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# Rationalizer: an emotion mirror for online traders

**Abstract**
Philips and ABN AMRO have joined forces in the development of Rationalizer, a product concept which aims to support serious home investors who trade online. Investors are typically driven by two emotions, fear and greed, which can compromise their ability to take an objective, factual stance. Rationalizer acts as a kind of 'emotion mirror' in which the user sees reflected the intensity of his feelings in the form of dynamic lighting patterns. An intense reflection alerts the user when it may be wise to take a time-out, wind down and re-consider his actions, enabling him to take financial decisions which are less emotionally charged and more rationally founded. We see this project as relevant to design practice in two ways. Firstly, we feel that the domain of emotionally intelligent products is burdened with unrealistically high expectations. This results in the development of complex emotion sensing technologies which may work in a strictly conditioned lab setting but falter when exposed to the experiential complexities of a real-life use situation. Using Rationalizer as an example, we argue that with more modest expectations and an understanding of the constraints of more basic emotion sensing technologies, interesting applications can be found which are feasible in the short term. Secondly, in the design of Rationalizer we encountered a number of semantic issues, including the connotations of emotion sensors, the aesthetic fit to the domestic context from an appearance and behavioural perspective, and the new product typologies which Rationalizer may point towards.

**Keywords**
Emotions, Online Investment, Intelligent Products, Ambience, Semantics, Behaviour, Aesthetics.

## 1 Introduction

In recent years, more and more non-professional investors have become active in the financial markets and are offered an increasingly complex and wide-ranging set of services and instruments. What was once the sole province of professional investors is now accessible to a much wider user base. European legislation [1] ensures that non-professional investors receive a higher level of protection from the bank than professionals get.

A well-known way for the bank to assess the knowledge, experience and personality of a potential investor is establishing the user's investor profile through a questionnaire. This questionnaire consists of two sections. One section, known as the risk profile, relates to the user's investment objective, his preferences regarding risk taking and his financial position. The questions in the other section relate to the user's experience in and knowledge of investment. The questions on risk taking are very much about the personality type of the user and his emotional response to fluctuations in the value of his assets portfolio.

When an investor trades via online trading applications without consulting the financial experts of the bank, the investor's profile helps the bank to validate that the intended transaction matches the investor's financial position, his financial objective, his knowledge and experience and the risk he is willing to take.
Now that trading through an online applications from the privacy of one's home has become commonplace, decisions are easily and quickly made. Unlike trading through written orders and phone calls, trading through the web allows the user little time for reflection and reconsidering his actions: the user can commit himself to his decision within seconds. Research shows that investors who switched from traditional discount brokerage to an online service nearly double their number of trades [2] and experience lower returns caused by poor decisions [3].
The traditional way to help the online investor perform better is education. Similar to many other banks and brokers, ABN AMRO has an online trading academy that helps to educate investors. Furthermore, ABN AMRO publicizes online bulletins, email newsletters and market reviews to help online investors gain more knowledge on the stock markets. All these measures are based on the assumption that investors make rational decisions according to the Efficient Markets Hypothesis [4] and therefore benefit from knowledge and information. However, critics of this Efficient Markets Hypothosis argue that investors make more often irrational than rational decisions. The sources of these irrationalities are attributed to psychological factors such as fear, greed and other emotional responses to price fluctuations and changes in an investor's wealth [5]. For example, driven by fear, investors may sell too hastily when share prices drop. Driven by greed, they may be overenthusiastic—too 'eager'—buying too many shares at too high a price. Whilst the risk profile may help the user in building a portfolio that is in balance with his emotional response to risk, it provides no protection from emotional decisions made during trading 'in the heat of the moment'.
A well-known way of representing emotional response is in the form of a two-dimensional plot, the affect circumplex model [6]. One axis of this model, called 'valence', indicates whether an emotion is experienced as positive or negative; the other axis, called arousal, indicates the intensity of the emotional state. According to [7], a clear link can be found between emotional reactivity and trading performance. Investors whose emotional reactions to monetary gain or loss were more intense on both the positive and negative side exhibited significantly worse trading results. This implies a negative correlation between successful trading behavior and emotional reactivity. This then leads to the following insight: non-professional investors may benefit—in addition to traditional education and risk protection—from a real-time alert that identifies their emotional response to market fluctuations and helps them to make more rationally founded decisions. This insight triggered a joint exploration project by the ABN AMRO Dialogues Incubator and Philips, leading to the Rationalizer product concept described here.
In the remainder of the paper, we first describe how Rationalizer addresses our insight. Then we explain how we worked within the limitations of current emotion sensing technologies. Finally, we discuss a number of design considerations in which we believe semantics [8] to play an important role, including the choice of sensor location, the fit between product and use context, the connotations of how emotions are rendered, the expression of dynamic light and the resulting new object typologies.

## 2 Description of the Rationalizer product concept

Rationalizer consists of two components: the EmoBracelet and the EmoBowl (Figure 1). The EmoBracelet measures the intensity of the user's emotion, also known as the arousal level, through a galvanic skin response sensor. This arousal level is rendered as a dynamic light pattern on either the EmoBracelet itself or on the EmoBowl. The higher the user's arousal level, the more intense the dynamic light pattern becomes: the number of graphic elements in the pattern increases, their speed increases and—in the case of the EmoBowl—their colour shifts from a soft yellow via orange to a deep red. One can think of Rationalizer as a kind of 'emotion mirror' in which the user sees reflected the intensity of his feelings.
An intense reflection alerts users when it may be wise to take a time-out, wind down and re-consider their actions. Rationalizer thus makes users conscious of their emotions during financial decision making.

The reason for creating two display objects is that we intend to test user preference for different ways of rendering emotion. The advantage of rendering the

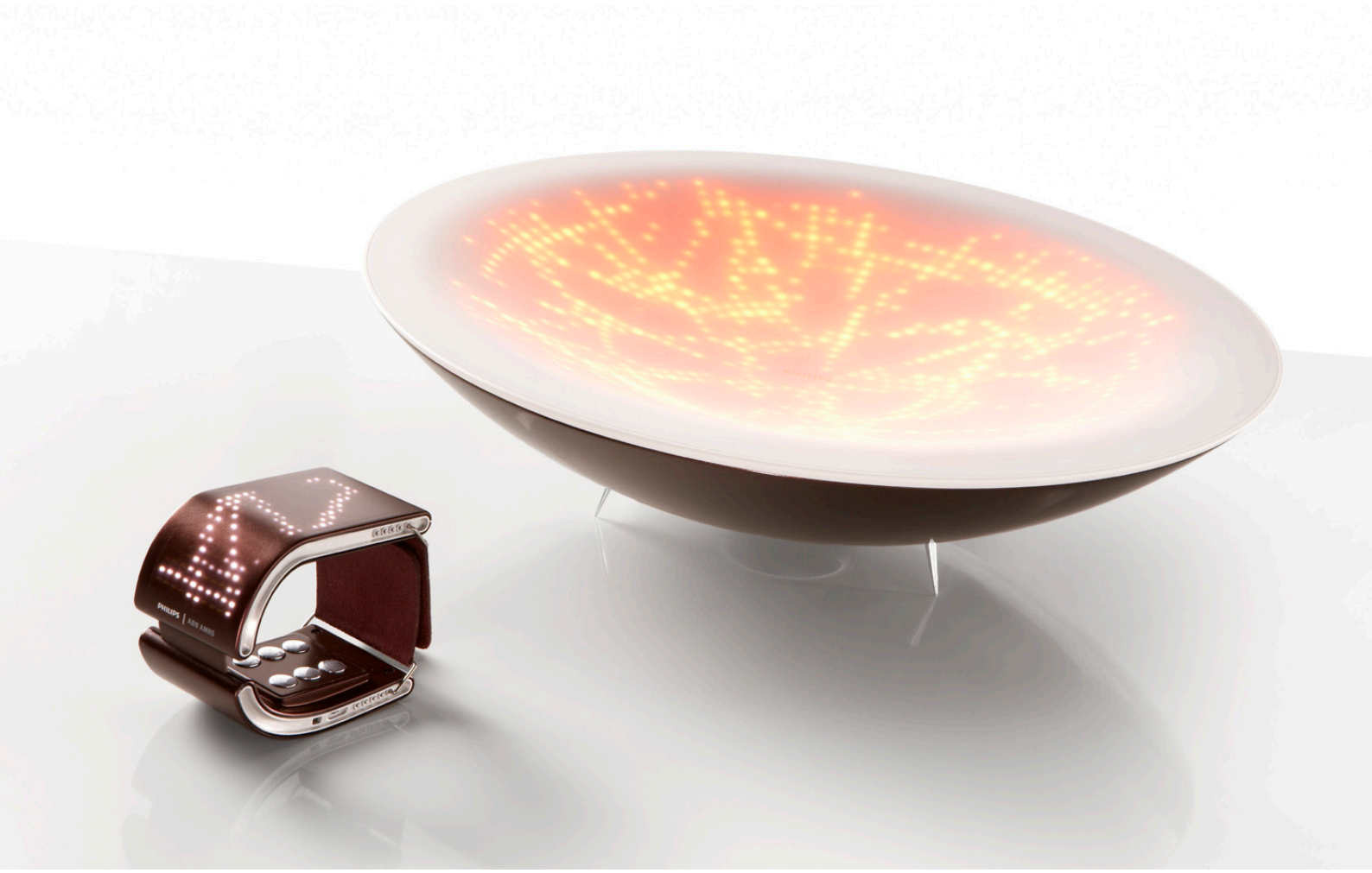

Figure 1. EmoBracelet and EmoBowl.

dynamic light pattern on the bracelet is that sensing and rendering become integrated in a self-contained device and no further objects are necessary. At the same time, we expect that some people may feel that a light pattern on a bracelet may simply be 'too much' and that they feel uncomfortable with the idea of 'a Christmas tree on their wrist'. When using a separate object such as the EmoBowl for rendering, the bracelet could be reduced to a simple measuring instrument without display capabilities and thus become more modest in size and more restrained in appearance.

## 3 An application suited to the limitations of sensing technology

Possibly cultivated by science fiction movies and novels, the domain of emotionally intelligent products [9, 10] is burdened with unrealistically high expectations. One such expectation is that emotion sensing needs to be able to determine the most sophisticated of human emotions with pinpoint accuracy, before emotionally intelligent products can be of value to the end user. This leads this research domain into a downward spiral of ever more complex and experimental emotion sensing technologies. Such technologies may work in a controlled lab setting but lead to a host of practical problems when exposed to a real-life use situation and its associated experiential complexities, pushing their application into the distant future.

What makes the Rationalizer use case interesting from a emotions theory point of view is that measurement of the arousal component of emotion suffices. A well-known way of describing emotions is through Russell's valence-arousal model in which valence indicates whether an emotion is experienced as positive or negative and arousal indicates the intensity of the emotion [6]. Russell's emotion circumplex plots the valence and arousal components of emotions in two dimensions. Typically, using physiological sensing the arousal component of emotion is much easier to determine than valence. Usually, the lack of a valence measurement is considered a serious shortcoming: whether we experience an emotion as positive or negative is such a fundamental aspect of everyday experience that it seems no emotionally aware product could do without it. However, in this use case it does not really matter whether the user is highly negatively or highly positively aroused: both situations may lead to tainted decision making. To put it simply, the online

trader should be made aware when entering either extreme state of arousal, be it positive or negative. This means that this application is well suited to the current limitations of emotion sensing technology.
We chose to use galvanic skin response (GSR) sensing technology for Rationalizer, which is a method of measuring the electrical resistance of the skin. GSR indicates emotional arousal only: it reacts to a startle response in the user without considering whether this response is positive or negative. In essence a GSR sensor is an Ohm meter, measuring the electrical resistance between two points. The sensor and signal processing software used in the EmoBracelet have been developed by Philips Research [11, 12].

## 4 Choosing a sensor location

### The semantics of sensor location

Part of the design brief was to make sensing as unobtrusive as possible. One approach is to follow the 'no-sensors-on-the-body' principle and to put sensors in the environment instead. In the case of GSR, a possibility is to embed the GSR sensor in a mouse. We rejected this option for a number of reasons. First of all, movement of the body relative to the sensor tends to create much noise in the GSR signal. Also, when the user happens not to be using the mouse, emotion events may be delayed or even be missed altogether. Finally, the user may alternate between a mouse and keyboard navigation or, in case of a laptop, use a trackpad instead.
Having to put a sensor on the body after all, an important consideration became its location as GSR is easier to measure on some parts of the body than on others. As GSR reacts to 'microsweat'—bodily transpiration which influences the skin's electrical conductivity but may not be perceived by the user—the best signal is obtained at places with sweat glands. Prime locations of eccrine sweat glands are the palms of the hands, the forehead and the soles of the feet. Whilst in a scientific lab situation these locations can be used to obtain the best possible signal, in a real world product these locations pose problems. Using a GSR sensor on the hand palm gives a good signal but only when the hand is stationary. In an everyday situation the GSR signal is easily disturbed by movements of the hand and fingers. Gloves or partial gloves may help holding a GSR sensor in place but are difficult from a user acceptance point of view: they are highly encumbering and are reminiscent of the old days of VR data gloves, giving the user a cyborg-like appearance. Using head bands or sensors on the feet may be even more problematic. Interesting here is that these are predominantly semantic issues. Though sensing devices designed for these locations may work fine from a technical and ergonomic point of view, the values and connotations which come with these sensor embodiments are at odds with the values associated with the application. Even when a sensor head band is dressed up as a wireless tiara, even when the sensors are elegantly embedded within shoes or socks, the associations that come with these sensor locations are simply unacceptable for a business-like application such as online trading.
For these reasons, we settled for embedding the GSR sensor in a watch-like product (Figure 2). Although the wrist is not the most optimal location to measure, it is a well accepted location for wearing technological devices.

Figure 2. The EmoBracelet is an integrated emotion sensing and rendering device worn on the wrist.

### Making the best of sensing on the wrist

We use two measures to improve the suboptimal quality of the GSR signal obtained on the wrist. The first is that the Philips Research sensor features adaptive ranging, meaning that the signal processing software automatically maps its range to the strength of the available signal.
The second is the use of multiple sensor tips. The current prototype of the EmoBracelet is equipped with six tips, even though only two out of six tips need to be active at one time. Close contact between tips and skin is crucial for a good signal and multiple tips provide some flexibility in finding the best measuring spot and


Figure 3. A plot showing galvanic skin response.

accommodating for different wrist sizes. Currently, the active tips are appointed manually. However, we envisage that the software could automatically identify the two tips which provide the best signal.
Figure 3 shows a plot of a GSR signal. The signal processing algorithm determines an upper and a lower limit. When the signal exceeds either limit an 'emotion event' is generated and the limits are adjusted. This particular plot shows a sharp drop in resistance corresponding to heightened arousal, triggering an 'emotion event', followed by a 'recovery'. Though there are some small 'emotional aftershocks', these stay within the new limits.

## 5 Product Semantics: fitting the domestic environment

As Rationalizer is targeted at non-professional rather than professional investors, the main use context is the home. Within the home, we envisage two use situations. The first is the user at a desk in his home office, an increasingly common space within the home for teleworking and doing administrative tasks. The second is using a computer notebook in the living room (Figure 4). The home being our use context, we decided to work with a domestic design language: rather than creating a visually obtrusive hightech gadget or an 'executive toy', our aim was to create a low-key object which would blend in rather than stand out in a domestic setting. Since the appearance of the EmoBracelet and EmoBowl is highly influenced by the dynamic light patterns, we discuss the semantics of their static as well as of their dynamic appearance.

### Static appearance

As we were looking for a simple decorative object which would fit naturally in a domestic environment, we came to work on a bowl. The notion of ambient objects—a visually restrained breed of consumer electronics which fits in with the environment rather

Figure 4. Using Rationalizer in a living room setting

than shouts out at the user—is a recurring theme within Philips Design. The Philips Design ambition with regard to ambient objects [13] is summarized by three pictures (Figure 5): the first one is a picture from the early 20th century in which consumer electronics are as yet absent. All other objects are typically domestic objects: a painting on the wall, a clock and a vase on the mantlepiece. The second picture is from the 1970s or 1980s: by this time, the living room had been invaded by a multitude of electronic devices, which all had their own aesthetic and fought for the user's attention. The third picture shows what a living room of the future may look like: electronic products have taken on a far more restrained aesthetic, inspired by traditional domestic products. The painting has become a flat TV, the loudspeaker and the remote control have become pieces of furniture. In a similar vein, the bowl on the table in the first picture could become an EmoBowl in the last picture: an object which historically fits the domestic context is augmented into an ambient object with behaviour.

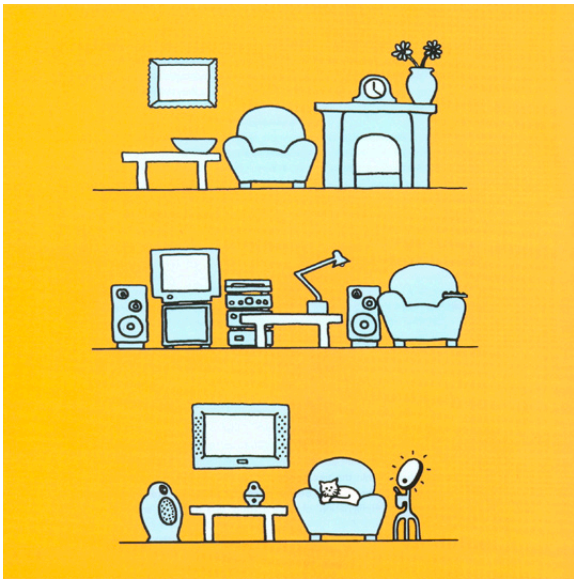

Figure 5. The Philips Design 1999 vision on ambient objects

**Dynamic appearance**

Many currently available devices which measure physiological signals show these measurements on LCD displays in the form of graphs and numbers. To improve the fit with the domestic context, we were intent on avoiding the clinical, laboratory connotations of these products and on rendering the user's arousal level in a manner more appropriate to such an intimate subject [14]. Rather than using graphs and figures which require reading and interpretation, we set out to represent the user's arousal level through animated light patterns which are intuitively clear. In ambient technology terminology these objects should classify as 'glancables': their status should be clear at a glance.

Both the EmoBracelet and the EmoBowl have four modes: (i) a fully-off mode, (ii) an ambient mode corresponding to low arousal in which the objects do not draw attention to themselves (Figures 6 and 9), (iii) an alert mode corresponding to high arousal in which the objects become the focal point (Figures 7 and 10) and (iv) an information mode in which messages (e.g. share prices, stock exchanges opening or closing) can be displayed (Figure 8 and 11). A change in the user's arousal level results in a gradual transition between the ambient and alert modes, similar to crescendos and diminuendos in music.

Both the EmoBracelet and the EmoBowl are executed as 'dead panel' displays. That is, the translucency of the product housing is such that in the fully off mode it is invisible that there are display elements underneath. This adds to the objects being perceived as non-electronic in the fully-off mode. Only when the displays are switched on does it become visible that these objects are in fact electronic devices.

Clearly, from a display point of view, the EmoBowl is more sophisticated than the EmoBracelet: it has a higher number of LEDs and its LEDs are of the full colour type rather than monochrome. The animations for both EmoBracelet and EmoBowl are based on a pattern of wavy lines. When shifting from the ambient to the alert mode, four parameters change: the number of lines increases, the number of curves in a line increases, the pattern's speed increases and, in case of the EmoBowl, the colour of the lines shifts from a mild yellow to an intense red. In the case of the EmoBowl, the transition from ambient to alert mode may be compared to breathing life into a fire: when the user's arousal level exceeds a certain threshold the light effects 'flare up'.


**Figure 6.** EmoBracelet in ambient mode, corresponding to low-arousal.


**Figure 7.** EmoBracelet in alert mode, corresponding to high-arousal.

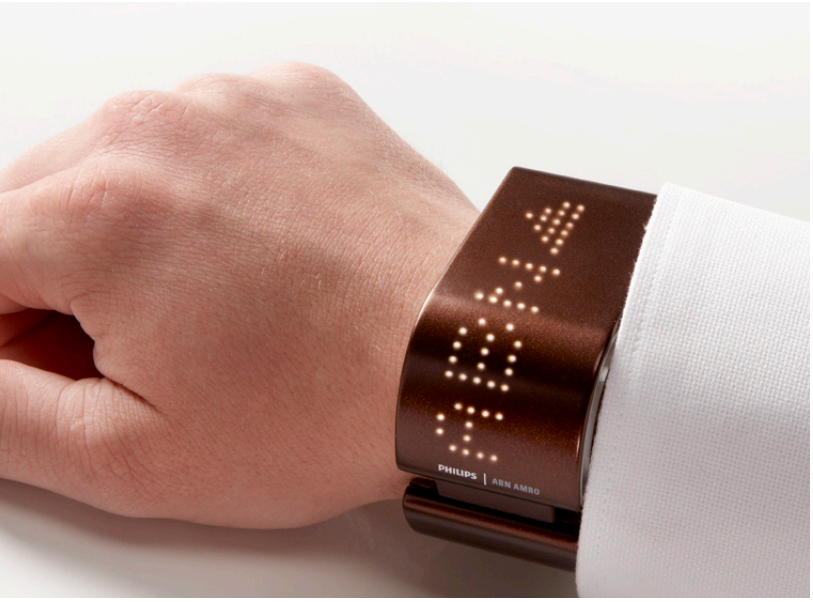


**Figure 8.** EmoBracelet in information mode, acting as a tickertape display with stock info.

## 6 New object typologies

### #1: The product is the display

In the Rationalizer project, we have experimented with both single curved and double curved displays. The aim behind our use of curved displays is the blurring of the distinction between product form and display. Current electronic products show a clear separation between form and display, often with the display being stuck onto a product without respecting its formal qualities [15]. Because displays are flat, the possibilities to integrate product form and display are limited.

In the EmoBracelet, the display curves with the product's form, if only in one direction. In the EmoBowl, the dish shaped display surface is curved in two directions. Though the current execution of the EmoBowl is still low in resolution, eventually this will lead to products with 'living skins' of which the double curved surface is a display at the same time. The notion of living skin will stretch the current understanding of product semantics. In a product with a 'living skin', the appearance and behaviour design will need to be considered holistically as the two will interact towards the meanings attributed to the product.

### #2: Low-res display or high-res luminaire

Currently, luminaires and displays are separate product categories: luminaires are meant for illumination, displays are for information. The EmoBowl blurs these boundaries. it can be seen as a new type of product which 'hesitates' between being a high-res luminaire and a low-res display and as such may serve multiple purposes. It has the flexibility to simply offer light, function as an ambient display or as an information display.

### The EmoBowl as high-res lamp

Since the EmoBowl features almost 1600 LEDs—which collectively have approximately the same light output as a 100W incandescent bulb—it is far brighter than an LCD display of the same size (Figure 12). This means that it may act as luminaire with display capabilities. As such, it can be seen as a next generation LivingColors lamp [16] which instead of showing one colour at a time can show abstract patterns of animated light. Apart from their decorative effect, such dynamic light patterns could be imbued with meaning. For example, dynamic light effects could be used used for non-goal oriented communication [17] (e.g. a particular pattern becomes the light signature of someone thinking of you), for

showing the emotional value of communication (e.g. to support e-mail or instant messaging) or as a music visualizer.

**The EmoBowl as low-res display**

The bowl can also be used as a low-res display showing tickertape-style messages. For the Rationalizer use case, we made the EmoBowl show stock prices (Figure 11). Other applications may be to use the bowl as a additional rendering device for other electronic products. When paired with a DECT phone, it could be used to show incoming SMS messages; when paired with an audio system it could show album title, artist and track information. An interesting aspect of EmoBowl is that it may act as a centrepiece on a dining or coffee table to share information in a group setting. As the tickertape information is displayed at a slant and travels in a circle around the bowl, it will eventually be readable to everyone gathered around the table.

## 7 Summary

Overly high expectations regarding emotionally intelligent products have a stifling effect on the uptake of emotion sensing technology in consumer products. Ever more complex technology is being developed in the hope of finding solutions which capture human emotion in its full complexity yet are robust and practical. Such a demanding requirement, effectively a moving target, causes the application of emotion technology to remain a promise.

If emotion technology is to provide true value to end users, solving the practicalities of emotion sensing won't suffice. For emotional products to be accepted, the values embodied by a new product proposition need to match our existing value system. This is by no means self-evident. The clinical and intrusive manner in which physiological signals are measured and rendered often seems strangely at odds with our everyday understanding of emotions.

The Rationalizer case study shows how with lower expectations and an awareness of the possibilities of currently available sensing technology it is possible to create emotionally intelligent products which are feasible in the short term.

Rationalizer can also be seen as a first step to come to a product language in which emotions are communicated in a domestically appropriate manner. We shared some of our considerations in developing

**Figure 9.** The EmoBowl in ambient mode, corresponding to low arousal.

**Figure 10.** The EmoBowl flaring up to alert mode, corresponding to high arousal.

**Figure 11.** The EmoBowl in information mode, showing tickertape messages


Figure 12. The EmoBowl can function as a 'high-res luminaire': the 1600 LEDs together are the equivalent of a 100W light bulb

this product language and improving the user experience of emotionally intelligent products from a semantic point of view. These considerations concern the aesthetic fit with our domestic environment, the connotations of sensor placement and the appropriate display of emotional information. Moving emotion technology from the laboratory into the home requires semantic considerations on many levels. Whilst this may hold for any type of innovation, it is especially true for emotion technology: the contrast between technology and human values is perhaps nowhere as jarring as here.

## Future research

We have planned a consumer confrontation test to evaluate how users react to both the concept of Rationalizer and its execution.

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