we looked into this measure initially.

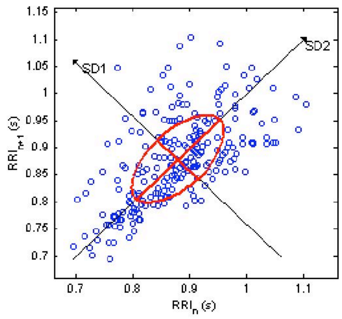

Fig. 2.1. A typical Poincare Plot from an HRV dataset

Something interesting that we observed when looking into HRV was the Poincare Plots. This is a way of plotting data onto a bidimensional chart which is made by mapping one value to its precedent. The resulting aspect, for values within a certain range, is a "cloud" of dots as seen in figure 2.1. Another aspect that was mentioned in literature was that whenever the heart was in stress, this cloud would appear more compact, and whenever the heart was healthy and relaxed, this cloud would appear more spread (e.g. Wood et al. 2002, Galland et al. 1998, Guzik et al. 2007). Without going into details on the validity of these claims, we, and specially our designer at the time, Malin Mäki, was particularly inspired by this, as we will see later on.

However, due to recommendations from professionals[1] and the inherent complexity of the issue at hand (cf. discussion by Sanches (2008)) we decided to abandon this path.

2.4 Sensors and stress monitoring systems

On account of the global recognition of stress as a serious potential health problem and also a major concern of modern societies, many efforts to develop helpful tools to address the issue have arisen. From the academic community but also from

[1] Personal communication with MD Yrsa Sverrisdottir, Sahlgrenska University Hospital, September, 2007.

private companies, owing to the profit opportunity, diverse systems and apparatus have emerged. We will go through the main available solutions, to bring out some important design qualities, similarities and differences to the affective health system.

2.4.1 emWave

The claims made by the emWave company are ambitious [2]. They state that through the analysis of HRV they can distinguish between positive and negative stress, thus upholding an informational view on emotions. HRV can reflect ANS activity, and the patterns shown by this, or so they claim, are a good indicator of emotional valence. By applying pressure with the finger (see figure 2.2) the small device is able to assess, through measuring HRV, the stress level and feed it back to the user through a linear scale (the amount of LEDs that light up are proportional to the stress levels).

Fig. 2.2. The emWave device

It is important to keep in mind that we are looking at a product from a private company (HeartMath[3]) and that their interest lies primarily in making profit. For this reason we are not surprised by the tone employed when promoting their product. The question is if they can actually deliver what they promise, which, from what we read on HRV, is not realistic, or at least not currently recognized. The extensive scientific and academic studies, they suggest were made, were, to the best of our efforts, impossible to track down.

2.4.2 eWatch

The eWatch [4], developed at Carneggie Melon University, is a wrist watch (see figure 2.3) originally designed to provide mobile context awareness (Maurer et al. 2006). It is equipped with four sensors: an accelerometer, a temperature sensor, a light sensor

[2] http://www.emwave.com/
[3] http://www.heartmath.com/
[4] http://ewatch.prnewswire.com

and a microphone. Its Bluetooth and Infrared communication capabilities allow it to interact with a PDA, for example, to store the information gathered.

Fig. 2.3. The eWatch

The eWatch has two desirable design qualities that we would like to pick up on: its mobility and seamlessness of use, which are two characteristics we are also looking to endow our system with, since these are fundamental for developing an everyday lifestyle application.

The possibility to use the eWatch for stress monitoring was not the original intention with which the system was developed. Studies are currently being conducted in order to assess its reliability and appropriateness in such a context. The underlying idea is that there is a peripheral temperature reaction to stress as a consequence of the dominance of the SNS over the PNS (Jänig 2003). This is a scientifically sound claim, accepted in the scientific community without controversy. It is however, we believe, a limited parameter to use by itself since it is influenced by external factors such as ambient temperature which are difficult to account for in an automatic fashion. It might be useful for self-reflection if valence is taken out of the representation since positive excitement and exercising, among other things, are also influencing peripheral body temperature (Jänig 2003).

Many accessories claiming to measure stress through this method are available on the market, as for instance, stress cards and thermometers[5]. They are however, one must keep in mind, measuring peripheral body temperature which does not correlate directly, in any way, to stress. The fact that there is no valence put on the result is in agreement with the literature on stress, which describes stress as neither inherently negative nor positive.

2.4.3 CocoroMeter

This is another interesting and original system consisting of a small gadget and some saliva sampling strips as shown in figure 2.4. It measures the alpha-amylase

[5] http://www.cliving.org/stresstools.htm

present in saliva as a marker for SNS activity which is in turn a useful marker of psychosocial stress (Rohleder et al. 2004) (Rohleder et al. 2006). We were already aware of markers in the human saliva, such as cortisol (Dahlgren 2006), that could be used to assess stress damage to the human body.

Fig. 2.4. The Cocoro saliva sampling system

What makes this system interesting, in our view, is that it is based upon ongoing scientifically sound research and evidence, and the company that produces it, NiPro [6] is a worldwide, medical supplies manufacturer with experience and a reputation to maintain. The main feature for us however, is the fact that the feedback provided by the system is not a number, a chart, or anything mapped to our conception of homogeneous scaling. It is a stick figure that appears more or less stressed according to the levels of alpha-amylase from the collected saliva samples. This is closer to the kind of open interpretation that we are striving for.

The main drawback however, that ruled out the use of saliva sampling in this project, is the inadequacy of the method for a real-time lifestyle application. Although it is a non-invasive method, it is an inconvenient one, going against our basic requirement of seamlessness of use.

2.5 Identified features

After our review on stress and related systems, we identified some features that we feel can provide valuable feedback to the user. First of all, the experience of acute stress or high degree of *arousal*, is a fundamental one. What happens physiologically that we can capture and display to the user for interpretation, allowing him or her to get insight on a possible stressful experience (be it negative or not) going on? Arousal was the first feature identified.

Secondly, we are interested in the activity of the ANS. The demand put on the ANS is a good indicator of psychological stress, among other things such as physical

[6] http://www.nipro.com/

activity (Jänig 2003). For this reason we are interested in capturing this feature, which we will refer to as *ANS load*.

Thirdly we want people to be more aware of their bodily activity. Arousal can come from many things. It can come from exercising, from receiving a great gift or other such situations which are not necessarily negative. By capturing *movement* users are able to recall, later on, that at that time they might have been at the gym, and so their high degree of arousal was nothing to worry about.

Finally, the most exciting feature we intended to capture was *adaptability*. This feature would measure the ability that the body has to adapt to external stimuli and change. After going through the stress literature the main conclusion was that the allostatic load was the reason why stress wears out people, both physically and mentally, an observation widely made but less often addressed as we saw in the currently available systems.

3

Background on Affective Computing and Interaction

The claim that rational behavior often attributed to humans arises from emotional processes might come as a surprise to some in the scientific community. Our western cultural tradition has, since long, placed the two concepts, of rationality and emotions, as opposite entities (Dror 1999). This distinction is deeply entrenched in our culture. We try to see decision making as a process in which logic, as pure as possible, is desirable and in which emotions, seen as an obstacle to clarity, should take no part. This is a reassuring belief in that it allows us to believe that we are indeed capable, if we try, to analyze the solution space of many problems in order to optimize the outcome in a logical way.

In 1967, Herbert Simon claimed that without accounting for the role of emotions we cannot create a valid theory of thinking (Simon 1967). Even though emotions were still given a secondary role to rationality, it is nonetheless representative of how views on thinking were on the verge of change. Later, Johnson-Laird and Shafir made an interesting observation, to the attention of the AI community, that it wouldn't be possible for logic to determine all the possible outcomes (and in turn the most suitable) from an infinite set of premises (Shafir & Johnson-Laird 1993). If we think that the world has an infinite (or so large that in our perception it is close to infinity) set of outcomes, then we can see how pure logic is not enough to make decisions, a judgement of value, that we do not yet fully comprehend, is needed to make choices.

These and many other evidences were analyzed by Rosalind Picard in a largely influential text for the Computer Science community, coining the term "Affective Computing" (Picard 1997). Her book gave rise to a new field of research in Computer Science where emotions play a fundamental role.

One of the main inspirations for Picard's work was the groundbreaking work of neuroscientist Antonio Damasio, *Descarte's Error* (Damasio 1995), where he uncovers the physiological basis for emotions and shatters the classical conception of mind-body dualism dating back to the times of Réné Descartes. This conception saw the body as a machine and the mind as a nonmaterial entity outside the realm of physical nature. We know now however, that mind and body are part of the same whole, mutually influencing and affecting each other.

While reflecting upon this idea, Picard followed a path that is still deeply entrenched in classical cognitive conceptions of emotions. Her approach was later named the *informational approach* (Boehner et al. 2005) to emotions. It tends to look at emotions as discrete and distinct units of information that can be broken down and analyzed through statistical methods, machine learning algorithms and other such classical approaches. Partisans of this attitude believe emotions can be automatically and accurately inferred from user's actions, facial expressions or body signals for example. The applications they build or envision will typically attempt to capture the user's emotional expression and map it onto a clearly defined emotional state. This is typical of an area where computer science dominates, and is often seen as the universal solution and method, and most problems are tackled in an informational manner. As Mark Twain put it: *"To a man with a hammer, everything looks like a nail"*.

At this point we should agree on three terms, as defined by Picard, in order to avoid confusion up ahead in the text. An *emotional state* is the internal dynamics of the emotion. It is impossible to define exactly due to the complexity of the body's functioning and social context, but it can be used abstractly to characterize the overall picture of body and mind. Another term that will be used is *emotional experience* which is what you perceive of your emotional state. The outer manifestation is designed as the *emotional expression*.

3.1 Affective interaction - a different approach

Unsated by the path of Affective Computing, some researchers branched off on what has been described as an *interactional approach* (Boehner et al. 2005, Höök et al. 2008), in which emotions are *"social and cultural products experienced through our interactions"* (Boehner et al. 2005), or put in another way, *"feelings are not substances to be discovered in our blood but social practices organized by stories that we both enact and tell"*(Rosaldo 1984). This approach, although recurrently using the teachings coming from the field of affective computing, as we will see later in this work, adopts a set of distinguishing design principles and goals.

Boehner et al. (Boehner et al. 2005) emphasize five distinct traits that characterize the interactional approach. First the acknowledgement of affect as *"social and cultural products"*, pointing out that systems developed do not intend to provide meaning outside of their interaction in a specific context. Secondly, this approach advocates *"interpretative flexibility"* as a way of encouraging the user to infer and deduce his/her own personal experience. Thirdly, and of utmost importance in this field, it *"avoids trying to formalize the unformalizable"* because this approach does not believe in discrete models for emotions for the system to deduce and feedback to the user (Höök et al. 2008, Laaksolahti 2008). Instead meaning will have to be supplied by the users themselves. Fourthly, it must support an *"expanded range of communication acts"*, so the inputs to the system, for example, do not have to be explicit and can be just a physical manifestation instead of a verbal or physiologically inferred one. Finally the main goal and focus is to aid the users of design systems to *"experience and understand emotions"*.

Emotions lie on the borders of human knowledge, where data is often confusing and blurry. The efforts to understand this phenomena are often built upon informational models. One of the reasons for this is that we, as humans, have difficulty dealing with uncertainty, specially in the current days, where classical science either has an answer or has models that alledgedly will, sooner or later, provide us with the truth in the form of clean cut answers. In psychology there are theories, on non-substance addictions, that deal with this issue of "addiction" to logical functioning, and the difficulty that humans have in dealing with non dualistic solutions (Gross 2004). If it is not black and white, if it is not on a linear scale, then we often get angry and abandon the line of reasoning.

This differentiation occurs also at a higher philosophical level, illustrating two different views on Science, and more generally, two different conceptions of the world. It opposes Constructivism with Realism (Oulasvirta et al. 2005). Disciples of the latter see the world as existing beyond our perceptions and experiences. They assume there are universal rules that regulate the way everything functions in nature. For them, these rules exist outside our experience, and we merely try to capture and model them as best as we can. In one word, there is a universal reality that we try to discover. This is the stand often taken by traditional cognitive sciences.

Constructivists however, oppose this view by stating that reality is just what we perceive and interpret. It does not exist beyond the sense we make of it and the meaning we give to things. It evolves and changes according to our interaction with the world surrounding us. This is the view upheld by Phenomenology, in which there is no such as thing as a disembodied brain, or mind, and that experiences, for example between two people, such as a conversation, are not in each person's minds, as an individual construction from successive input/output actions, but somewhere in the middle (Dourish 2004).

3.2 Affective Loop and Self-Reflection

The Affective Loop (Sundström 2005) states that emotions are constructed through an interaction feedback cycle. In this cycle, the context around us is influenced by our actions and perceptions, in turn, we are influenced by what surrounds us. The effect created by this loop can amplify the emotions we are experiencing or help us moderate them (Fagerberg et al. 2003). By trying to understand and participate in this Affective Loop we can increase knowledge about ourselves and enhance self-reflection.

This concurs with research made in Cognitive Neuroscience and Neuropsychology, stating that, although emotions frequently arise in a subconscious manner, reflection and cognitive assessment of the situation can help modulate those same emotions (Banich 2004). This also concurs well with the idea of self-reflection, by many acknowledged as important to mental balance (e.g. Tangney & Fischer 1995, LeDoux 1998).

3.3 Ambiguity to support Self-Reflection

Designing systems in the Affective Interaction stand, where the meaning is supposed to be provided by the users, can be challenging. What exactly is the role of the designer? This has been a question often raised (Höök 2004) by researchers in the field. Well for one, and talking specifically about biofeedback systems, the designer has the role of creating a layer between the raw information provided by the multiple sensors and the representation that the user is fed.

One path to designing this layer between user and system is through making the representation somewhat ambiguous. Ambiguity is not contradictory to usability. To describe something as ambiguous is not the same as describing it as being confusing. The first to formalize the idea that the human-machine interaction field would be better off served if they embraced ambiguity as a potential resource for design were Gaver et al. (2003). They advance the idea of ambiguity as a virtue in design, not to be confused with bad design. In their initial paper they distinguished between three main categories of ambiguity. To sum them up shortly we first have *Ambiguity of Information* which comes from the way information is presented to the user. It can be for instance fuzzy, incomplete or filtered. The user has to fill in the gaps of what is presented to him. Secondly they talk about *Ambiguity of Context*, where although the information might be fully presented, the context in which things are presented might be ambiguous. Finally they speak about *Ambiguity of relationship* which deals mostly with the observer's relationship with the artifact, which might be unclear (duality of feelings towards it for example).

The idea is to open-up for self-reflection, or *"Making space for stories"*(Aoki & Woodruff 2005) by leaving just enough for one to interpret as opposite to clearly stating to them absolute truths of any kind. One good example of interpretation done on information is music. When hearing a concert, or listening to a record, one could instead look at the raw information, the score. Instead we choose to let the artists "interpret" the score partly, transforming it into sound waves, that are much less informational but often much more pleasant.

3.4 Dimensions of emotions

As mentioned earlier, emotions are complex in nature and our goal is not to map them to numerical values from physiological measures. It is useful however to look into models of emotional dimensions such as Russel's circumplex model of affect (Russell 1980). In this model, Russel associates two dimensions to emotions: valence and arousal, as shown in Figure 3.1. This model serves us well since it separates what we can and cannot infer from biodata. Valence is the highly individual dimension that is beyond our scope to determine and which we leave for each user to reflect upon.

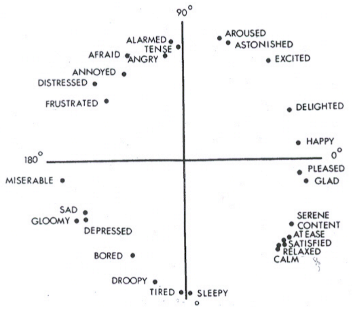

Fig. 3.1. Russel's circumplex model of affect with some emotions mapped onto it

Arousal however has been strongly correlated with many physiological measures. Galvanic Skin Response (GSR) (Boucsein 1992), the measure of the electrical conductivity on the skin, is one such measure. It is influenced by many factors such as sweating but also, for example, vein dilation (Boucsein 1992) (Jänig 2003). It has a linear correlation to arousal (Lang 1995), and, to the best of our knowledge, represents the fastest physiological indication of arousal (cf. discussion by Sanches (2008)).

3.5 Affective Systems

Our system deals with topics such as self-reflection, behaviour change and stress. There are many systems developed in this area with more or less relation to the work we are doing here. We will go through, as examples, three systems that exemplify the three topics above.

3.5.1 UbiFit - A behaviour change system

The UbiFit garden(Consolvo et al. 2008) is an application intended to be used to improve user's relationship with physical activity. The system does not assess physical activity in an absolute manner nor does it dictate what the user should be doing.

Instead the system allows for the users to set their own goals and gives them feedback on whether they are accomplishing them or not. The way to do so is by populating the garden interface on the users' mobile with flowers, when they are engaged in physical activity, and butterflies, when the users reach the goals they have set up. The representation is shown in Figure 3.2.

Fig. 3.2. The UbiFit garden

The system has two characteristics that we like. First, the goals are set by the user and are not predetermined. We believe this to be an important step towards behaviour change, that users take control of their own situation, and reflect upon what their wishes are. Secondly, by providing an interface that is not composed of numbers and charts, one is drifting away from the traditional way of thinking about physical activities and bodies in general.

The problems with this system, apart from specific problems detected by the developers such as the measures of physical activity picked up the system not conforming to the user's own perceptions, is that the feedback given by the system, although not totally explicit, is still very valenced. The fact is that, as its their own premise, no one wants an empty garden without butterflies or flowers thus giving the user the impression that something is wrong, without the consideration for the users own interpretation.

3.5.2 PMobile for monitoring stress levels

A system called PMobile (Picard & Liu 2007) was developed by Picard et. al. The underlying idea of the system was to detect stressful episodes through monitoring of heart rate. Whenever the system detected such a situation the user would be asked, by the system in an interruptive manner, about the situation at hand.

Two different systems were used in comparison. One was considered *empathic* in the sense that it tried to transmit to the users an understanding of the situation they were experiencing. The other was a more analytical one that would prompt the user with very direct questions. The idea of the researchers was to compare both in their interaction and make a case for empathic agents.

We appreciate the fact that there is an effort being put into understanding the users perspective and we think that, to some extent, it can be important to design for empathy. We will not delve on the complexity of this topic as it is outside the scope of this work and would require a deep analysis.

The problem with this approach is, first of all, the assumption that one can automate user stress detection. Depending on how one defines stress, for example as acceleration of the heart rate, a case could be made for this assumption. Even if that is not the main point of their work, we feel that the underlying premises are somewhat contrary to what we advocate and to the complexity of the stress phenomena.

3.5.3 Affective Diary

The Affective Diary is a self-reflection tool developed at SICS (Lindström et al. 2006, Ståhl et al. 2006). The users wear a BodyMedia armband [1], that stores GSR values picked up and it is also equipped with an accelerometer allowing to register movement. The user is also equipped with a Bluetooth and camera enabled cellphone to pick up on contextual data. This way, nearby Bluetooth devices, received SMSs and pictures taken during the day are all recorded.

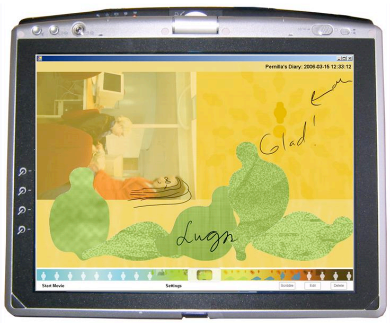

Fig. 3.3. The Affective Diary tablet PC displaying a typical representation

The system is not intended for real-time feedback but instead the data is uploaded to a tablet PC. The contextual phone data and the biometric data are then

[1] http://www.sensewear.com/solutions_wms.php

represented graphically on the screen in an organic yet ambiguous manner (see Figure 3.3). Everything is placed in a timeline which you can scroll. The bodily activity as picked up by the accelerometer is mapped into person-like figures, as seen in figure 3.3 and figure 3.4. The more this human-like representation seems to be standing, the more movement was picked up. The GSR is mapped into the figures' color according to the commonly known theories on colors (von Goethe 1840) (for a more comprehensive review (Derkert 2003). The red color was mapped to high arousal, the blue to low arousal and the intermediate values were mapped through a gradient of in-between colors.

The representations varied according to the data picked up. In figure 3.3 we see a greenish figure, in an intermediate movement level, suggesting that perhaps the person was relaxed at that point but not totally motionless. On figure 3.4 we see a red "standing" representation that could mean the user was in the gym, since it is reporting high levels of movement and arousal. It could mean something else such as the user hurrying to finish a task to which there is a deadline. Only the user can make proper sense of the representation.

Fig. 3.4. The Affective Diary with an aroused indication

The results obtained were very interesting as people would over interpret the representations, giving it meaning it could not possibly have, from the limited data collected. This is known as the *horoscope effect*. This was interesting because you could see that people were really trying to understand what they had been through and infer meaning from their day or week or just a couple of hours. Users were also given the possibility to alter the representation if they felt it was not accurate with their emotional experience,thus bridging the gap between lack of accuracy in everyday measurements and subjective experience. From the combination of, observing the data collected by the sensors and represented without valence, with the possibility to alter the data to better suit their subjective inner feelings, arose a feeling of appropriation (Höök 2006) that was the goal of that, and also this, project.

❖ 4

Project background

This project results from previous experiences, from other systems, as well as long brainstorming sessions, where different approaches were suggested at first and iteratively reformulated and adapted to arrive at the point where we are today.

4.1 Leading to a problem description

From what was learned through the usage of the Affective Diary, we felt it was necessary to go further. The system was successful in provoking the users to reflect on their bodily experiences, connecting them to their own cognitive experiences and drawing conclusions that were meaningful to them.

The Affective Diary team and ourselves felt, however, that a few aspects could be improved and added. Real-time biofeedback was one of these aspects. Not only the users showed some curiosity over such a feature but the whole research team felt that this would represent a significant improvement. Not only to give the users the opportunity to go back and review their day at the end of it, but also to be able to control the situation at hand.

Another important aspect was increased mobility. We wanted a system that would be more seamless in its use. One that users could forget that they were even using, as this factor alone can potentially influence the experiencing of the situations themselves as well as the daily routines. The usage of the cellphone as a means of storing data collected by sensors, providing a visual representation to the users, as well as being a collector of contextual information is for us fundamental. The main reason being the extended, almost universal usage of this device making it a main contender as support for lifestyle applications. The sensors are also affected by this requirement. They have to be small and allow for the user to be as unaware as possible of their presence.

Most of the other characteristics of the Affective Diary were to be preserved.

4.1.1 Driving force

The driving forces for the project is self-reflection, and to achieve this openness and identification emerge as two fundamental aspects. Openness so the user can make his own meaning over the representation that his being supplied to him. Leaving valence out of the representation is thus crucial. Our intention is not to provide any kind of medical diagnosis as it is not in our competences but also to avoid leading the users' interpretation of the data in any direction other than the one he wants to give it, as we do not even believe we could infer valence.

This leads us to the concept of identification. It is not in our aims to craft a system that impels the users to use it for the ludic aspect of it, as a game for example. It is our aim to create a system that the users feel as their own. One that they look at and feel that it is reflecting themselves. One that makes them sufficiently curious to start questioning their experiences but also that they can identify with and not see as an external artifact.

Self-reflection is in the basis of our views on emotions and, therefore stress experiences. Meaning of events and situations can only arise through self-reflection. We can, as a third person, read into the bodies of people and derive some conclusions. We feel however that this is limited. The truly important conclusions can only come from the person him/herself. Not only the study of inferring a persons subjective thoughts and emotions is a vastly unknown field, we are not even sure that we will ever be able to do so. Self-reflection comes then as an important tool for better understanding your own emotions as well as preserving mental balance and even for healing (Tangney & Fischer 1995, LeDoux 1998).

4.1.2 Choosing the sensors

As explained earlier, the features we intend to present rely on HRV, GSR and movement measures. We wanted the sensor device to be as seamless as possible. The goal was to have a piece of jewelry or any kind of aesthetic artifact that would interfere as little as possible with the user's day-to-day routine.

The reason for the seamlessness requirement put on the sensors, mentioned above but not developed, is essentially because the usage of bodily sensors is know to alter one's relationship with their bodies as well as with the physical space surrounding them (Troshynski et al. 2008). Since we want to develop for lifestyle applications, this is an important quality we want in the sensors as we do not want to interfere (or as little as possible) with the experiences.

Exmocare

We came across what seemed to be an all around solution to our problems, the Exmocare watch[1] 4.1. It measures all these components and could even be used as a fashion accessory.

Fig. 4.1. The Exmocare wristwatch

After testing and comparing with reliable data, gathered with the use of other, validated sensors, we concluded that the device is not working properly and we await further developments in this area. A new device, with a better design, is coming out soon.

Kiwok

Another interesting apparatus that we're looking into is being developed by Kiwok [2], known as the BodyKom. Allowing to take ECGs and upload the data wirelessly, it would fit perfectly with our HRV measuring needs. However, in its present form it's still quite burdening and we held meetings with Kiwok and await a soon to come development, consisting of a plaster like device, very thin and comfortable, with the same functionality.

4.2 System designs

The group has held various meetings concerning the system's interface design. Malin Mäki was the former responsible for the system's design, and it was her task to implement some of those ideas, as well as others she came up with.

[1] "http://www.exmocare.com/"
[2] http://www.kiwok.com

We will go through the most influential designs that she confronted us with. Ambiguity, meaningfulness and aesthetics were the desirable design qualities aimed for. The evaluation of the design is not directly part of this study. Not as an aesthetical artifact at least, but indirectly, due to its influence on the user's perception, and in consequence, the whole subjective experience. For this reason the design must be taken into consideration.

4.2.1 Heart analogy

The first idea that Malin Mäki presented to the rest us is shown in figure 4.2. The idea is to display to the user a sequence of small hearts placed on top of bars. The color of the heart is mapped to the arousal level of the individual, the height of the heart relates to the movement picked up by the sensors and finally the adaptability is represented by the size of the heart.

As the number of hearts increase, the past ones move to the background, fading away progressively and discretely.

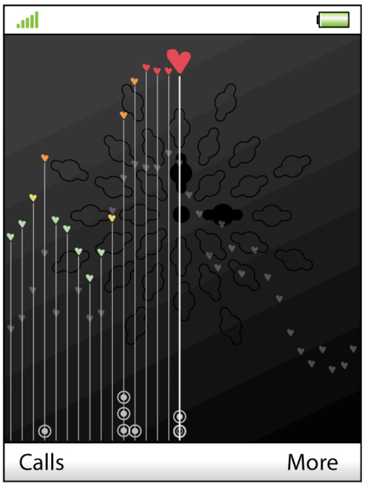

Fig. 4.2. Hearts placed on sticks representation

This design idea was put aside mainly for being overly explicit. It didn't leave much room for ambiguity and appropriation. It failed to open up for self-reflection as the "graphic-like" representation did not leave much room for interpretation. The heart symbol was also indicative of what we were measuring potentially leading the user to view this as an EKG or another medical equipment for heart measurement. This could be problematic as we are not in position to provide medical feedback and we are concerned of the effects on the user to think of the feedback he is being given as such.

Since self-reflection is one of our goals, and not the development of a specific medical application we felt this idea fell short on that. Nonetheless this design has some interesting aspects, mainly it incorporates history. The evolution of the representation in a progressive way, would allow the user to look back into a specific period of time. We felt, based on the experiences from the Affective Diary that this might be an important aspect to keep.

4.2.2 The butterfly effect

The second design idea is shown in 4.3. A butterfly flies around the display, being that the location of the butterfly on the screen is mapped to the arousal. The butterfly wanders around the colors that are representative of the users' arousal levels. The pace at which it's wings are flapping are linked to the user's movement and the outline of the butterfly is more or less rugged depending on how well the user's adaptability is.

The idea of leaving behind a path came, as for the first idea, from the potential significance of history for self-reflection.

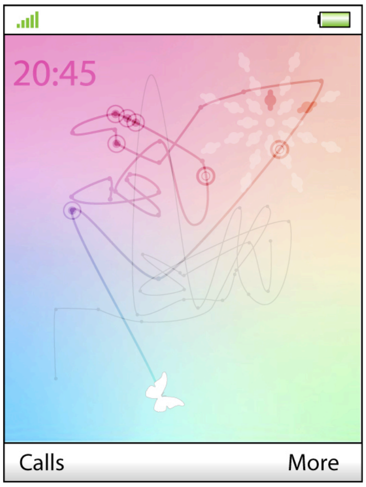

Fig. 4.3. Butterfly flying around the display screen, leaving a trail

Although the design was good in terms of ambiguity, since there was barely any interpretation or strong valence in the representation, it failed in two respects. Firstly the beating of the wings and their roughness were not only hard to perceive on the mobile phone's small screen, due to their reduced relative size, but they also caused some interference with each other, making it harder to distinguish the roughness if the wings were flapping strongly. Secondly the history path was very confusing, resulting in a quasi-impossibility to follow it properly after just a short period of time.

However the openness of the design and also its organic and aesthetic qualities were two positive aspects of this idea.

4.2.3 Dot cloud

This third idea came to us from the observation of the Poincare Plots. We used a more relaxed representation than the original Poincare Plots since we do not intend to make any kind of medical and/or diagnostic equipment. The dispersal of the dots is increased when the heart is not in stress and decreased when the heart is more stressed. Arousal is then mapped on the dots through color, which in turn pulsate at a faster or slower pace according to the movement picked up by the sensors.

The strategy for mapping adaptability in this design is to draw a closed line, centered on the display. If it is fine and round (see figure 4.4) it should mean that your general adaptability is good, if it smaller with rougher edges (see figure 4.5) then you should worry as your body might be lacking in adaptability.

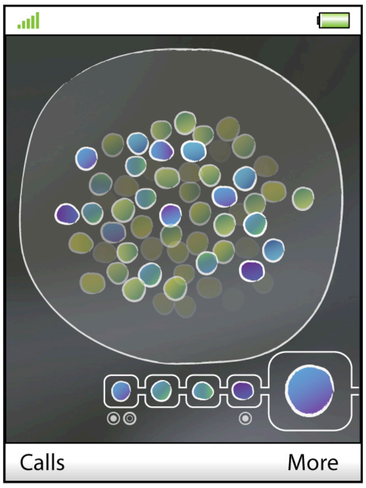

Fig. 4.4. Dots spread on interface with a good adaptability assessment

Dots would show up in real-time containing the information for the latest period of time, and the older dots would fade away progressively into the background. This way a cloud-like shape was formed to give users a sense of their bodily data.

The pulsating, slightly irregular, dots have a very organic quality to them. This is achieved without evoking organs or physiological features explicitly, which would make it unsuitable as a lifestyle, self-reflection tool, since it would be hard to avoid valence.

All the aspects, arousal, adaptability, heart stress and movement are distinctly mapped. There seems to be little or no interference and, for the user, ignorant of

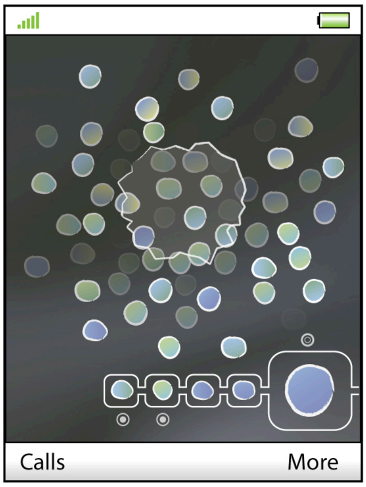

Fig. 4.5. Dots slightly more spread on the interface with a negative assessment of adaptability

the Poincare Plots, the meaning of the cloud would be open for interpretation as it wouldn't have any medical implication.

4.3 Set of design considerations that need to be studied

We held several meetings with professionals in stress medicine and treatment. Particularly in Gothenburg where we were received at the Institute for Stressmedicin and at Salghrenska University by professionals on stress and on the autonomic nervous system. From these meetings a variety of concerns were raised, some of them recurrently.

4.3.1 How do people react to real-time biofeedback?

The most common concern was the potential damaging impact of real-time biofeedback on an already stressed user. This question was raised by nearly everyone we talked to. Are people going to be more stressed when confronted with their own stress levels? This goes along the lines of our conception of emotions, and specifically, the Affective Loop, which can result in a reinforcement of emotional experience. In this case, possibly a negative one.

First of all this raised one important question, what is real-time? Merriam-Webster dictionary defines it as being *"the actual time during which something takes place."* This term, used mainly for computer related phenomena, works fine when talking about discrete systems, but what about continuous ones?

4.3.2 How does the representation influence the experience?

We must also consider the possibility that the representation itself is influencing the experience. How can we isolate the impact of the design from the impact of the real-time biofeedback?

It is of vital importance to design the study in order to account for this factor, and try and separate the experience of the representation from the experience of the feedback.

4.3.3 What other lessons can we learn?

Since we are putting together a user study that will imply means, financial, human and temporal, we should take the opportunity to open for other feelings the user might have towards the system. The challenge is then to make the study open enough so that we can address the questions we have *a priori* but also allow the users to express other, perhaps unexpected thoughts and feedback on system usage.

We advocate participatory design as a means of constructing a useful device. This is a principle, followed throughout the history of Scandinavia HCI design. The reasons are political as well as philosophical. The initial goal was the empowerment of workers (Bjerknes & Bratteteig 1995), by getting them directly involved in the design process. The latter reason is a belief that we do not know what people want or need. It is up to them to tell us, our job is merely to guide them and provide them the technological means to attain such goals. This implies being empathic with a user group which is not ourselves. But how can we understand others? Inviting them to experience how technologies could be like and letting them speak for themselves is, we esteem, a good start.

4.3.4 Posterior considerations

As a final note from these meetings, there was a lot of debating over the adaptability aspect. The ability of the body to adapt to stress is extremely hard to quantify due to its complex nature and number of variables involved. Also, how to represent it without valence since, per definition, it has valence. It is not easy to imagine low adaptability as something positive or vice versa. Secondly it is a difficult problem to approach due to lack of baseline values leading to a certain uncertainty over how to measure it and what meaning to make of it. It is certainly problematic to undertake such task without falling in the mistake of trying to develop a medical application.

After long conversations we decided to drop, for the time being, attempts to represent this feature. Instead this should be inferred by the user, from the frequent analysis of his or her results throughout longer periods of time. If the user is recurrently exposed to stressful situations with which he/she is having a hard time coping with, then they should be able to deduce the latent perils emanating from such repeated episodes.

5

Study setup

The underlying difficulty of the study was due to technical limitations. The sensors we had at our disposal were either not functioning properly or they made use of proprietary software to access the data, making it impossible for us to access it from within our own software. This was a great challenge for us, and me in particular.

It would be ill-advised to continue implementing a system which capacity to accomplish the goals we set out was still doubtful. We needed to know what to change, remove or add to the system without having to wait for it to be fully implemented, wasting time, money and other resources.

5.1 Addressing study goals

To circumvent these limitations, while still getting to test the system in a realistic way, we thought of a methodology often used in such situations, which is called Wizard of Oz. The basic idea of such study consists in getting users to interact with a system, making them believe that it is an automated system interacting with them, when, in reality, there is a Wizard, a person, which is receiving the user's input and responding back as if it were the system (Dahlbäck et al. 1993). This type of methodology is very often used in natural language processing systems and in system with intelligent agents (Dahlbäck et al. 1993). This usage is due to the fact that these type of systems, while extremely hard to automate, are extremely easy for a human to manipulate. So if feedback is needed on how a user would interact with such a system, it is extremely easy to fabricate an artificial situation.

We were inspired at first by a project called SenToy (Paiva et al. 2002), which made use of the same technique to guide the implementation of an affective sympathetic interface. This project consisted of a doll, which had motion sensors integrated into it. This doll served as control for a character in a video game. The users were invited to express certain emotions, using the doll, and observe the impact on the game. The input from the users' interaction with the doll on the game was provided by a Wizard that was observing the users'.

5.1.1 Real-time impact

The issues approached here are different, however, from the ones studied in the SenToy study. As mentioned earlier, we wanted to study the impact of real-time biofeedback on users' stress experience. For this we had to built the system to work, not only in real-time, but also in non-real-time, so the user would have something to which compare its real-time experience against.

We decided to implement the system so it would be updated in real-time but, also, in fixed intervals, every 5 seconds. The idea is to update the interface with the average values of the biodata collected during each interval. This way the user is not being constantly bombarded with visual change.

Obviously the amount of information displayed will suffer some losses with the averaging. We took care in asking the users how that made them feel, making this an issue to be taken into consideration in this study.

5.1.2 The design as an influencing factor

Another aspect that we were concerned about was how much of the users' stress experience was due to the real-time nature of the feedback itself, and how much of it was due to the design. We mentioned how important for us it is to leave valence out of the representation as we do not want, or can, provide the user with any kind of diagnosis. However this is quite challenging since the use of color, shape, motions, etc. is difficult to separate from valence. For example, as caricature, blinking red will typically alarm users, whereas a smoothly flowing dark blue is usually appeasing, even though the blinking frequency of the former or the flowing speed of the latter could be mapped to the same exact variable.

The first design we chose, was the inspired on the one we saw previously, with the dot cloud (figure 5.1). The arousal is mapped onto the color of the dot. The ANS load, taken from the heart rate is mapped to the spreading of the dots, meaning that the more spread they are the lesser the load. The movement is mapped to the vibration of the dots, which we unfortunately cannot see here.

To account for the influence of the design in the stress experience we created another representation that we felt was a good contrast to the original one (figure 5.2). This one is continuous and smooth while the other is discrete and sharper. This design however, did not inherently have enough dimensions to express all the variables we were trying to put forward to the user. To solve this problem we combined the dimensions of arousal and heart rate, or ANS load, as we will see later on, into one, the color. The combination of these two dimensions made it slightly harder

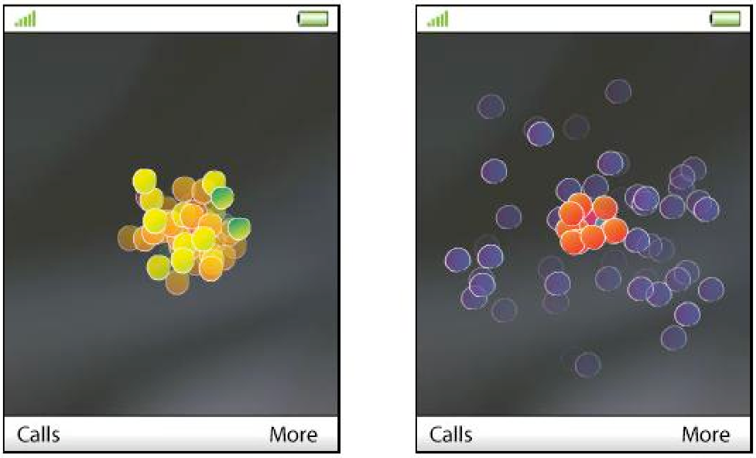

Fig. 5.1. Dots design. On the left the dots are relatively concentrated and yellowish, suggesting average arousal and ANS load levels. On the right the outer purple dots fading away suggest that there was a period of low arousal and ANS load, but the incoming, concentrated, red dots point towards increase in these variables

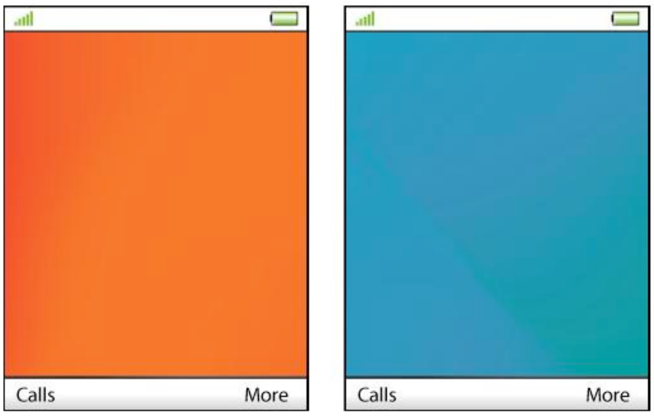

Fig. 5.2. Background design. On the left the background indicates low arousal or low ANS load, on the right the "redish" color suggests the opposite

to perceive the difference between the two. We feel this is acceptable since we are trying to provide contrast to the other representation, which is more action filled and visually overcharged. The dimensions are still there and we were interested in knowing what the impact on the user would be.

The representations we wanted to show to the participants were then 4. 2 of them in real-time and 2 in "delayed"-time. In each of the cases both of the designs. This made us divide the study sessions in 4 intervals each so the user could experience all the representations.

5.1.3 The setting

As the goal is to build a lifestyle application, testing it in real life situations is essential. The technical limitations however, do not allow us to use the system in daily life. We tried to design artificial situations that could be simultaneously simulated in a controlled environment and still induce feelings of stress and relaxation as realistically as possible.

5.2 Participants

In a first phase of testing the system we recruited three participants from the project group, that although deeply involved in the project on a conceptual level, where not totally aware of the technicalities. As such, they were led to believe that the system, for the purpose of the study, was indeed working. One of the main reasons to bring these three subjects first was to circumvent ethical complications due to the fact that the participants bodies were being monitored and also the fact that the Wizard of Oz setup implies omitting to the participant, throughout the session, that the system they believe to be working is, in fact, being partially simulated by the wizards[1].

In a second phase, the recruitment of users was done through e-mail, by sending them to mailing lists of companies and education institutions mainly in Kista, a technological pole north of Stockholm, where the user study was being conducted, essentially for practical reasons. From all the replies we got, seven participants were selected and successfully appeared on the date that was set. The criteria for selection were mainly to try and get people of different educational and professional backgrounds, as well as gender and age diverse. In the e-mail it was explained that we were conducting a stress related study and, in almost all the answers we got, the participants referred to worries about stress or curiosity over gaining better insight over themselves. There was also a material reward for the participation which consisted of two open cinema tickets.

5.3 Procedure

We will now describe the procedure undertaken during the study for each participant. There were minor differences in the protocol followed for one participant if we noticed that some improvements could be done after a particular study. These small changes were done trying to preserve the core goals of the study and will be, of course, pointed out.

[1] For practical reasons it was necessary to use two wizards, as will be explained in section 6.3.2

Table 5.1. Participant classification.

Participant	Age	Gender	Job Description
1	35	Female	Professor
2	43	Female	Researcher
3	36	Male	Researcher
4	32	Male	Research Engineer
5	26	Female	Research Engineer
6	26	Male	Systems Engineer
7	37	Male	Medical Doctor
8	41	Male	Researcher
9	41	Female	Receptionist
10	62	Female	Public Relations Officer

5.3.1 Situations

Prior to the beginning of the study situation, the participants would be briefed on the nature of the study, what kind of system we were testing, what we expected from them, what the sensors we would place on their bodies was measuring, confidentiality issues, etc. The sensitive part here was to omit that the study was partly simulated, and that there were two wizards reading the data and introducing this data on the system, manually. We would leave this part for the debriefing as it is essential for the study that the users believe that everything is working.

First situation used

The first situation we thought of was to get the participants to present, to a live audience, some of their research material, this came up in conversations with other researchers that suggested that even though they are used to giving presentations, it is always a source of stress. The idea was that, being the participants researchers, this would be an ideal stress generating situation that relates perfectly to their daily life. A dark room with no windows, to try and add some tension to the situation, served as setting for these three studies (see Figure 5.3).

The audience was recruited through e-mail asking everyone specifically to avoid giving positive feedback to the presenter, in an attempt to amplify even further the stressful situation. An attempt was made to get as many hierarchical superiors, from the speaker, as possible in the audience. We had four different representations to present to the participant and so they were asked to do four different presentations, about five minutes each, to give us the opportunity to switch between the different representations.

Each of the three first participants, that underwent this type of procedure had a different support for the representation. Each had respectively a PDA, a Laptop and

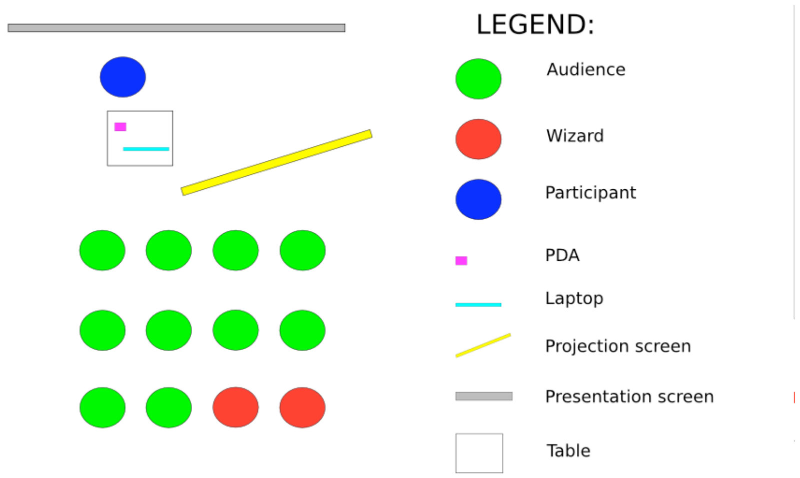

Fig. 5.3. Sketch on the first setup for the user studies.

Fig. 5.4. Pictures of the room setup for the first situation.

a Screen where the representation was being projected. The idea was to check which of three supports was more attention catching, for the remaining participants. The appearance of the room is shown in figure 5.4, although we do not include the screen dumps of the actual session because of poor image quality and privacy concerns.

Second situation used

The remaining users were coming from less homogeneous professional background. At the Institute of Stress Medicine in Gothenburg we observed study setups where the idea was to cause the participants to feel stress. The test used is called Trier Social Stress Test (Kirschbaum et al. 1993). The main idea is to place three actors at a table and call in a participant. The user has to talk about him/herself for some minutes. The three actors are sitting expressionless at the table, staring at the participant and writing notes, thus giving the impression to the participant that they are drawing conclusions from what he/she is saying. The actors however are mainly focused on avoiding any kind of reassuring feedback, such as nodding the head in agreement or smiling back. This attitude is extremely difficult to maintain as we had the chance to verify by ourselves since everyone seeks empathy with his/her looks, not giving it back is very challenging.

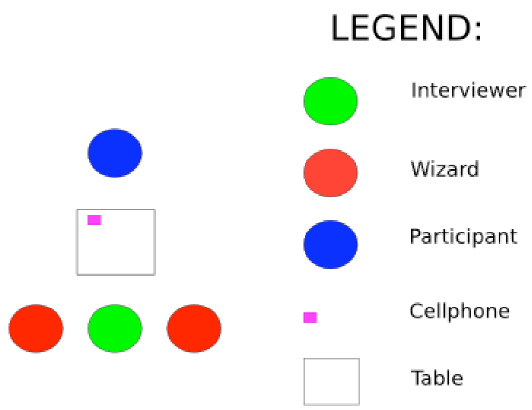

Fig. 5.5. Sketch on the second setup for the user studies.

We created a setting similar to the one that we had observed and read about (see Figure 5.5), with one slight difference. Instead of asking the participant to talk about him/herself for five minutes, as in the original version of the test, we conducted a fictitious job interview. We prepared a list of guiding questions that one would expect in a job interview, focusing mostly on questions that tend to arouse discomfort or introspection. Questions such as “what was your biggest job-related mistake”, “what do you consider to be your three worst flaws” or “what kind of wage do you expect to earn”, among others. The look of the room setup can be seen in figure 5.6.

Fig. 5.6. Pictures of the room setup for the second situation.

We preserved the awkward silences generated in the original test by not asking another question immediately after the participant ceased answering the previous one but, instead, waited for some seconds to create this discomforting atmosphere. Role-playing situations as this one, are since long validated as a means to engage participants in their roles in a somewhat surprisingly realistic fashion (Iacucci et al. 2002, Iacucci et al. 2000). One notorious, and extreme, example of the level of engagement one can achieve with role-playing is the Stanford Prison experiment [2]. This is a working methodology as we also had the opportunity to get as feedback from the participants.

In this type of setup, one of the wizards, in charge of switching representations, would interrupt the interview every five minutes to say which interface we would be switching to next. Once the participant had had time to appreciate all four representations, we would drop the act and engage in a friendly, reassuring, dialogue which gave us very valuable, fresh “off the oven” feedback on the situation.

Relaxation, questionnaire and debriefing

Once the participants were reassured, we would step into another room, the coffee room. This room is bright and relaxing. We would sit in couches, ask the user if they wanted some coffee, tea or if there was anything else we could get them. The purpose at this stage was to engage in normal conversation with the participant, trying to relax them while, again providing them with the same type of feedback they had before. We would talk them through the four representations again but, this time, we wanted them to see themselves through the system, while in a relaxed situation. This way they would be able to compare both situations and better make sense of the system.

After this we would start introducing the questions we had previously prepared. The idea was to ask all the questions, or address all the issues that we intended to cover, but in a non scripted manner. Actually, most of the times, the participants, very naturally, brought up all the issues that we planned to ask them about, without our intervention. We would just check the list to make sure that we were not missing any points. Our strategy was to open up the dialogue, as much as possible, so that the user could give their perceptions on the situation and experiences. The videotapes were also analyzed in order to assess differences between statements made by the user, such as how often they looked at the interface, with what we could observe from the videos.

The most sensitive part came at this point. Before officially putting an end to the study we had to carefully explain that they had been, partly, mislead. We also explained to them that the values we got for Heart Rate were the ones measured by the chest band and the movement was being observed on them. The wrist sensor was the only that was truly misleading.

[2] http://www.prisonexp.org/

5.3.2 System

Material

Two sensors were used. One was the Exmocare wristwatch showed earlier on figure 4.1. Although not working, this was the sensor we attributed the movement and Galvanic Skin Response measurement capacities to. The other was the Polar chest-band (see Figure 5.7), completely functional, it transmits to the corresponding Polar wristwatch (see Figure 5.8) the heart rate data picked up. The user did not wear the Polar wristwatch but the wizard in order to get the data to input to the system.

Fig. 5.7. Chestband used for picking up the Heart Rate data.

A camera was recording the whole sessions. The purpose of the camera was to get the transcripts but also, in the first part of the study to add to the stress situations, as done in the original form of the Trier Social Stress. The camera would at this point focus solely on the participant giving him/her the impression of being under a stricter type of scrutiny.

Fig. 5.8. Watch where the Heart Rate data from the chestband could be observed.

Two laptops were necessary for both of the wizards. One would be capturing the movement level of the participant, as he was perceiving it, the other would be registering the heart rate data obtained by watching the Polar watch. The Galvanic Skin Response, although not measured, was calculated thanks to the variability of the heart rate data. This is not a precise measurement, but it has been suggested in studies (e.g. Malmstrom et al. 1965, Sanches 2008) and, lack of better sensors, served our purpose.

The laptops used by the wizards would communicate their data to a tunnel application, responsible for aggregating the results and managing the client representation accordingly. This application resided on another computer, not physically present in the room. All the communication was realized through TCP/IP sockets connected thanks to the wireless network present in the building.

Software

The wizard applications were written in C# for the .NET platform. There were two of them. The main wizard application that was used for inputing the heart rate data as seen in figure 5.9. This wizard also had an updated view on what values the other user was inputing for movement, as well as what GSR values the system was calculating.

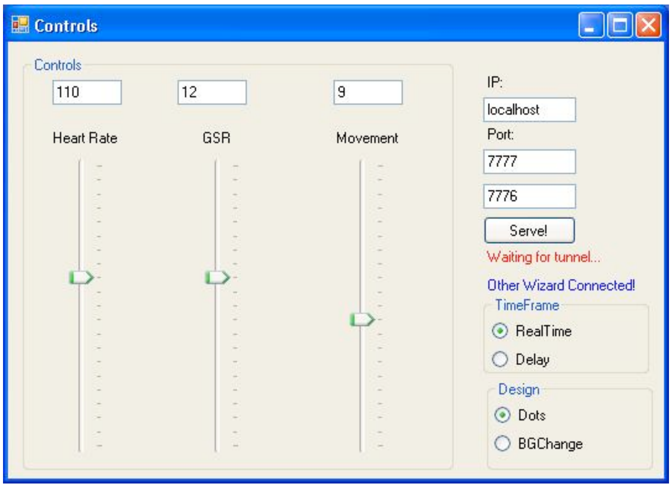

Fig. 5.9. Main Wizard application.

The wizard responsible for the movement had a simple interface as shown in figure 5.10, with some guides on how to map the movement. These guides consisted of short descriptive sentences to help the wizard. The input was also practiced in advance so we could have a coherent set of data being input into the system.

Both the interfaces could be efficiently manipulated using the up and down cursors of the laptop's keypad.

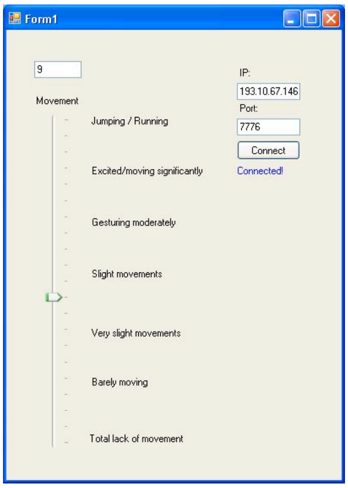

Fig. 5.10. Application for the wizard in charge of the movement input.

The tunnel application was written in Java and hosted on a third computer, outside the study room. The goal of this application was to aggregate the results generated by the two wizards and update accordingly the user interface.

Finally the client application was designed in Flash due to portability issues. Nearly all the logic of the application was transferred to the tunneling application, making it lighter to run. This was mainly because of the cellphone's limited processing capabilities. This application was therefore designed to serve merely as a graphical output generator, from the data it was receiving from the tunnel application.

5.3.3 Mapping of the data to the representations

Heart Rate

The heart rate in the dots representation served to place the dots on the screen. We used a high value for the heart rate, (150), to place the dots near the centre of the display. A low heart rate value (50) was used to place the dots as close as possible to the extremities of the display. The in-between positions were linear breakups of the heart rate values inside these upper and lower limits.

In the background representation the color of the background was mapped linearly to the same range of intervals.

Arousal

For the arousal the mapping was slightly trickier. For the dots representation, the color of each dot was mapped to the variation of the heart rate data. If the data was varying much in the sense of going up, then a higher value for arousal was computed. Inversely, if the heart rate data was varying in a descending sense, then the arousal was deemed to be lower, how much lower was proportional to the heart rate variation.

In a similar manner, the background color, in the background representation would momentaneously change to account for these variations in the arousal level (or more precisely in the heart rate data). This was the way we found to circumvent the fact that the background representation had one less dimension that the dots one.

Movement

The movement was made in a linear scale. It is highly subjective as it is observed rather than measured. However, as you can see in figure 5.10, some indications were provided in order to help the wizard in maintaining coherence.

The values that were input by the wizard responsible for observing the movement were then mapped to the frequency of the movement perceived in the interface. For the dots representation this meant the movement of each individual dot, whereas for the background one this meant the movement of the background.

❖ 6

Results

We grouped our results into the topics that we were interested in studying as well as all the others that occurred recurrently during the interviews either by us asking about them or by participants suggesting them from their own initiatives.

6.1 A typical account

First of all let's go through one of the participants journey in this study in order to get a feel for how a typical study session developed.

P4 is a 32 year old Research Engineer, working for a very large multinational corporation that deals essentially with new technologies. When he arrived he seemed very confident and relaxed, or at least it was the subjective impression he gave to all of us conducting the study. He was shown the designs and was explained the procedure. He was reassured about his privacy rights to which he showed very little worries about. He generally seemed curious about the study but at the same time extremely comfortable, without concerns over the situation he was about to undergo.

During the interview the participant did not frequently look at the interface. He was a seemingly well humoured person and from time to time he would make funny comments, and smile or laugh expecting empathic feedback from the panel, which he did not get. During these moments we noticed he looked at the interface a couple of times. As he later explained he is used to getting feedback from his coworkers, or friends, in this type of situations and, after not getting such feedback from us, he would feel tempted in looking at the interface to avoid the awkwardness of the situation.

Like all the other participants he afterwards said that in a stressful situation one would not look at the interface, as he would be too focused on the task at hand. We could perfectly see this during the interviews which lasted approximately 20 minutes each. The few times he glanced at the display, seeing different images, did not induce any stress in him, he said, just a sense of curiosity.

After the interview was over he was seeming much more enthusiastic about the study, claiming that the interview, contrary to what he had predicted from a made-up situation, was actually successful in inducing stress. At this point he was extremely inquisitive about how the system worked, what we intended to do with it and suggested several improvements. He showed also a great deal of interest in going back and being able to look at his data in retrospective.

The participant was then invited to continue the conversation while taking a coffee or tea and some biscuits, with us, in a much more relaxed atmosphere. During this period, as with most of the other users, he tried to make the system respond by, for example, waving his arm. This participant showed immense interest in the system, he made many suggestions and we engaged in a very fruitful exchange of ideas about the system, its possible uses and even the field of Affective Computing and its relation to industry.

He claimed to identify more with the interface showing the dots, updated in real-time. The real-time was important to him, since if he were to look at the interface he would want to see as accurate and actual information as possible, in order to feel in control. He was very sensitive to applications enhancing lifestyle improvements and to self reflection in general, being critical of today's emphasis on work and competition getting people to treat their bodies as machines, leading many times to depressions and burnouts.

Let us now turn to a more systematic account of how our 10 users reacted to the interface, in order to get answers to the questions in the introduction:

"How do users experience real-time biofeedback, as stressful in itself or helpful?"

"What can we make better?"

6.2 The system did not increase the stress experience

One of the main issues we wanted to tackle was whether the system would amplify the stress experience. The Affective Loop could potentially result in this undesired situation.

All of our participants denied the claim that during a stressful situation, having such a system would not amplify their stress experience. For one they do not think they would look much at the system during an actual stressful situation. Secondly they considered the information empowering rather than alarming. When we asked if having dots constantly popping up on the screen or having a background change frequently would scare the user, P8, along the same lines of the other participants answered: *"No. The first time maybe you would feel stressed, it's like you are getting to know yourself more, and it's always scary. But when you get used to it, I don't think it needs to be stressful".*

P9 was even more categorical: *"I think you are too careful about people. Because what is the purpose of a thing that is not accurate right now?"*. She thought we were being overzealous in our concerns and was interested in getting all the information she could get to raise her own self-awareness.

Concerns regarding the possibility of the system increasing the stress experience, which was our main concern in conducting the study, were expressed by P4: *"I could say that for different people, I mean people who fare good in stress then it would not be a threat because they know that they are doing good in stress. But for people who are not doing well in stress, then just seeing that you are stressed is just amplifying this"*. However he classified himself as one of the former users he described and thus, his concerns are the same to ours, but we are interested in his own perception.

P7 was the only one showing a preference for the delayed representation: *"I think it is less stressful, actually, the tempo is a bit lower and it gives me time to actually watch where the bubbles end up and I can form a better picture of how they relate to each other"*. Later adding: *"I have a fair time to see that bubble ended up there and the next one ended up there, so I have time to sort of reflect on that relationship."*.

Even though P7 preferred the delayed representation he, like the other users, did not feel stressed by the real-time one. His concerns were more towards the fact that with the delayed one he could better look at himself. We should take this consideration in the sense of making a more comprehensible real-time system and not as a incitement for abandoning the ideal.

6.3 Scrolling to support reflection

The system used during the study did not support scrolling back the representation. The only sense of history was the one provided by the agglomeration of dots on the screen which gave a perspective on the last 60 seconds or 5 minutes depending on if the system was in real-time or delayed mode, respectively.

This was also a recurrent topic in the conversations we held with the participants that arose partly from the fact that during the interview they could not get a good look at it, as P6 notes: *"If you are doing an interview like this and you are sort of living yourself into it, you are not going to watch the phone all the time"*.

P4 expresses the willingness of going back to check what her reactions were to which moments: *"I would really like to see how actually the level of stress increases or decreases or when do you feel that you are comfortable with the question or not"*. As P6 she did not believe that the system would be used during stressful situations: *"at times when you experience such things you are not really focused on this. You forget about that. You are not interested, I mean you want to solve the problem and then you are not interested in looking for how stressed am I."*.

The possibility of looking back into the past, was not only a way of looking at data potentially missed during a specific situation, but also to be able to look into different spans of time as P8 said: *"I can sort of look at afterwards to see how is my development going, how was this week for instance"*, to compare different periods of time, in this case he mentioned weeks as an example, and reflect upon them. Most users felt that, in order to be able to take self-reflection further, and be empowered by their bodily experiences and the possibility to improve themselves, they needed this type of control over the representation generated from their biodata.

An interesting observation came from P8, that showed a special sensitivity regarding the possibility of looking at past stressful experiences in retrospective: *"If I really thought it was a very stressful experience perhaps [I would] not [want to scroll back], because that would be a bad experience"*. On the other hand the same participant suggested that *"It could be interesting of course to see if I, on the other hand, thought that I did well, then I would be interested to look at it just sort of trying to confirm that"*

The possible use of the system as a long term self-reflection tool was also noted by P8, suggesting that the system could be used in the same was as a diary is used: *"It would give me a chance to do it sort of offline and not just a tool to see how am I feeling at the moment. But also to use it more in a diary sense"*

The only user that was not interested in the possibility of scrolling back in time was P7: *"Personally, I am not that interested at the end of the day to maybe go back. [...] But of course the possibility is very good"*. We got curious to why the possibility was good but he answered the question before we could ask it: *"it was the same with the polar watch. Some people they do their running and then afterwards they feed it into their computer and then they have all the tables and that"*. He related his usage of this system with the usage of the Polar watch as a training device. The difference in usage was attributed, by him, as a personality trait and not as a dislike for the feature.

6.4 Contextual data is needed

Another very interesting observation that all the users made was that, in order to make sense of the data *a posteriori*, it had to be associated with contextual data, taken from the environment. As P10 put it: *"You need to have some kind of hooks if you run it backwards [...] because otherwise it's just colors, if you cannot relate it to a specific moment in the interview. Because when you are in a situation like that and you replay it afterwards, you need both [the representation and the contextual information]. Ok, you got stressed there, but why?"*.

Making the same observation, when asked if he would be interested in looking at the data after a specific situation, to reflect upon it, P6 replied: *"If you could see* *what triggered a certain event perhaps, yes.”*. P5 takes a similar stance: *“I would really like to see how actually the level of stress increases or decreases, or when do you feel that you are comfortable with the question [in the job interview] or not. I mean more or less you remember the questions in the order that they were being asked, so I would say that would give quite a good indication of [. . .] your weak points”*

The unlikeliness of the usage on the situation was again reinforced by P4: *“if you look and you see that you are stressed then it’s just another thread of things going in the background, which is kind of distracting you from the task at hand. But definitely it’s good to have it as a post mortem”*. The need for extra data *“that are synchronised with this so you can see like oh, here I really didn’t do good, and why? Was I too stressed or was I not stressed enough.”* was also expressed by P4. All of the users showed this interest in understanding the why of the data.

To enhance and potentiate self-reflection, as all the users noted one way or the other needs contextual information, mapped alongside the representation.

6.5 Tendency towards increased interactivity

Another important question was figuring out which of the design qualities were most attractive to the participants. After providing them with two designs with different characteristics (the background being full and continuous and the dots being discrete and situated) we asked them in many different ways which of the two they related more to and why.

Overall, the dots was the representation the participants related more to. P1 when asked about her connection to the two designs, said : “*“I was making it do something [speaking of the dots]. I am having an impact here and, I mean, with the background [representation], it was so smooth so I didn’t really see much there”*. This participant was emphasizing on the discrete quality of the dots representation as opposed to the more fluid background. P6 had similar insight: *“In general I would say that the dots were superior to the background changing. That felt very vague, whereas the dots feel more, I don’t know, not as abstract.”*.

This preference was observed, with more or less enthusiasm, in all the users, without them necessarily verbalizing it so explicitly. The choice was often based on an emotional level without the participants explaining why, as we see from P6 statement that: *“for some reason the dots just spoke more to me than the background did.”*, or P4: *“I guess it is just on a very emotional level that I like this one [referring to the dots].”*

Still, we asked them to try and develop their answers, and after we insisted a little bit other explanations and insights came up. Interactivity was often referred to as a desirable quality, apparently more strongly connected to the design with the dots, as P7 puts it: *"I still like the dots more because somehow I like when things are moving. [It feels] more interactive somehow."*.

Another quality that seemed important was quantity of information. P8 for example, felt that the dots gave away more information and P7 expressed the same idea observing that indeed the background lacked one level of information: *"From the dots I get even one more level of information, not only the color but also how they are spread."*. Even though the spreading of the dots, reflecting the stress on the heart, is actually expressed as the color of the background (as well as the arousal, as it was explained earlier in the text), the distinction between the two was apparently not evident and thus creating this sense of missing information.

P2 thought that the dots representation was *"beautiful"*, but at the same time she was also the only one that unequivocally detached herself from the design: *"This thing feels much more unconscious and so I don't feel that I am interacting with this thing at all. [. . .] I feel detached from it and I feel that I can't do anything, I can't click on these things, I breathe, I do things and it's like not part of me yet, it might become part of me. But right now it feels like it's not part of me."*. She expressed frustration of not being able to interact with the dots that kept popping up. She felt she was not influencing the representation by changing her bodily expression, but also she said she wanted to click on the dots and see something.

6.6 Necessity of displaying trends

Another significant difference between the designs that we had not really given much thought prior to the study, but that was noticed and mentioned by all the participants was that the dots, by remaining on the screen for a period of time after popping up, kept a visual representation of recent history. In the background representation there was no such information, you could only see the "right now" and there was no way to see what the tendency was.

All the users except one emphasized the importance of this recent history in order to get a quick perspective over the recent trend on the bodily data as said by P8: *"You don't know if you are building up to a climax or if you are coming down from one. Kind of if it makes it hard to see trends, sort of, what is happening, where am I going, am I becoming more and more stressed or am I sort of starting to relax?"* when referring to the background representation, that did not display the trend.

P9 corroborated this claim: *"if you have a short history you have more time to see that this can happen, and then you can look and see what happened"*. Or as P10 put it: *"So for me the dots carry a lot more information and also you know the layer, the layering of the information so to say"*. P10 referred to this trend effect as *"layering of information"*.

P4 however felt that this choice of design could result in confusion deriving from information overflow: *"Even if you look at the dots you can see that some of them are fading away but they are superimposed so you are not getting it at the same time as you get it from a plot"*. This user was particularly worried that too much might be displayed on the screen creating noise and making it harder to read and make sense of. This way it would be hard to tell the trends since everything was mixed together.

The observation made by P4 does not mean that users do no want to see aspects of the recent past in order to know where they are coming from. It just tells us that if we implement this type of design quality we have to make it as clear as possible to the users, otherwise they will not be able to infer the progression of events.

6.7 Openness for interpretation

One of our design goals is to leave as much interpretative effort to the user as possible. The aim is that users relate their subjective experiences to their bodily data and derive their own meanings. To get users to identify with the system one must make it as 'open' as possible while at the same time showing real and consistent data. The arousal was mapped to the interface through the use of a color code. The main advantage of using a color scale to represent the different levels of arousal is that colors induce different experiences to different people in different situations. However, the interpretation of colors is also culturally grounded and somewhat embedded in people's personal experiences. Most of our participants reflected upon this and initially assumed that the colors implied negative or positive valences. They still questioned whether the system was using the same color significance code as themselves as P5 pointed out: *"So when I would see one of the bubbles in a blue-greenish that means that I would say at this moment like I am not really fully relaxed at this point, it's [. . .] being a little bit excited I would say, but does it reflect that?"*

When asked if the color code currently displayed was reflecting him at that moment, P6 said: *"If that means I am calm and relaxed, yes, I think so."*.

As most of the others did, he suggested that other interpretations could arise with increased knowledge of the system: *"If I was at home and relaxed, just watching TV, and it was blue. . . aha! I would think that when I am relaxed it's blue. And then I was out running on a treadmill or something and. . . oh! it's red [. . .], I am in a car accident and it gets really red. Then it would be OK, I would sort of understand the different meanings"*.

Others like P7 were initially very assertive in mapping meaning from the colors: *"Of course blue often represents calm"*, although his way of deriving meaning was not consistent throughout the interview as he had earlier claimed, when asked what "blue" meant for him: *"That I am more or less depressed. I feel very blue"*. Although both of the emotions he referred to are characterized by a low level in arousal, they are very different in valence, which is what we intended, to portray arousal without inducing valence.

P5 gave another good example of how the interpretation of the color can change according the subjective personal emotional experience. *"No, actually it was all blue I think in the beginning when I was kind of relaxed because I said: Yes, I am in this interview. I have a job!"*. She associated the predominant blue color on the display, at this point, as an indication of calmness on her behalf from realizing the fictitious character of the situation.

After however, she interpreted the same color as a sign of slight excitement: *"So when I would see one of the bubbles in a blue-greenish that means that I would say at this moment, like I am not really fully relaxed at this point, it's a point of being a little bit excited"*. What this shows is that according to the own personal subjective feeling, the interpretation of what is shown can change. This is relevant because we want the users to make up their own meaning, not be fed one. But like we said before, the mapping of the biodata to the representation was consistent so they could see patterns, otherwise it would be meaningless.

The spread of the dot cloud was often over-interpreted by the users. P4 said: *"My first impression would be that there are two axis and because there are two axis there should be two dimensions of the measurements and then every red dot is registering some-thing on one dimension or every dot is registering something on one dimension and on the other dimension"*. Although there was only one dimension, which was the distance to the centre, the participants tried to make more sense of it. Along the same lines P5 asked: *"What did you say about the axis?"*, when told that there was only one dimension and not two he replied: *"Oh, I see because what I was thinking from the beginning maybe that when the Y or X when it was close to the left side it would mean that the pulse is quite low and then higher up. But I was not sure"*. This can be due to poor explanation of the design, prior to the study, or even to poor design itself. We thought however that it was interesting that they were making this interpretative effort, as it shows an interest in relating the experience he was feeling with the representation that was being displayed.

The movement was often not interpreted in many ways since it was mapped to movement on the screen. This aspect was the most understood and less problematic. None of the users showed any problems with the way this dimension was mapped or what it meant.

To finish this section one of the most interesting aspects for us was illustrated by participants attributing different subjective meanings to similar visual feedback: After laughing at a funny comment, P5 said: *"I thought I could see another red dot that came after that, when I actually started laughing, so I don't think that I was seeing the peak really of arousing at that level and at that point."* Since she was laughing and experiencing, in her opinion, a positive emotion, she thought the red color on the screen, portraying a peak of arousal, was an error on the interface. This interpretation came from the previous observation that red, in the previous situation, was illustrating her nervousness, and thus had a negative connotation. At this point we reexplained that arousal has no valence, and can come from a positive emotion as laughing at a good joke, as well as feeling stressed when asked a tough personal question during a job interview, for example.

6.8 Training to improve oneself

One of our ideas, when developing this system, is that we might help people adapt their behaviours in ways that are more healthy for them. The system is in this sense mirroring your body, helping you better understand your physical reactions and connect these with your own feelings and, in this way, gaining better insight on what is good for you and what is not.

After we identified the necessity of a scroll back mechanism for the system, with the contextual data, one can still wonder if reflecting on past events can be helpful to people in dealing with new stressful situations that may occur. Some users suggested that continued interaction with the system would give them the possibility to learn more about the patterns of stress in their lives and how they dealt with it, thus helping them to "train" themselves at, not only avoiding certain types of situations, but also how to better cope with them. As P10 observes: *"I think I could learn more from it really, because job interviews are really a thing like acquired taste, you know, and you have to train for it"*.

6.9 Everyday use

The Affective Health system is intended for everyday usage. Although the present study did not contemplate this aspect due to its limited nature, all the participants showed a great deal of interest in using the system for longer periods of time. For example, P7: *"I think it was really interesting [the study] and of course the application could be very, very good for everyday life. Not only as a fun thing for people to have, but also to maybe learn something from, especially if you know that you get stressed in certain situations and then maybe you could do something about it."*.

The usage of the system on a daily basis, connects with the previously noted results that users would want to use the system for training with the possibility of scrolling back in time and synchronizing this with contextual data.

Developing the application for everyday use however, poses challenges that transcend the interface design. The sensors used (the chest-band and wrist sensor) were considered bulky and uncomfortable, by most users, and would not qualify for a lifestyle application intended to be used everyday, as seamlessly as possible, as P2 notes: *"The strap is strapping my chest so I felt like I wanted to take a deep breath"*. It is not just a matter of discomfort in itself, but also the consequences of this discomfort, that may induce the user into altering, more or less dramatically, his/her behaviour, thus interfering with the actions instead of just accounting for them as P9 exemplifies: *"This is a big, heavy tool, and you don't feel you would like to move it. I was afraid that with my arm I would hit someone"*. The accountability for the fact that sensors may interfere with experiences and influence the way one lives their daily routines has been recently addressed by Troshynski et al. (2008) in a very relevant text for the affective health project as a lifestyle application.

6.10 Metafeedback on study

The study had two phases, with two slightly different methodologies to create the stressful atmosphere. However, in both cases, all the users reported that the situation was successful in inducing stress.

The first phase did not account for individual coping strategies of the participants and so, the capacity to induce stress varies. For example P1 stated that, with her, stress normally occurs before the presentation takes place, and not during: *"I have a strange stress code. I would have been stressed yesterday if I had an official presentation today, I am usually stressed like before. And then on stage it is OK."* Still she acknowledged that she felt *"A little [stressed], mainly because it is a presentation that I am doing in English"*. And she also claimed that the audience *"did a really good job looking kind of bored"* and even though she said: *"I don't think I would have been stressed only by that"* it added to the experience which was our intent, that all the individual components, audience, situation and different language would add up.

The language issue was actually one that we had not properly thought about since the studies we read on stress-inducing situations failed to address this issue as they assumed mother-tongue to be used. However, due to the international nature of our team we were forced to conduct the studies in English which was an additional factor of stress as P9 notes: *"It is a bit stressful to be asked difficult questions in English. When you cannot answer in your own language."*.

On the second variant of the study, all the participants agreed on the fact that it was a good method to cause stress. We were pretty confident from the beginning as it was based on a validated stress generating test. P9 provides a good example when she says: *"even if I know this is role playing, it stresses you anyway"*.

Regarding the evaluation of the system in itself, some participants mentioned that the 5 minutes they were given to appreciate each of the 4 different types of feedback, during the interview, were not enough as P9 notes: *"If this would be sort of* *a lifestyle application like it's intended to be, I expect you to be using it continually and then you would learn how it functions"*

The WoZ setup was successful in the sense that all the participants truly believed that the system was fully functioning with the sensors communicating directly with the interface on the mobile phone. P1 is the best example as she was involved in the initial part of the project, but unaware of the study setup, and when she was asked to put on the sensors, she looked surprised and asked "So these are actually working", to which we answered positively, getting her to believe in that throughout the study.

As for the debriefing phase of the study, we were as careful as possible, as we did not want the participants to feel "cheated" in any way. None of them expressed any kind of resentment against the team. Generally their reaction would be of laughter as we showed them the WoZ interfaces and how everything was setup. The feeling they got was sort of a "Candid Camera" one, when the people realize the situation was fabricated.

7

Design implications

We were able to derive important design input for the Affective Health project. We grouped the results into groups of considerations we should keep in mind to continue designing and developing our system. Some of these reflections were published earlier this year (Ferreira et al. 2008).

7.1 Identification and Interpretation

We learned from the study that the bodily data in itself is of little use in lifestyle applications. It became apparent that in order to make sense of the collected data, contextual information, has to be added. Video or voice for example, as suggested by the users, but we can also go further, when thinking of a real-life setting. We are using a cellphone and so, data like SMSs, calls, received or dialed, positioning, geographic or social, or Bluetooth presences, among other data should be considered for use.

The reason for the necessity of this contextual data is that the biodata collected is ambiguous and needs a connection to the subjective experience in order to make sense. How to distinguish from the data that a user was running in the gym or from a bear? How to tell from the data that the low arousal coming from the user is due to a nice warm feeling of being at home or from another type of feeling such as giving up on a given issue, because the user felt that it was too much for him? These are clean cut situations, but the complexity of human emotions requires that the data be interpreted by the user to make any sense.

Also interesting is how this connects to stress. We know that a stress experience is neither good nor bad in itself. Actually one might argue that in fact it is generally good as it represents a valuable mechanism of survival. The problems occur when this situation is sustained for a long period of time, is recurrent or/and is negative in nature. For a situation to be negative it not only involves what is happening, such as losing a job or being late for a deadline, but also the cognitive hope that it will get better somewhere in the future. If a user is then to make sense of his/her data then he/she needs to know why, when, where he/she was experiencing the situation depicted on the interface.

Of great interest is that, without our suggestion, all of the users pointed, naturally, towards this fundamental requirement, which indicates that people are aware of the complexity of an emotion such as stress.

7.2 Bits of the past

A representation of a short term history, existent in the form of the dot cloud, was considered useful and necessary by most participants. In order to assert the “now”, one needs to compare it to the previous states. The future designs should keep this into consideration.

We also know, from our life experience, that a state is generally relative to what could be instead. Taking the simple example of heart rate monitoring, to see that your heart rate is 100 could be either good or bad depending on what were the previous values, in other words, what is the trend. If the previous values were coming down from, let us say 140, due to exercise, for example then it is ok. However, if the user sees the heart rate going up to 100 from 60, and they do not immediately realize why, then it could be a matter of some concern. One might argue that our perception of the present is always related to our knowledge of the past.

This was an unanticipated effect of the dot representation. We had not thought about it before users started suggesting it. We feel that we were able to explore this aspect further due to our usage of semi-structured questionnaires, which were more like dialogues where the users and other ideas were invited to emerge. We could have missed such input if we had followed a strictly structured questionnaire.

7.3 Reflection and training

The next step will be to try the future system, incorporating the changes suggested by this study, in everyday life. One aspect that we consider positive and encouraging from this study is that the users manifested interest for reflecting on their past experiences and training themselves for future situations.

In today’s western way of life, where everything is faster, quantity of production is often a top priority in people’s life, taking the lead over personal satisfaction and well-being. Quantity of work hours or quantity of products manufactured are some of the values put on human beings, not only by external entities such as the boss but also by the people themselves who see in this measures an evaluation of their own merit. Success and even personal satisfaction is often derived from factors such as financial rewards or public acknowledgement.

The problem we see is that people forget more and more about understanding themselves. They stop trying to find meaning in their lives and experiences and instead push their bodies to the limit, treating them as machines, means of production that can be taken to whatever extent is necessary in order to achieve certain goals. The result is increased number of accounted for depressions and other such issues that could possibly be avoided through more self-reflection and adoption of different lifestyles. To quote P9: *"for me I see a problem that we are forgetting how to know our own bodies, because it is further away, we make technical things instead of getting to know yourself and take yourself seriously"*.

If this system can raise people's awareness of their bodies, the experiences they go through, their inner feelings... then we think that it is a definite success. By increasing self-awareness people can prepare better for the daily challenges and achieve inner peace, hopefully, in the long run, improving their own quality of life. To paraphrase the title of the book by Swedish psychotherapist, Anna Kåver, "To live a life, not winning a war"[1] (Kåver 2004).

7.4 Real-time is not a problem as it enhances empowering

One of our initial fears was that, through the Affective Loop, the feedback given to users, when in a stressful situation, would act as an amplifier of that emotion, instead of helping him or her deal with it. The participants however, showed us differently.

Most of the users in fact wanted to have control, see what was happening, as it was happening, so they could take action and hopefully change the course of events. They did not want us to be censoring information that they felt they could make use of.

This was perhaps the most important conclusion that we obtained from the study for two main reasons. First because it validates the path we chose to follow, and the system in particular. Secondly it justifies the study we decided to do since it allowed us to drop a prejudice regarding the future system. Without this conclusion we could have perhaps taken this concern at heart and denied the real-time feature to the users. This was a lesson in user empowerment that should incite researchers and designers to ask themselves more often the question whether their concerns over the users are not condescending.

[1] In Swedish: "Att leva ett liv, inte vinna ett krig"

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