Taking affect into consideration

Iterative user-centered design for an affective and ambiguous mobile application

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Abstract

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This thesis considers issues that may arise when designing interactive systems for users when not only usability is considered in the interface design process, but when the purpose of a system is its ambiguity and when it is important that users have the ability to read their own personal meaning from the representations in the system. The system treated in the thesis is called Affective Health. It is a lifestyle system which is supposed to aid users in reflecting over their stress. The system uses biofeedback data which is collected through sensors attached to the user’s body which then is presented to the user on a mobile device. Users should be able to identify stressful situations instantly, but also historically by reviewing periods of time and identify peaks of stress.

In seven user-studies the system is tested both in respect to ambiguity and how this fulfills the purpose of the system and in respect to usability. The user tests are part of an iterative user-centered system design methodology which means that the system was being developed between the user tests based on the feedback given from the each test.

The tests are summarized and the systems strengths and shortcomings are analyzed in respect of purpose and usability. Based on this the challenges of developing and evaluating systems that demand graphical interfaces that may impinge on usability are discussed. It concludes that usability goals shouldn’t be neglected as this may inhibit the evaluation of the systems underlying purpose.
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1 Introduction
Stress has been getting more and more time in the lime light in recent years. Research has proved that stress not only affects our psyche but also our bodies. Recently it has for example been shown that there is a correlation between stress and strokes (Jood, Redfors, Rosengren, Blomstrand, & Jern, 2009) and between stress and type-2 diabetes (Rosengren, o.a., 2010). Finding ways to cope with stress can therefore be seen as increasingly important, but not only from the perspective of the individual. Corporations suffer financially from employees whose performance may be negatively affected by stress. Stress or stress induced illnesses might even be the cause for sick leave. This will also have socio-economical consequences as non-working, ill people are costly for society. Today the World Health Society (WHO) considers stress a major occupational health concern. (Ferreira, 2008)

The Affective Health is a system developed at the Mobile Life Centre. The system has been designed as a tool to empower its users with an extended self-understanding and thereby aiding them to cope with stress. This is achieved by collecting personal continuous biofeedback data that is stress-related and presenting it back to the user.

This thesis is based on an iterative user-evaluation of the Affective Health system. The focal point is the design of the interface of the system and on the representation of the biofeedback data.

2 Background
Stress is a natural reaction and can be described as a bodily adaptation to changes in the environment. However as modern humans no longer figure in the natural environment from where we originated reactions of stress can arise in situations other than intended. In most cases today stressful situations aren’t resolved by the either fight or flight. If the body fails to shut down the stress or arousal reaction it continues to release stress hormones, such as cortisol, into the blood. This keeps the body in a state of stress and prevents it from relaxing which can be harmful in a longer perspective. We do not know all of the implications stress has on our health but it is known that long-term stress can be a cause of chronic illnesses such as cardio-vascular diseases. (Sanches, 2010)

As a result of this, different methods of coping with stress have been introduced. One of the most common methods today is using introspective analysis. A tool for this, used by clinical therapists, is journaling. Writing down experiences and feelings of everyday events is thought to enhance self-reflection and can be an aid in identifying stressful elements in one’s life. Identifying these elements and their reasons leads to getting deeper in touch with oneself. This can be a way of coping with these stress inducing elements. (Sanches, 2010)

Biofeedback has successfully been used as a complementary therapy. If biofeedback data is collected in a controlled environment, therapist and patient can use this data to deepen the analysis of the inner bodily processes of the patient. This then can lead to a greater understanding of the patient’s stress reactions and increase the patient’s control over them. For the therapist the data can give a better understanding of the patient’s personal reactions to stress by creating a so called stress profile.

This type of usage can be seen as the base and inspiration to the Affective Health project. There is however a significant difference in how the problem is approached. Rather than being a tool for diagnosing a patient, the Affective Health system aims at increasing self-reflection in everyday
The Affective Health system is intended to be a lifestyle application and not a medical tool. Rather than being used sporadically in controlled environments, the Affective Health system should be used continuously over longer periods of time in users’ day-to-day life. (Ferreira, 2008)

2.1 Obtaining biofeedback data
There are various methods to relate biofeedback data to an individual’s stress reactions. It is e.g. possible to see indications of stress in the saliva or in the tension of the muscles (EEG). Through careful deliberation and testing of different sensor equipment with the requirements that the sensors should,

1. measure bodily features that could capture arousal and adaptability;
2. be comfortably wearable, mobile, and unobtrusive;
3. provide reliable and consistent output with minimal personal variation; and
4. be robust and durable,

it was decided that the measurements that were feasible to capture and could give an indication on stress reactions were: heart rate, skin conductance and movement.

2.1.1 Heart rate
Heart rate is highly related to stress. For a better signal quality a type of electrocardiography (ECG) is used rather than a sensor made especially for measuring heart rate. Heart rate is commonly used and referred to and is easy to conceptualize for end-users.

2.1.2 Arousal
Skin conductance is not as familiar as heart rate to common people, but it is a measure of arousal. It is measured through applying a constant voltage to two points of the skin. The flow of the current will vary depending on the conductance of the skin. The conductance varies as a result of dilatation and perspiration in special sweat glands (eccrine glands) found in high concentration on the forehead, on the palms and on the feet. These fluctuations vary rapidly and are known as galvanic skin response (GSR). Since the behavior of the eccrine glands is related to a person’s level of arousal GSR can be seen as a measure of arousal.

2.1.3 Movement
Heart rate and skin conductance can be affected the same way from stress and physical activity. And as the responsibility for interpreting an increase rests with the user, it is important that the user can make a distinction between the two. Because physical activity will render similar biofeedback data as a stress reaction in reference to heart rate and GSR it was important to also bring in the aspect of bodily movement. A simple accelerometer is used for this purpose.

2.1.4 Sensors
To measure these three variables a total of six sensors are used in the Affective Health system. Two sensors are used for the GSR, three sensors for the ECG and one for the accelerometer. Technically the accelerometer contains three sensors, one for each dimension x, y and z, but they appear to the user wearing them as only one sensor. The placement of the sensors can vary but it was found that the best way to place them during the tests were according to Figure 2.1. Placing the ECG on the fingers using a small strap mostly gives the best signal, but it can be obstructive to the user. Placing
the sensor on the fingers means that they need to be removed for bathroom activities, washing up dishes or activities where the sensors are in the way or risk being damaged. They are also in clear sight for other people. There are many reasons to why a user might want keep the sensors concealed may it be only to avoid bringing up the subject of the system and its purpose in conversations, after all the system is meant to blend in to everyday life. Given these reasons the wrist is the better placement for the GSR sensors, as it has proven to give a good enough signal in most cases.\footnote{The quality of the signal for various placements of the GSR-sensors was decided by informal tests.} The three ECG sensors can also be placed in various constellations, but a way of placing them that has been shown to give a good undistorted signal is with one sensor on each collar bone and one sensor by the lowest rib on left side of the body, the heart side. The accelerometer can be placed anywhere as long it follows the body’s movement, typically in a pocket. The ECG and GSR are attached to the body using stickers. These stickers needs to be replaced every once in a while depending on the user’s actions. Sweating and exposing the stickers to water will shorten their durability. The stickers typically need to be replaced at least once a day.

![Figure 2.1 An illustration of how the sensors are placed and then connected to the hub. This image is taken from a manual made for the user study to help explain sensor placement.](image)

### 2.2 Visualizing the biofeedback data

There are many different ways of representing the biofeedback data in order to make sense of it. But to avoid it becoming a simple diagnostics tool and approaching good visualization for self-reflection it can be argued that using graphs, diagrams or other conventional methods should be avoided. Instead, an interface utilizing an open and ambiguous visualization encouraging the user to interpret and read meaning into it should be used. This approach is based on Boehner et al. (Boehner, DePaula, Dourish, & Sengers, 2005) whom suggest a set of guidelines for design that view emotion as something that can be constructed through interaction. Hopefully this would allow users to experience emotion from interaction rather than just inferring it from data values. This is based on the view that emotions are too complex and diverse to simplify as discrete values. Further, Boehner et al., suggest that these principles give systems that will mirror users’ emotion in a rich form which would allow a more personal interpretation, and possibly a changed behavior. It can be seen as unique for the Affective Health project to implement such an, affective interactional, approach to represent biofeedback data. What the principles of affective interaction means for the Affective Health system is to step
away from discrete states (such as e.g. emoticons) to represent emotions when designing the system. This would make it easier for the user to read their personal meaning into the representation.

An earlier study using two types of interfaces in a Wizard-of-Oz study\(^2\) had showed that users desired *ambiguity and openness to interpretation, interactive history of prior states, fluency, and aliveness* (Ferreira, 2008). The interfaces used to draw these conclusions were not proper working applications, but the results has served as a base for the further development.

![Figure 2.2 The interface used in the Wizard-of-Oz study. The color of the dots represents arousal. The dots pulsate corresponding to the user’s movement. The circle represents the adaptability. A large smooth circle represents a good adaptability while a smaller circle with rough structure means an inability to adapt to changes and would be a reason for concern. (Ferreira, 2008)](image)

By combining heart rate and skin conductance into one weighed value it is possible to get a more accurate measurement of stress reactions (Sanches, 2010). But since the heart has such a fundamental function in our bodies it seemed sensible that it would be represented by itself. It is also very well understood and does not require medical interpretation. Recent work in interactive body-centered art has shown that an immersive experience by using the rhythm of the heart can be achieved. An example is George Khut’s work where he makes use of biosensors in interactive artwork, turning visitor’s heartbeat or skin conductance measurements into colorful, suggestive, organic shapes. (Khut, 2010) So to avoid losing the aliveness that the heart rate contributes the ambition is to portray it as organic and pulsating and by itself.

Fluency was considered important as it was found that to have an active interface that is also pleasant to interact with, it is important that changes in the interface happen in a fluent way. In this case it means smooth transitions between changing colors and animations. For example the change between two colors is done by blending the two colors and incrementally increasing the new color.

The first fully functioning version was the *Layer interface*, seen in Figure 2.3. The interface design was inspired by leaves falling to the ground. The user’s most recent state is shown at leftmost top falling on top of previous states which move towards the rightmost bottom building layers of historical data. Each layer represents a mean value of one minute of data. The topmost layer shows the data in real-time and when a whole minute has passed it be will summarized (using the most prominent biosensor data averaged from the whole minute) letting it fall down to the top becoming another layer and thereby adding it to the history. In the Layer interface the heart rate is visualized by a circular shape pulsating with the heartbeats. Accessing the parts of the history was done by scrolling

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\(^2\) A Wizard-of-Oz study is a type of study where subjects interact with a seemingly autonomous computer system. However it is in fact controlled by an unseen human being.
back in time by pushing layers upwards or downwards, using the finger or the stylus pen of the mobile.

As mentioned above stress and physical activities may have similar looking data given skin conductance and pulse. It is therefore important to be able to distinguish contrarieties quite clearly while still retaining ambiguity and interpretative openness. This has consequently been done through adding the accelerometer data representation to the interface. In the Layer interface movement was portrayed as a spinning star-like shape. A faster rotation speed represented more physical activity.

This was one of 15 different visualizations that had previously been designed and discussed in the project.

It should be mentioned that the platform to which the Affective Health system was developed was the mobile operating system Symbian. And the smartphone used to test the application has consequently been a Sony Ericsson P1. This device has a touchscreen measuring 2.6 inches in size with a resolution of 240 pixels wide and 320 pixels high.

Figure 2.3 The Layer Interface

2.2.1 The Spiral Interface

The second fully working version, the Spiral interface which is the interface treated in this thesis, utilizes a circular way of representing time. The interface allows users to view their data in a continuous way rather than standard units as in the Layer interface. The underlying idea of the design is the thought of time as cyclic and constructed of reoccurring resembling periods. This can be seen in religions such as Hinduism or in the Gregorian calendar.

Please note that the grey scale images are mock-ups while the colored images are actual screen shots of the application.
2.2.1.1 The basic appearance and functions of the spiral

The spiral consists of two main components (Figure 2.4). The center of the interface always shows the real-time biofeedback data; the user’s current status that is. This data then grows outwards from the center into the spiral creating the history.

Being able to compare similar sets of time with each other is one the thoughts behind this design. Minutes, hours and days will be aligned so that the same periods of different units will be found at the same angle from the center (see Figure 2.5). This facilitates users in comparing, helping them to find patterns in different parts of their data.

The application consists of three similar looking views. Each view shows the data in the same way except that the time scale differs. As the spiral ribbon represents historical data each revolution symbolizes a standard time unit, meaning that a revolution can either represent one minute of data, one hour of data or one day of data depending on which one of the three views is used.
Figure 2.6 The three views of the application. In the left-most view each revolution is one day. In the middle view each revolution is one hour and in the right-most view each revolution is one minute.

At the top of the screen is a time label (Figure 2.7). What is shown in this label is decided by the focus area. This is a small outlined box linked to the spiral ribbon which can be moved around by the user. This is done by tapping anywhere on the spiral ribbon. The time label then shows the interval of time contained inside the focus area. The focus area is also the link between the three views. When changing view from the left-most view to the middle view in Error! Reference source not found. The three hours in the focus area will be the three hours appearing in the spiral ribbon in the middle view. The same principle abides when changing from the middle view to the right-most view.

The user can spin the spiral ribbon in any direction. To move to past history the spiral ribbon is spun towards the center (Figure 2.9). To move towards the present the user then can spin away from the center (Figure 2.8). It is also possible to move beyond the present into the future (where no data is found).

The whole spiral ribbon rotates, while the center remains fixed in position. This means that the spiral ribbon disconnects from the center creating a disjoint between the two (Figure 2.10). As the center displays the real-time data at all times there will be a graphical mismatch here.
Spinning is achieved by pressing a finger (or a stylus) against the screen and then moving it in a circular motion. This is the main method of getting to and viewing different parts of the biofeedback data. It is also possible to quickly get back to real-time by double-tapping the center. This reconnects the spiral ribbon with the center and actively updates it as if it is flowing out from the center.

It is possible to get a closer perspective of the spiral ribbon by keeping the finger pressed on fixed position anywhere on the screen for a shorter period. This renders a zoomed-in perspective as seen in Figure 2.11. In this perspective it is possible to press and drag the finger around the screen to move to different parts of the view ("the zoomed-out perspective"), much like common map applications like e.g. Google Maps.

If there is no data gathered for certain periods of time or is missing for other reasons a thin line will be visible as can be seen in Figure 2.12.

As can be seen in Figure 2.6 there are guidelines (the grey lines radiating out from the center) that are thought to aid the user in navigation tasks. The guidelines are set to divide the standard time units into smaller parts. In the middle view one guideline represents 0 minutes, the next guideline represents 15 minutes, the next one 30 minutes and then 45 minutes. In the right most view the guidelines represent 0, 20 and 40 seconds and in the left-most view they represent 0, 6, 12 and 18 hours.

**2.2.1.2 Representation of data**

Please refer to Figure 2.14 and Figure 2.13 while reading this section for a better understanding.

The center and spiral ribbon consists of four tiers as can be seen for instance in Figure 2.6. The bottom tier is colored with a varying color which symbolizes the value of the skin conductance. The scale can be seen in Figure 2.13 where dark blue represents a low value passing on through green, yellow, red and finally dark red which represents the highest value. On top of this are one black semi-
transparent tier representing pulse and one white semi-transparent tier representing movement. The value is represented by the width of these tiers. A narrow tier represents low pulse or movement while a wide tier represent high pulse or movement. On top of these, in the center, is a narrow tier which also represents the skin conductance. The difference between this tier and the bottom one is that the latter one displays a mean value over time while the former one shows an unprocessed value causing it to appear more active with faster alterations. The aliveness of the heart is captured in the center of the spiral which is pulsating with the heartbeats.

![Color Scale](image1)

**Figure 2.13** The value of skin conductance is translated into this color scale

![Diagram](image2)

**Figure 2.14** The different elements of the biofeedback data representation shown in a cut-out of the spiral. Please note that these colors may be a bit different from the ones used in the actual application.

### 3 Objective of this thesis
The objective of this thesis has been to evaluate and improve the interface of Spiral interface. This has been done with several aspects in mind namely achieving a higher degree of usability while not compromising the properties like those stated above.

- Improve and evaluate the interface and the system
- Evaluate how the method of User-Centered System Design works for abstract requirements

### 4 Theoretical framework

#### 4.1 Visualization
When visualizing data it is important to remember that our mind and perception have certain limitations and behaviors. The short-term memory can only store from three to nine chunks of visual information at a time. (Few, 2006) This means if something more than, at most nine chunks, is to be stored in the short term memory then something has to fall out. Keeping this in mind is essential when designing systems that require the users to keep track of several types of data. It is important
not to solely rely on the short-term memory. This can be done by keeping all the information needed visible at the same time.

Once visual information reaches our eyes it is stored in the so-called iconic memory. The information is held there very briefly, but still there is time for a preconscious type of processing. This is called preattentive processing. This is where we recognize things that stand out and this is where we recognize patterns such as grouping of objects. Humans are pattern-seekers by nature, and preattentive processing will happen without consideration to conscious logic analysis or learned behavior. It can very quickly emphasize what needs attention by the user (see Figure 4.1). This is why this is so important to consider when designing systems for visual information. (Few, 2006)

Figure 4.1 A few examples of how visualization can make us notice or group objects through preattentive processing. The examples illustrate how the principles of color, size, grouping, shape, enclosure and position (from left to right and top to bottom).

4.2 Iterative user-centered development
As a base for the method of improving or developing a system I have used Key principles for user-centred systems design (Gulliksen, Göransson, Boivie, Blomkvist, Persson, & Cajander, 2003). It states twelve principles that can be seen as a way of applying a user-centred system design approach to a development process. Each principle should be linked to an activity concretizing it. In respect of the small scale of the project, the short period of time for development within the frames of this thesis, the limited number of people fully dedicated to the project and so on, some of the principles/activities have been more or less included in the process. But as Gulliksen et al suggests, all
principles aren’t always applicable. But exclusion needs a valid motivation, and has to be agreed upon. The principles are as follow:

- **User focus** – the goals of the activity, the work domain or context of use, the users’ goals, tasks and needs should early guide the development
- **Active user involvement** – representative users should actively participate, early and continuously throughout the entire development process and throughout the system lifecycle
- **Evolutionary systems development** – the systems development should be both iterative and incremental
- **Simple design representations** – the design must be represented in such ways that it can be easily understood by users and all other stakeholders
- **Prototyping** – early and continuously, prototypes should be used to visualize and evaluate ideas and design solutions in cooperation with the end users
- **Evaluate use in context** – baselined usability goals and design criteria should control the development
- **Explicit and conscious design activities** – the development process should contain dedicated design activities
- **A professional attitude** – the development process should be performed by effective multidisciplinary teams
- **Usability champion** – usability experts should be involved early and continuously throughout the development lifecycle
- **Holistic design** – all aspects that influence the future use situation should be developed in parallel
- **Processes customization** – the UCSD process must be specified, adapted and/or implemented locally in each organization.
- **A user-centred attitude should always be established.**

### 4.3 Measuring affective responses

The Sensual Evaluation Instrument (SEI) was developed as response to research among psychologists and neuropsychologists which in recent years suggested that our logical and conscious verbal manner does not capture or explain all our actions or feelings. (Höök, Isbister, & Laaksolahti, 2006) The SEI was especially designed to deal with affective processing. It has been shown that much of the brain activities in this area happen at other levels than cognitive and word-oriented processing. Using the physical figures shown in Figure 4.2 subjects can express feelings or attitudes without having to formalize them into words. They key benefits of this are thought to be that it:

- Preserves benefits of subjective measures (easy to use, portable, and empowering to user).
- Transcends language and cultural barriers.
- Provides results more in line with current research about affective processing—potentially less distortion through the ‘lens’ of the verbal mind.
- Is more fun for the user!
Figure 4.2 The Sensual Evaluation Instrument

5 Method
When I joined the project there was no finished plan for how the study should proceed. On my suggestion we decided to have an iterative approach according to Gulliksen et al’s method. Each of the iterations would preferably involve at least one or two user studies.

To properly evaluate the system’s ability to encourage self-reflection and how well users can identify with the representation of biofeedback data it was crucial that the user tests were performed on the subject’s personal data and not on generic test data.

It should be mentioned that the people involved in the project varied a bit over time. Most of them were also involved in other projects. There was one developer which was the only one who worked full-time on the project. It should also be mentioned that the project has its origins in previous master theses and that some original actors no longer were included in the development. This is why there was no clear project plan or development method at this point. This can obviously be expected when actors are involved for shorter periods.

5.1 Iterative user-centered development, 5 iterations
The ambition was to include as many of Gulliksen et al’s twelve principles as possible. There was no specific time span set for each iteration. Since the time for the whole project was quite short the iterations were also made short so that as much improvements/changes as possible could be made and tested. As parts of the team were involved in other projects and for other reasons absent from time to time there was generally only one group meeting per week. This meant that iterations had to be fitted to these meetings since new versions of the application had to be discussed and agreed upon by everyone in the team. This in combination with the scheduling of test subjects decided the pace of the iterations.

As the development process was very user-centered during this period the start of an iteration was defined by when a new version of the interface was tested for the first time. As mentioned above this time differed for each iteration depending on how many tests we felt were necessary.
5.2 Involvement and documentation

At the beginning of my involvement in the project there was no clearly stated method for the design process. That is why a part of the work has been to introduce a standardized documentation routine for system development, to introduce an iterative design process and to try to coordinate involved actors towards this approach.

To increase involvement in the design process, to centralize information involving the design process I decided to use a wall in the office were each iteration was posted. Here feedback and ideas was available to everyone in the project. The ambition was that everyone would use it to centralize information. I tried to press on documenting feedback and reasons to changes in the design. If there was a change made, what were the reasons? The reason could be a personal opinion or user feedback. So during an iteration opinions, feedback or ideas could be posted here by anyone. All ideas would be documented, but not all implemented. In group meetings it was decided which ideas should be prioritized.

For each iteration a sheet describing its properties were posted (Figure 5.1). Everyone were then free to post comments and suggestions here. Orange post-its were used for internal feedback (from team members), yellow post-its for external feedback (from user tests), green post-its were used for ideas that were to be implemented or already had been implemented during the iteration, and purple post-its for ideas that would not be implemented during the iteration. Team members were also allowed to scribble and encouraged to connect feedback with ideas for improvement by drawing lines.

Figure 5.1 An iteration documentation sheet at the beginning of an iteration
When testing started on a new version of the interface all posts from the sheet were defined and printed out as seen in Figure 5.2. This then replaced the sheet with post-its on the wall.

This was done mainly for my own interest in writing this thesis as I needed information about all the changes done to the system. Although I think it can also be a valuable resource for further development.

5.3 Test subjects

5.3.1.1 Selection of test subjects

All test subjects served voluntarily. Almost all who applied got to participate in the test. The subjects were gathered partly through posters and partly through spreading the word through my social network. The posters were put up in office hallways in the Electrum building in Kista and in hallways at different departments of Uppsala University. The reason only known persons and people in the near vicinity were prospects was that the sensor equipment is quite expensive and there was a small concern about giving it away to strangers. That is why it was decided not to advertise the test in public spaces.

It was decided from the start that all participants should be speaking Swedish as their native language. Even if an individual has very good knowledge of a language and speaks it fluidly, the knowledge of the native tongue shouldn’t be underestimated. Especially in a case like this where it is required to put words on feelings and abstract entities. If the test leader and the subject speaks the same native language it should open up for a clear and undistorted verbal communication.
As a token for the subject’s contribution to the study they received a voucher for the cinema valued 200 SEK (Swedish kronor). This was both to make participation a bit more attractive and to put a value on the effort done by the subjects.

5.3.1.2 Age and gender distribution
The gender distribution was even. In total four males and four females participated. The age distribution was very narrow. Seven of the eight subjects were between 22-28 years old.

5.4 User testing
The subjects were asked to wear and use the whole system for approximately four hours, while conducting their everyday activities. The activities had quite a wide range and included studying, working, doing household chores, cooking and bicycling, amongst others.

The starting time of the test was decided by when the subject had an open slot for an interview. Thereby the start of the test was scheduled to four hours before this time so that a sufficient amount of data was captured. We also tried to make sure that the sensor gear wouldn’t interfere too much with what the subject would be doing. We did not want the sensors to stop the user from e.g. going to the gym or having an important meeting. That meant that the time set for the test also had to be when the user had “sensor friendly” activities planned.

Subjects’ experiences are hard to quantify, especially when it comes to subjective parameters such as personal emotions and reflections. A combination of their statements and my observations of their usage of the system found the base for the data that is seen as the result.

5.4.1 Semi-structured interviews
All interviews were carried out individually as soon as the subject was finished with the testing. The idea of this was to capture all of the subject’s thoughts while still fresh.

5.4.1.1 Set of questions
Not only usability was addressed in the questionnaire, but also wearability of the sensors, representation and comprehension of the biofeedback data, perceived identification with the representation. We wanted to address the previously requested properties namely ambiguity and openness to interpretation, interactive history of prior states, fluency, and aliveness. The questionnaire can be seen under 11 Appendix A - Questionnaire (Swedish). The questionnaire was used as a guideline. As mentioned above the interviews were semi-structured so that I could follow up on topics brought up by the subjects and skip parts that had already been talked about.

5.4.1.2 Audio recording and transcription
The interviews were audio recorded in whole and then transcribed by a professional.

5.4.2 Tasks
To stimulate the subject in an attempt to increase reflections on the interface different tasks were used. The tasks were constructed with an intention to be of a simple and straightforward type. In general three tasks were given regarding usability and navigation. These were:

- Show a detailed view of 14.15.
- Show an overview of the period from 12.00 to 13.00.
- Show an overview of the whole day.
This set of questions was constructed to evaluate the most basic tasks of the interface. An assumption was made that the time navigation function of the application would be poor if these tasks proved too difficult or tedious. It is also assumed that navigating in historical data is an important part of the application’s functionality. Another set of tasks were used a bit further down in the questionnaire.

- **Show me the data from when you ate lunch. Tell me what you see.**
- **Can you show me a period of time where you reacted strongly in a situation?**

These tasks required from the subjects, in contrary to the first set which was more or less a way of verifying how well the history navigation worked, to use more inputs given by the system. This means that the user had to make conclusions based on the graphical representation and the timestamps combined with personal memories of the period.

After each of the tasks followed an open question about how the user had perceived the task, if it was difficult or easy and why this was the case.

All of the tasks, but especially the former set of tasks, also had another intention; namely giving an idea about the level of difficulty the subject experienced with these simple tasks. Observing the user’s actions while trying to perform the tasks gave an idea about factors such as confusing elements, interfering and missing interactions and information given that might be misleading or shortcoming. Although all the tests are divergent due to the subjects’ individual differences, this would also give a clue about task completion time for the specific task.

**5.4.2.1 Video recording**

To be able to go back and review the subject’s interaction with interface all interviews were also video recorded. This was helpful because often the user’s wanted to point to an element in the interface or use hand gestures to illustrate what was difficult to verbalize.

A difficulty that I encountered was getting a good shot of the screen. As the light in the environment for the interviews differed from time to time it proved difficult the get settings on the camera that resulted in a clear picture of the screen. Despite this it is still possible to get an idea of how the subject is interacting because of the small variation in interface layout. There will always be a spiral and the same set of buttons in the interface.

The video could also be used to time the tasks the users performed. This was not done because of the small number of subjects in each iteration didn’t provide enough material for quantitative measures as such. There was no point in comparing the task completion times between each iteration as it was almost certainly too heavily influenced by individual differences.

**5.4.3 Using the Sensual Evaluation Instrument**

This part of the questionnaire can be viewed as experimental, and as an attempt to capture feelings and opinions that can be hard to put into words and that perhaps do not have to be put into words. This part was deliberately put at the end of the interview so that it wouldn’t interfere with the parts that were more certain to yield results.

The subjects were shown all of the figures and got a short explanation of their purpose. They were then asked to pick a figure that best suited their attitude towards different aspects of the system. An
example is “Which figure best symbolizes what you feel when navigating in the history?” or “Which figure best represents how the bio feedback data is visualized?”. After the subject had selected a figure they were asked to explain why they had selected that particular figure and what feelings they had towards the figure. In Figure 5.3 the figures have been numbered in no particular order for future reference.

![Figure 5.3 The SEI numbered for reference purposes](image)

### 6 Result

At the beginning of the iterative user-centered design process the interface has the properties and appearance described in 2.2.1 The Spiral Interface.

#### 6.1 Iteration 1

The first iteration involved no formal user testing as described in 5.4 User testing. Instead I gathered my own opinions and impressions, as the interface design was completely new to me, and suggested changes based on my knowledge of usability and interaction design. I also performed a few informal user tests. There were also several group meetings where issues with interface were discussed.

One issue that was brought up was that the difficulty to know where you were going (back in time or forward in time) when spinning the spiral ribbon, especially for users new to the system. The only way to know this was by paying attention to the digits in the time label to see if they were decreasing or increasing or by perceiving whether the spiral was spinning towards or away from the center and understanding the meaning of this. We decided to add labels to the guidelines. These labels where added at the end of each guideline and can be seen in 6.2 Iteration 2. This could be a possible aid for the user giving a visual cue to what precedes and what recedes a certain point thereby knowing in which direction to spin. This could also be helpful for the user to find certain times in the spiral ribbon.
It was also thought that the amount of visual information displayed at the same time was quite overwhelming. A cross section of the spiral could contain up to six different colors due to the two tiers representing skin conductance displaying one color each, and the intermediate semi-transparent tiers which altered the hue of the bottom tier (as can be seen in Figure 2.14). Two ideas that was discussed and later implemented were:

- Representing pulse as color
- Removal of the short-term arousal tier

By representing the pulse with the same color scale as the skin conductance and using this color for the tier representing movement it reduce the number of tiers by one (Figure 6.2). It was also unclear whether the short-term skin conductance actually fulfilled any purpose as it was the same data as the bottom tier, and if it was really necessary to have both. So to further simplify this tier was also removed.

The map-like navigation when using the zoomed-in perspective had a slightly chaotic feel. There was no time label visible so the user had to remember the current time that was being viewed, scroll to the top to view the time label or zoom out to view the time label. It was then decided that we should try only allowing the user to zoom in to the top of the view. This would keep the time label visible even though the perspective was zoomed in. Instead of the user moving the perspective, it would be fixed and the user would be able to spin the spiral like in the standard perspective.

Using a “tap and hold” interaction for zooming in proved to be interfering with spiral navigation (spinning the spiral). If users hesitated for a moment when spinning the spiral the result would be going to a zoomed-in perspective instead. That way it seemed better to use a double-tap interaction to zoom in instead.
It was unclear to why the background had the appearance it had, so it was decided that it should be changed to something simpler like a gradient or a solid color. This would isolate this factor from interfering with the understanding of the representation.

Changing views between the views proved to be very difficult and it interfered with other interactions like spinning the spiral. It was debated how this could be done in other ways. While this was discussed and tried in development a temporary solution was implemented. This solution meant changing views by using a hardware scroll wheel on the side of the mobile phone.

6.2 Iteration 2

<table>
<thead>
<tr>
<th>Change views:</th>
<th>Hardware scroll wheel on the side of the Sony Ericsson P1.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zooming:</td>
<td>To zoom, double-click anywhere on the spiral ribbon. The zoom view is a fixed close-up of the top part of the spiral. In this view it is possible to spin the spiral as in the regular perspective.</td>
</tr>
<tr>
<td>Focus area:</td>
<td>Focus area is in a fixed position. It has different colors for the different views.</td>
</tr>
<tr>
<td>Time label:</td>
<td>The time label is fixed at the top of the screen.</td>
</tr>
<tr>
<td>Guidelines:</td>
<td>Appears as mentioned in 2.2.1 but with labels on each guideline.</td>
</tr>
<tr>
<td>Visual feedback:</td>
<td>-</td>
</tr>
</tbody>
</table>

6.2.1 Feedback

6.2.1.1 External

6.2.1.1.1 User Opinions
The glitch between present time (the center) and historical time (the spiral ribbon) that occurs when spinning the spiral proved to be a bit confusing and unclear (Figure 2.10). It looked as if though the spiral ribbon and the center still were connected, but the data did not fit together.

One subject was frustrated with the small screen and said that a bigger screen would be better. There was too much information crammed in to a too small space. This made it difficult to focus. The subject suggested that users should have the possibility to view historical data on a computer as well. The subject also suggested that a more linear representation of historical data should be an option. It
would feel more familiar and it would be easier to understand the chronology of the data, the subject explained.

The center of the spiral had at this point an overlaying texture which altered the GSR color to a more or less brownish color. Subjects questioned this asking by why this was brown and not corresponding to the color of the GSR seen in the spiral ribbon.

When spinning the spiral the numbers of the label where changing so fast that it was hard for the subjects to know which direction in time they were going. The label showing the time proved to be a bit hard to understand and read. Another possible cause is that the gap between the label and different points in the spiral since it requires flicking the eyes between the points tapped in the spiral and the time label at the top.

User observations showed that the zoom-in function constantly interfered with the spiral navigation. This was due to that a long-press was being used to zoom in. If the user intended to scroll, pressing the screen, but hesitated in starting the circular movement the application would zoom in instead. Over all navigating and spinning the spiral and making sense out of it was still too difficult. Understanding how the spirals were connected through the focus area was also a problem.

6.2.1.2 Internal
In group meetings we discussed a few matters. One of the issues that was addressed was that there was no visual feedback when the application changed view on the user’s command. The only way of telling when the view changed from e.g. minutes to hours was by observing that the label had changed. It was agreed that this was far too subtle.

The fact that the user had to remember how the three spirals were connected and which was the most detailed was another issue that was brought up. We felt there was a need for an onscreen guide to help users know “where they were” in the application.

We also agreed that using the wheel on the side to change views was just a temporary solution since it is hardware specific and will not work on other devices.

6.2.2 Reflections and ideas for improvements

6.2.2.1 Implemented ideas
It was realized that the illogical gap between past and present had to be visualized. A simple solution that was implemented here was to completely remove the center when the user is spinning the spiral.

A floating time label was implemented. This would show the time label where the user taps the spiral instead of showing it at the top of the screen. Hopefully this would be easier for the eye, and wouldn’t require as much eye movement to connect points on the ribbon with the time they represent. This also led to the removal of the guideline labels. As their purpose also had been to guide the user to where certain periods of time could be found in the spiral, the need for both couldn’t be justified. It was better to make the screen less cluttered and the bio data more visible.

To aid users when spinning the spiral and navigating historical data, music player arrows (fast forward, rewind and play) were added to make it easier to see if you were going back or forth in time.
Adding on-screen buttons for changing views would resolve several issues. They could be ordered and visualized to help the user understand the order and meaning of the view. Simple circles were used. When a view was selected the corresponding button would be colored black thereby telling the user which is the current view. This would also solve the issue with the hardware specific wheel mentioned above.

An animation was added when the view changed from one to another. This should function both as a response from the application and as an illustration to how the focus area link the spirals together.

The texture was removed from the center which resulted in a clear view of the color of the GSR.

6.2.2.2 Postponed ideas
As a response to subjects finding the amount of information to large it was suggested that users should have the option to select what data should be visible. Three buttons should be added one for GSR, one for ECG and one for movement. Then the users could view only the data that were interested in. This idea was not implemented here due to lack of time.

6.2.3 Results from SEI
In response to the feeling of using or navigating in the interface one subject started by comparing Windows XP with figure 7 and Mac OS with figure 1 explaining that the former has a rugged feel while the latter feels smooth without interruptions. The subject chose figure 8 for the Affective Health interface explaining that it felt somewhat sprawling but that the spinning interaction felt smooth and followed the finger nicely. The second subject also chose figure 8 motivating it by it not being completely streamlined but not rugged and inaccessible like figure 7 either. The subject also referred to it as a bit erratic and expressed that a desirable feeling would be more like figure 2 being predictable and streamlined.
### 6.3 Iteration 3

<table>
<thead>
<tr>
<th>Change views:</th>
<th>Using on-screen buttons seen at the top of the screen. The left-most one brings up view I, the middle one brings up the view II and the right-most one brings up view III (Figure 2.6).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zooming:</td>
<td>To zoom, double-click anywhere on the spiral ribbon. The zoom view is a fixed close-up of the top part of the spiral. In this view it is possible to spin the spiral as in the regular perspective.</td>
</tr>
<tr>
<td>Focus area:</td>
<td>The focus area appears where the user taps the spiral.</td>
</tr>
<tr>
<td>Time label:</td>
<td>The time label is floating. It appears where the user taps the screen. It’s angle is dynamic towards the center of the spiral.</td>
</tr>
<tr>
<td>Guidelines:</td>
<td>Only one guideline marking the start and end of a time unit (minute, hour or day).</td>
</tr>
<tr>
<td>Visual feedback:</td>
<td>When changing the views there is an animation stretching or compressing the spiral depending on between which views the user changes. There is also a label stating e.g. “Switching to hour view”.</td>
</tr>
</tbody>
</table>

### 6.3.1 Feedback

#### 6.3.1.1 External

**User Opinions**

When trying to cognitively connect a segment in the history with a real life event one subject brought up the idea of additional user input. The subject had difficulty remember exactly what history segments belonged to which events. So the subject requested the function to input text into the application when something notable occurred. This text should then be represented by a marker at the particular time. This would be a good aid when reviewing the history was the subject’s motivation.

There was some critique towards the names of the screens. The view where each revolution in the spiral is one minute was at this point called “Seconds view”, the view showing three hours was called “Minutes view” and the view showing three days was called “Hours view”. These names referred to the amount of time in the focus area. The subject pointed out that it would be more logical to name the view according to the amount of time of one revolution in the spiral.

Another critique towards the different screens was their similarity. As all three view’s spiral ribbon and center have exactly the same appearance the subject found it confusing that they all looked the same. How they were connected was very abstract the user pointed out. It was not clear how the spirals could fit into each other. The user said that it would make more sense if the user wanted a more detailed view of a portion of a spiral it would be as straight line and not as another spiral.
The focus areas provided two confusing issues. One was the color of the focus area which varied depending on which view was selected. The idea was that this color should be linked somehow to the view it represented, either using some background color or by coloring the view selection buttons accordingly. Since this part had not been implemented the colors had no context and therefore confused the subject. The second issue was a bug when looking at data in a zoomed-in view. The focus area would simply not appear where the subject tapped the screen but at another seemingly random place.

One subject thought that a complimentary application for use on a computer would be useful finding it hard to get a good overview on the small screen of the Sony Ericsson P1.

Observing the subjects when interacting with the new floating time label gave the impression that it was easy to use and that it worked in the way that it was intended. The subject was a bit frustrated that the label had a different angle towards the center rendering it to be upside down on the left side of the screen. This required the subject either to read the digits upside down or turn the phone upside down. The subject did not see the purpose of this.

The onscreen navigation buttons for changing between the views seemed to be the best solution so far. The way to interact seemed simple to understand and it didn’t interfere much with other functions in the application. It also served as a cue to which view the subject was currently using and what other views there was as well as how they were related.

Observing and asking about the guide arrows didn’t give any clear answers to whether they actually helped the subject. It seemed the tasks didn’t really require the aid of the arrows. The arrows also became partly obscured by the finger used to spin the spiral.

6.3.1.2 Internal
It was suggested that the newly implemented guidance arrows were too big thereby taking too much attention and obscuring the spiral and the biofeedback data when spinning the spiral.

6.3.2 Reflections and ideas for improvements
6.3.2.1 Implemented ideas
To approach the issue with the readability of the time labels we decided to try to flip the label at the top of the spiral and the bottom of the spiral. This means that the label never would be more than 90 degrees of from 0 degrees and therefor easier to read.

It was agreed to change the names of the three views to what the subject had suggested. The names used in this version had not been chosen with thought of the users; it was rather an old convention that had remained.

To resolve the issues with the focus area it was decided to change the color of all the focus areas to black. This would be easier than to go through with the idea with color coding each view in some way.

To approach the issues mentioned with the guidance arrows it was decided to decrease them in size and move them to the top left of the circle. This would keep them in sight at all times when spinning the spiral and they would not cover any part of the representation of biofeedback data.
6.3.2.2  Postponed ideas
There were several ideas to address the issue of the similar looking spirals. One of them was to make the spirals look different from each other, e.g. using different numbers of revolutions for the different views. Another idea was to do what the subject had suggested; use only one spiral and a more linear view of the segments for more detailed views. A third idea was to use an animation showing exactly how the spirals go together. All of these ideas were deemed to be too much work for one programmer in the given amount of the time left of the project.

6.3.3  Results from SEI
In response to the feeling of using the interface a subject chose figure 6. The choice was motivated by that the figure has a few obstacles and bumps but they are not spiky or completely prohibitive. The look of the interface was also best described by figure 6 as there is a lot of information and there is many things happening on the screen all of the time, but it is still not intangible or too disturbing. The subject would rather see that the interface resembled figure 4 as it was described as simple, and easy to understand and free from obstacles. The other subject thought that figure 7 best fitted their experience of using the interface as it was sprawling and confusing compared to the preferred feeling of figure 3 which represented balance, simplicity, flow and being a part that fits in (at the same time showing how it is easy to grasp and fits in the hand).

6.4  Iteration 4

| Change views: | Using on-screen buttons seen at the top of the screen. The left-most one brings up view I, the middle one brings up the view II and the right-most one brings up view III (Figure 26). |
| Zooming: | To zoom, double-click anywhere on the spiral ribbon. The zoom view is a fixed close-up of the top part of the spiral. In this view it is possible to spin the spiral as in the regular perspective. |
| Focus area: | The focus area appears where the user taps the spiral. |
| Time label: | The time label is floating. It appears where the user taps the screen. It’s angle is dynamic towards the center of the spiral. The text flips at 0 and 90 degrees. |
| Guidelines: | Only one guideline marking the start and end of a time unit (minute, hour or day). |
| Visual feedback: | When changing the views there is an animation stretching or compressing the spiral depending on between which views the user changes. There is also a label stating e.g.: “switching to hour view”. Smaller guideline arrows as can be seen in the picture. Different shades for the background in the different views. |
6.4.1 Feedback

6.4.1.1 External

6.4.1.1.1 User Opinions
A modification to the applications way of storing history was made. This caused an artifact in the form of a visual glitch in the bio data visualization in the spiral as can be seen in the screenshot above. This glitch got a lot of attention from the subjects and thereby served as a distraction.

Due to the old way of navigating between the three views, it was not possible to go from the day view directly to the minute view or vice versa. Using the wheel or the swiping motion did not allow these navigation operations since moving from minutes to days (or the opposite) always required passing the hours view. This new button solution gave the appearance that it was allowed to jump directly to any screen. The subjects wanted to do this and were frustrated when it didn’t work.

It was noted that subjects had to tap a lot as a cause of the new floating label. As there was no fixed place indicating the time at all the subjects had to tap a lot before finding the right time. There was also a problem with the time label when spinning the spiral as it was not possible for subjects to read it since the label spun with the spiral.

It started to become clear that subjects had some problems understanding the chronology of the data in the spiral form. This means that it was hard at some points to see what preceded and followed a given point in the spiral. It was also noted at this stage that the spiral seemed to be perceived as a spatial object. This could cause some confusion for the subject as the spiral is seemingly flat. Segments of the spiral compress and expand depending on where in the spiral they are located, but only in one dimension. The length of a segment will vary but the height will remain constant. This both causes the spiral to appear rubbery and distorts the visualization of bio data as it travels along the spiral.

When the application is updating the biofeedback data in real time this is shown very clearly in the minute view, however in the hour view and day view though this is not at all clear.

6.4.1.2 Internal

6.4.2 Reflections and ideas for improvements

6.4.2.1 Implemented ideas
The new floating label seemed to work very well if the subject first had identified an interesting set of bio data and wanted to find out what time it had occurred, but not as well if the subject was trying to find a set of bio data for a particular time. The lack of a time label that was static when spinning the spiral was obvious. Such a label was added which would guide the user when spinning and would refer to the end point of the spiral instead of where the finger touches the screen.

A problem with the guidance arrows had been that when a user spins the spiral the finger will pass the arrows in the opposite direction that the arrows are pointing. To get around this while keeping the analogy to music players, forward and rewind, the spiral could be flipped horizontally or the arrows could be moved to the bottom of the spiral. We were satisfied with the position of the arrows to the top right where they clearly can be seen while spinning the spiral so we decided to implement the other option which essential meant mirroring the spiral. This could be done very easily in code.
6.4.2.2 Postponed ideas

As a response to the observations that there might be a problem grasping the chronology of the bio data and the potential problem of the spatial properties, a possible solution was proposed. If the bio data was to be proportional all the way from center to the end, the spiral would in theory get a spatial depth as can be viewed in Figure 6.3. It would also cause a segment to grow and shrink instead of being compressed and distorted as can be seen in Figure 6.4. It might also make it easier for the user to understand the chronology of the data as is illustrated in Figure 6.5.

Figure 6.3 Spatial aspect of proportional vs. compressed visualization. Compressed data is what is used in the Affective Health application.

Figure 6.4 Distortion aspect of proportional vs. compressed visualization. Compressed data is what is used in the Affective Health application.
Figure 6.5 Chronological aspect of proportional vs. compressed visualization. Compressed data is what is used in the Affective Health application.

6.4.3 Results from SEI
In response to how it felt to use the system the subject chose figure 8. This was primarily motivated by that it was quite hard to get an overview of the interface and the data representation therein. The more preferred figure was number 2 as this had a simpler shape, was easier to grasp both physically and cognitively and not so hard to understand overall.

6.5 Iteration 5 and the final interface

For the last iteration we summarized some of the most prominent and frequent feedback given by
the subjects. As a response to the impression that the information could be overwhelming at times, new buttons were introduced. These would allow the user to select what data should be visible as can be seen in Figure 6.6. This should allow users to better focus on e.g. movement if they are interested in this.

The fact that there was no visualization of the current time posed some problems for users when they had to use other devices such as other mobile phones or wrist watches or asked the test leader what time it was. A simple solution, where the current time is displayed as a floating label when the user taps once in the center, was implemented.

![Figure 6.6 The final result. Showing the same set of data with different data visible. To the far left only skin conductance is visible, the next one to the right is showing only movement, the next one is showing only pulse. The far right view is showing all the three values.](image)

7 Conclusions

7.1 Representation of, and identification with, biofeedback data

- The representation of the biofeedback data worked well. Even though it to some subjects was confusing exactly which color represented what data, e.g. which color represented pulse and which color represented skin conductance all subjects could easily relate the colors to events. This can be seen as a sign that the ambiguity really works. Without having numerical data or at times even a complete understanding of how the representation worked, subjects could still identify themselves in situations like eating, bicycling, meeting people that made them nervous, being forced to tell a lie, feeling awkward about an embarrassing TV show, dancing or simply relaxing.

- A negative aspect of the representation is that it sometimes appeared to react stronger than the subject, meaning that e.g. the color of the skin conductance came very close to the color representing the maximum value even though the subject didn’t feel that their reaction was that strong. This also caused the history to look very swingy, sometimes going from dark blue (the minimum value) to red (the maximum value) back to blue or green again, which did not correspond to how the subject was feeling. This is likely due to noise sensitive sensors or that the system calibration to the subject’s personal values had not been carried through properly.

- Aliveness is mainly achieved in the minute view where the spiral has an apparent movement. Some subjects questioned why the spiral was not moving in the other views. The lack of
aliveness in these views was apparently an issue. It is also in the minute view where the spiral works best together with the center. In the other views the connection between the spiral and the center appear disjoint as the center still shows real time data and the spiral shows a mean value of the data over time.

7.2 The spiral concept

- Merely the visualization of historical data as a spiral can be hard for users to grasp, but even more so when navigating the history.

- Some subjects navigated the history without much difficulty while for others it was nearly impossible to understand how the navigation worked. When spinning the spiral ribbon to view different parts of the history there will be many visual changes as all data in the spiral continuously changes its angle to center. This caused some subjects to feel unsecure, and several subjects actually preferred to just view the data in the minute view.

- One of the issues for the subject’s has been understanding the chronology of the data e.g. understanding what precedes and what recedes a certain point in the spiral, what is the end and what is beginning of a segment of data or what segments follow upon each other. The changes and implementations we made seemed to make it easier for the subjects.

- It is hard to draw any conclusions to how well the spiral design encourages comparisons between time units as there were no spontaneous comparisons made by the subjects under the short test. A longer test period is probably needed to make proper conclusions in this matter.

7.3 Wearability

- The tests have proved that the sensor equipment at times could be worn without the subject feeling hindered by it and at times even forgetting that they were wearing it. This, however, were mostly during sedentary activities like working at a desk, watching TV and indoor activities. Sensors falling off and wires getting stuck in clothes were common and having to remove the sensors to take a shower or to work out was seen as a big inconvenience.

- Some subjects felt awkward with the wires connected to their body and would not want to leave the home without clothing that properly covered all of the sensors, the wires and the hub. Either this would make them feel as being seen as a patient of some sort or they were concerned that it would catch too much attention and that this would make them feel uncomfortable.

- The relatively time consuming procedure of putting on and taking off the sensors was discouraging to most of the subjects. This was said to be a possible factor of stress itself, especially when considering hectic mornings when there at times is not even time to eat breakfast.

7.4 Context

- It became increasingly apparent that context data will be very important if users should be able to draw conclusions from detailed biofeedback historical data. Remembering what has happened the last three or four hours and associating this with the biofeedback data on the
screen is very much possible, but if users should be able to remember what happened a day, a week, a month or a year ago some sort of context data must be a part of the interface.

7.5 Methodological approach

- Having continuous user input gave valuable feedback on all aspects of the system allowing the development team to quickly evaluate new implementations to the system.

- Fast iterations made it possible to try many ideas and implementations. Disqualifying some ideas while keeping others.

- It is possible to incorporate unconventional system requirements such as those of flow or ambiguity into a user-centered iterative design approach. Working with more abstract concepts like these means that it is important to have definitions of what they mean to the design and what their purpose is. Everyone in the design process needs to have a common understanding of what is to be achieved and how.

- Most of the 12 principles were utilized during the development process and this affected the result, but surely not as much as if they had been implemented from the very beginning of the project. Testing already early on using lo-fi prototypes always with an active user involvement will ensure that the development is not lead in an uncertain direction.

- Documenting reasons for changes is important for the development process, especially in user-centered and iterative development process as there will be a lot of feedback and changes done to the system. The documentation should cover every bit of the systems interface and interaction.

8 Discussion

8.1 Representation and identification

Almost all the tests indicate that the representation of biofeedback data is familiar (or intuitive) to the user. There seems to be a unanimous understanding of the way the color is mapped. Users wouldn’t have any problems recognizing motion and physical activities either. When the middle tier grew users could identify this as their motion and explain what had happened when viewing the history. Motion was mostly coupled with color changes in both GSR and pulse.

Mapping the pulse as color in the same way as GSR made the interface look less cluttered. This also made the ribbon appear as more of an entity with a tier in the middle and one tier surrounding. The side effect of this was that GSR and pulse would have different amount of representation depending on the movement. For many purposes this could pose a problem. But as the idea of the Affective Health is to invoke thought and self-reflection, perhaps that is not the case here. Users can learn the significance of representations anyway. If the pulse is narrow, but red in color, this will have a special meaning to the user and therefore will get the attention it deserves. User’s will learn what data, that is interesting to them, looks like and they will find it if they want. This has been confirmed in the tests where subjects reflected on slots where low GSR values and higher values on pulse could be observed causing a certain color combination. This shows another effect of showing both pulse and GSR as color. The values will contrast each other, creating an entity of changing shapes and colors.
As one subject pointed out that in China red is considered more positive than green. While western cultures commonly use red as a color of warning or an indication of something being wrong. So we can question whether these cultural differences affect how the colors are interpreted. Do cultural factors affect, increase or in fact state the familiarity of the color mapping? If that is the case we would also need to explore how this influences learnability, self-reflection and identification. Would it only result in a larger learning threshold or would it have wider consequences? When feeling calm, is it harder to identify yourself as red rather than green, even though you know and have learnt the meaning of the color? In short, does the cultural context influence the individual’s ability to identify with color-mapping?

8.2 Visualizing historical data as a spiral
The spiral concept seems to have both some advantages and some drawbacks, at least in the current implementation. It seems to work to view data and to identify interesting sets of data. Users can point out events in a given screen.

The function of comparing similar sets of time was one of the general ideas of the spiral design. This seems like a reasonable function that could be useful for certain cases. It would however be good to contemplate whether this function should be an optional one and whether it should be more dynamic. With the spiral design comparing becomes limited and pre-decided. It is only possible to compare certain consecutive time segments of three. A user might want to compare a Monday and a Tuesday or an afternoon with a morning. This is what happens when there are no requirements on tasks/usability, you don’t really know what you’ll end up with. During the tests there were no spontaneous comparisons between adjacent revolutions in the spiral made by the users. This can likely be explained by the fact that different hours of the same day or different minutes of the same hour don’t share the same pattern as days, weeks or years do. For a typical working person or just a person with routines there will certainly be at least a few similarities. E.g. each day begins when you wake up and it ends when you go to bed. Each week starts with a busy Monday and ends with a lazy Sunday. For most people there are no similar structures for each hour. There is no typical beginning for an hour and no typical end.

As mentioned in the conclusions the greatest difficulty with the spiral concept was the spinning interaction. This is not because it is a difficult gesture to perform or that the screen is unresponsive but it seems to be purely a cognitive problem. It is difficult to organize the data chronologically, and to understand what comes before and what comes after. Just viewing a segment requires quite some thought before the user knows what is the end and what is the beginning of it. The other factor leading to problems is likely to be all the visual changes the spinning implicates. This most likely affect the preattentive processing which makes it difficult for the users to focus and to view the data that passes by. However it seemed to get easier with the rather small alterations that were made and the visual aids that were added during the iterative user-centered design process. It cannot be precluded that further development would facilitate users when interacting to such an extent that it would not be much difficulty to use. This could perhaps be done by changing the spinning interaction for some other way of interacting with the spiral, causing fewer or smoother changes. Decreasing the number of revolutions (and thereby the amount of data on the screen) or adding labels that make it clearer to the user what, where and how are other ways of making it less demanding for the user.
8.2.1 Aspect of proportion and spatial depth

It seems that because the spiral resembles a spatial object, the users have certain expectations to how the object should perform and behave. If it doesn't behave as they expect it can be a cause of frustrations for the user. E.g. imagine a bicycle that moves forward when you pedal backwards. Really stupid. But it's easy to model a bicycle. A spiral on the contrary is more difficult, since it's so abstract. People's only reference is the real world with its with physical laws and the body's interpretations of these. Therefore it renders some confusion when the spiral acts like nothing in real life. It seems like users try to get the pieces to fit together, but they can't quite get it. The data is compressed one way, but not the other. This makes the spiral appear as if it was flat, e.g. lying on a table. When the spiral is spun it compresses or expands (depending on which direction it is spun), and then disappears behind the center or off the screen. What kind of "material" acts like this? Yes I say material because it seems that due to the physical nature of the interface, the users expect it to be made of a material. When it doesn't act like something familiar, it gets confusing and unpredictable.

Can't it be learned then? Yes possibly. But I think that it's difficult when there is no haptic feedback to learn like it was a real physical object. Instead i believe it would be better to imitate existing objects. Spirals are mostly parts of other things such as screws and bottle caps. We associate rotating a spiral with going back and forward along the z-axis of the object we rotate.

I think that a possible solution is to make the spiral so that it would compress not only the length but also its width. The reasons for this are stated in 6.4.2.2. It would e.g. give the advantage that only a quick glance at the screen would tell you chronology of data. Figure 8.1 is showing an actual working implementation of the Affective Health interface with varying width. As can be seen the connection between the center and the spiral is quite awkward. This version was made very late in the development mostly to get a feel of what it would look like.

8.3 Effects of the iterative designs

So what did the project get out of the iterative design process? As the process started so late in the development there were several restrictions, namely lack of time and lack of programming resources, the result was far from what it could have been if the iterative process had been implemented at an earlier stage. There simply wasn't time to implement all the ideas of improvements and all the modifications that were thought of during the process. There was no time for any major changes in the design so we had to concentrate on building some usability into what already existed. This is quite the contrary to what today is believed to be necessary for a good end
result in terms of usability, readability and accessibility. Iterative design should be implemented from the very beginning of a project with continuous user feedback if you want to achieve these properties in the end result. But on the other hand the spiral ribbon design did not have any specific usability objectives or requirements from the beginning.

It should however be pointed out that this is not a conventional commercial project and the resulting artifact may not be as important as what is found along the way. Usability has not been the main goal of this project from the beginning. However I reckon that to properly test the system with user’s there needs to be a certain degree of usability and therefore it should be considered during the development process.

8.3.1 Test subjects
As the system is intended for a wide age group this could be an issue as the test group was quite narrow. It is important to incorporate users that are in the target group to use the system when the testing to achieve a high accessibility for this group. As there were a lot feedback from the subjects we had which rendered more work than the developer could handle we thought that this was enough. The system development is probably taking a leap from the Symbian OS and the small screen of the Sony Ericsson P1 so concentrating on whether details on the screen were visible or not to older people with poor eye-sight was not considered top priority.

8.3.2 Using the Sensual Evaluation Instrument
The Sensual Evaluation Instrument came to be an interesting part of the testing. If nothing else it worked as platform for discussion. It was perceived as a fun part of the testing by most of the subjects and seemed to invoke curiosity. When asked to pick one of the figures most of the subjects could choose one without too much hesitation. Using the SEI worked both as a replacement for words and as an aid in verbalizing thoughts and emotions.

It seemed that the feeling of using the system that was preferred by the users corresponded to the simpler shapes with a predictable shape and a smooth surface, whilst none thought that this was the feeling they got while using the system. However it cannot be precluded that the figure chosen for the system would correspond better to the desired one if the subjects had a been given a longer period of time for using the system and the interface.

Drawing conclusions directly from which figure was selected leaves a lot to the imagination of the test leader in this case, but as the result from each test pointed at a certain consistency in which figure was selected in response to different aspects of the system it doesn’t seem unreasonable that so can be done. This would perhaps require a more elaborated questionnaire and/or sets of tasks and better knowledge about how subjects react to the SEI.

8.4 Further development

8.4.1 Context
With fresh memory it is possible to interpret the representation of the biofeedback data and connect it with recent events. Problems will however surely arise if it is thought that the user should be able to recollect what they did during a four hour period one month ago, that is why context is important. What context that is necessary can’t be said without proper testing. It can probably be tested somewhat without the system since it would probably require subjects to wear the system for a
prolonged period of time. A good start could be to connect the system with subject’s digital calendars and see how much that helps and then perhaps experimenting with adding other context like location.

8.4.2 Simplicity
The interface probably can’t be too simplified. An ordinary calendar for example has different ways of showing years, months, weeks and days. There is a tradeoff between overview and detail, it’s hard to get both at the same time. That doesn’t mean that it’s impossible of course, but it can be good to keep this in mind. At the same time it’s likely that the distribution of various data necessary may have to be varied in different views so the user can interpret it. Figure 8.3 shows a possible model for how to distribute the information. The more detailed the view is the more context is provided. If you try to recall what you did in March of 2007, you will probably remember where you spent most of your time and what project you were working on with just a small amount of context data. So if you have a graphical representation of biofeedback data from this year you can connect the dots. Then try instead to recall what you did between 13.00 and 14.00 13th of March, 2007. One can imagine that this will require more context data to draw proper conclusions about biofeedback data than the former example. This also makes sense since context like location and calendar posts only have a meaning when shown together with the biofeedback data they correspond to. Perhaps it’s also worth considering stepping away from static views and using one view with dynamic content. Zooming in continuously brings up more content data the closer maximum zoom level you get.

**Figure 8.3 A model for content distribution in the interface**

8.4.3 Requirements
Working with abstract requirements such as aliveness and flow has proved feasible and this is surely an essential part of a project like this, however I would encourage to also set practical and functional requirements. One thing for example, which has crossed my mind during the tests, is the ability to delete data. Almost all other data that people have stored on computers and mobile device can easily be deleted. SMS, e-mails, history in a web browser or files and all be erased. Not being able to easily delete biofeedback data, which can be considered very private, is almost intrusive. If the system is to contain various personal context data this should of course also be possible to erase easily. From this aspect encryption of data should also be considered. Many of the subjects in this study expressed that they wanted the ability to input their own data like text or audio. Working with
scenarios, user interviews and workshops will likely render in more preferred functionality like these. The most prominent could then be considered as requirements.

8.4.4 Development process
I suggest that continued development utilize an iterative design process somewhat like what has been used in this study. Active user involvement from the very beginning and early evaluation of prototypes will support all actors involved in making good decisions.

Regarding the complexity of knowing how a completely new concept like the Affective Health could, should and would be used I suggest making open spaces for context, functions and representation and not starting with a complete interface sketch. Working with object oriented programming ensures that it is easy to change the representation, add or remove functions and alter the content of the context data. When the requirements are reached within the pieces they can be merged into one entity.

I would also suggest considering using a medium with a larger screen like a computer or a tablet. This would provide more space for context data and better possibilities for overviewing data. In parallel a stripped-down version for a smaller screen like a smart phone could be developed. The devices would be complementing each other. The big device would be for reviewing and reflecting on longer time periods. The small device would be for viewing real-time data and recent history.

8.4.5 Sensors
This study has shown that people can identify and reflect on their behavior using an ambiguous representation of biofeedback data. But use after four hours is still limited. To be able to properly test the system it is crucial that the sensors are more wearable. I believe that the system needs to be tested in tests that last at least a week. The system should be possible to wear during all activities without the system interfering. This is to ensure that physical activities like working-out, doing yoga or social activities like going to a party or travelling do not fall out of the picture.

9 Final words
If I would summarize my experience with the Affective Health I would do it as follows. I would say that the concept is very interesting and has potential to be a tool that actually works. The idea of an ambiguous representation is interesting and certainly has a point to it. However I would strongly encourage that also usability is considered from the beginning of development. This would make it more attractive to end-users as well as favor user testing of the systems main purpose, stress management. Abstract requirements and usability requirements can be combined.
10 Bibliography


11 Appendix A - Questionnaire (Swedish)

Bakgrundsdata

Ålder:

Kön:

Övergripande frågor

Hur har det gått att använda systemet?

Vad var lätt?

Vad var svårt?

Frågor kring användande, bärbarhet och sensorer

Blev du begränsad av systemet?

Visualiseringen/navigering

Hur lätt är det att förstå vilken tid en viss punkt i spiralen symboliserar? Dvs, om man fokuserar på en punkt i spiralen hur stor/liten ansträngning är det att ta reda på vilken tid den symboliserar

Uppgifter:

Visa en detaljerad bild från 14.15.

Visa en översiktsbild över tiden 12.00 – 13.00.

Navigera till en översiktlig bild över dagen.

Frågor:

Hur gick det att lösa uppgiften? Varför?

Förstod du de här linjernas syfte? Använde du dem? Hur?

Hur fungerar det att navigera mellan de olika vyerna? Förstår man hur de olika spiralerna hänger ihop? Förstår man ”fokusområdena”?

Är det överflödigt eller nödvändigt att både ha en inzoomnings funktion samtidigt som det finns olika vyer? Vilken variant är mest användbar?

Hur fungerar det att gå från översikt till detalj för en viss tid och vise versa? Användaren vill veta mer om en viss tidpunkt hur smidigt är det att gå från den översiktliga vyn med timmar till den mer detaljerade med minuter samtidigt som man vet var ska titta för att se det tisdintervall man är intresserad av?

Hur fungerar animeringarna mellan vyerna? (Hjälper de eller stjälper de?)
Historik/Förståelse

Uppgifter:


Kan du visa mig något tillfälle (i historiken) då du var utsatt för någon situation som fick dig (och gränssnittet) att reagera starkt?

Frågor:

Hur gick det att lösa uppgiften? Varför?

Representationen

Kan du beskriva vad färgen visar?

Kan du beskriva vad det grå området visar?

Kan du beskriva vad det vita området visar?

(alternativt det färgade fältet i mitten)

Hur väl fungerar representationerna? (Förstår användaren och kan den utläsa stor rörelse vs. liten rörelse, hög vs. låg puls etc.)

Hur tror du färgen relaterar till det/de andra fälten?

Var det vid något tillfälle du lade extra märke till något i gränssnittet? I så fall vad och när? Vad trodde du att det var eller vad det berodde på?

Identifiering

Tyckte du att gränssnittet hängde ihop med vad som hände (inombords och utanför)?

Jämförelse med den andra varianten som de inte testat (puls som färg eller inte) – vad tycker de?

SEI

Välj en figur som beskriver hur det känns att navigera i gränssnittet.

Välj en figur som beskriver den samhörighet du känner med ”personen” gränssnittet.

Välj en figur som beskriver ”personen” bäst.

Välj en figur du tycker representerar gränssnittet bäst.