Ambiguity as a Resource to Inform Proto-Practices: The Case of Skin Conductance

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Skin conductance is an interesting measure of arousal level, largely unfamiliar to most end-users. We designed a mobile application mirroring end-users' skin conductance in evocative visualizations, purposefully made ambiguous to invite rich interpretations. 23 participants used the system for a month. Through the lens of a practice-based analysis of weekly interviews and the logged data, several quite different – sometimes even mutually exclusive – interpretations or *proto-practices* arose: as stress management; sports performance; emotion tracking; general life logging; personality representation; or behavior change practices. This suggests the value of a purposefully open initial design to allow for the emergence of broader proto-practices to be followed by a second step of tailored design for each identified goal to facilitate the transition from proto-practice to practice. We contribute to the HCI discourse on ambiguity in design, arguing for balancing openness and ambiguity with scaffolding to better support the emergence of practices around biodata.

1   INTRODUCTION

We have designed and studied the use of a wearable, bio-sensor-based mobile application named Affective Health, where we intently provided an open-ended interface to invite interpretation and reflection. The system is built around a skin conductance bio-sensor measuring the variation or sweat gland activity on the skin [7]. Sweat glands respond to a variety of factors such as changes in temperature, as well psychological or physiological arousal [2]. This leads to increased electrical conductance between the two points of contact with the skin, measurable through electrodes. Previous studies have shown the value of skin conductance in supporting recall [67] or reflection on emotional everyday experience [76]. There are a number of practices for measuring skin conductance in laboratory settings, as well as studies that associate skin conductance responses to various conditions [7]. However, when we designed this system, there was not yet any common practice to rely on (as there is for e.g. pulse, heart rate variability or simple step counters [81]) in how to represent the data nor how users could understand and make use of the data when it is measured in everyday life.

XX

Whenever an entirely new product category is introduced on the market, the pedagogical task of helping users to make sense of it and integrate it with their practice is more challenging than launching yet another product in an already well-established category. For example, launching a new car today, even if it is an electric vehicle of an entirely different kind, is easier than launching the first car in the beginning of the last century. An entirely new product requires work on behalf of the consumer to create meaning and make it fit with their practices. Consumers' understanding is dependent on framing that marketing and design may provide. If the product is launched into a tight-knit community where there is already sharing of practice and use patterns, the practice can spread faster, but the market may be much smaller, and the product might only be used in a limited manner. On the other hand, launching to the general customer requires substantial pedagogical work [72]. One example is smart-watches. Studies on user engagement with smart watches in everyday life [43,60] point out the importance of previous experience with technology, personal interest, social support and developing routines as factors that determine if the devices are domesticated and used in everyday life, or if they are abandoned after a short time.

As designers, we might frame the problem as having to do with the form giving of the product, the signs and signals the product emit and what functions it provides. For example, designing a new wearable product and making it look like a sports device should help make the semantics focus on behaviors, goals and ideals in sports that the that the user knows of and can relate to, such as achieving a particular goal of training for a marathon. Or if it is designed to look like a health device, those connotations and functions will guide the users to figure out how to integrate it with their everyday practices relating to health. But as stated by Krippendorf already in 1989, product semantics goes beyond the surface and functionality of the system:

> "While all design could be regarded as an intervention in our practice of living, I am guessing that product semantics be concerned with human interfaces, i.e. with that layer of cognition in which we experience how we interact with our environment, that layer of cognition which renders things understandable, meaningful, transparent, alive and useable or that layer of cognition which centers us in our own experiential world. Product semantics resides where human cognition and machine logic fuses into practice. Let me go further and argue that understanding and practice are inseparable twins and the understanding of something always is the key to its practical use."[36:5–6]

His argument is that semantics and practice are mutually dependent. When launching an entirely innovative product, there is not yet a practice to rely on. For example, when heart rate monitors for athletes were first launched, the form giving of the product and the way data was represented was from the intended viewpoint of athletes. But since there were no common practices to rely on, the athletes did not know how to interpret the data. The scientific studies of heart rate levels had been done with a different purpose in mind [56]. Quite a lot of experimentation had to be done by the athletes and their trainers in order to figure out what level of pulse was appropriate to a particular individual when training or competing. It was only when there was a community sharing their insights, that heart rate monitors could reach a larger segment of the market. Athletes shared insights, such as tables where depending on your age, you would be told the optimal training level: "*when 50 years old, your maximum is 170 beats per minute, but your training should aim for 85 – 145 beats per minute to achieve optional training effect*". Given these tables, various advice that makes sense to us irrespective of our background can be given, such as "*during the first few weeks of working out, aim for the lower ranger of your target zone (50 percent) and gradually build up to the higher range (85 percent). After six months or more, you may be able to exercise comfortably at up to 85 percent of your maximum heart rate*"

The establishment of a new practice may take years – if it ever succeeds [72]. Once there is a practice, it is easier to launch new products, variants on the same theme or incremental improvements of the previous ones for achieving the same effect more efficiently or adding new functionalities. A technology latched on to the wrong product category, no matter how useful and potentially powerful, might fail entirely. Or, as shown in this paper, depending on which practice end-users associate a new personal tracker with, their product categorization will be dramatically different, leading to entirely different interpretations of the data colored by the category they associated the product with.

This paper makes three key contributions. First, it describes the design and long-term use in naturalistic settings of a novel system: Affective Health, integrating wearable biosensors with mobile interface visualizing arousal. Thus, we present a month-long study with 23 participants using the system.

Second, given people's limited familiarity with the meaning of skin conductance, their engagement with the prototype was largely exploratory. Thus, we highlighted how such emerging practices, whose elements are still to become integrated, can be usefully framed as proto-practices [41]. Furthermore, we discuss the value of open design in supporting people's appropriation of the system for a range of goals and their proto-practices. Indeed, while the study introduced the system in the same way to all participants, most of them associated it strongly with specific goals in terms of one (or several) of the following product categories: stress management; sports performance; emotion tracking; general life logging; personality representation; or behavior change goals. Depending on their associations with one of these (alongside prior knowledge of skin conductance or similar sensors as well as their interests and aims) the practices arising around the system also tended to differ. Sometimes to the extent that they did not "see" data that spoke against their idea of what the system was conveying. Our study analysis shows how bio-data engagement with an intentionally open-ended design allows for many sorts of product associations, but at the same time lacks more specific functionality tailored to each of these categories. This suggests the value of a two-step approach in designing completely new classes of technologies for which users have limited prior understanding: a purposefully open initial design to allow for the emergence of broader proto-practices – which is what our study has focused on – to be followed by a second step of tailored design for each identified goal to facilitate the transition from proto-practice to practice. Third, we further contribute to the HCI discourse on ambiguity in design, arguing for the importance of balancing openness and ambiguity with scaffolding to better support the emergence of proto-practices.

We start by providing a brief background to product semantics and practice theory, drawing in particular on Krippendorf [37], but also practice theory [56]. We then describe the Affective Health system in more detail, how we deliberately used product semantics to design it open-endedly. We finally turn to our study set up, participants, method, and results.

2   BACKGROUND

Let us start by providing a brief background to product semantics and practice theory before turning to the digital/bodily material that we designed with: skin conductance and open-ended interfaces through evocative balance.

2.1   Engagements with data: Through the lens of practice

Researchers of self-tracking and commercial applications often focus on one type of tracking – a goal driven aim [53]. This is tracking where people have a specific goal in mind, such as running faster or losing weight. However, a study by Rooksby and colleagues [58] looking at how people *actually* use commercial personal trackers characterizes different styles of tracking emphasizing different goals. For example, people can track themselves just for the sake of documenting activities, rather than changing them. They name this documentary tracking. Another type of tracking is diagnostic tracking,

where the goal is to find correlations between different behaviors or bodily processes, often in order to detect or diagnose a problem. Finally, some users simply have an interest in gadgets, and are interested in novelty. Some early adopters of trackers, for example those active in the Quantified Self community can be considered extreme users, and have been found to be motivated by different reasons, including simply the desire of finding new life experiences [11]. Even elite athletes using trackers for instrumental purposes (such as improving an athletic skill), report an experiential side to the practice of tracking: it supports and enriches their sporting practice [82]. Moreover, in their stage-based model of personal informatics systems, Li and colleagues [44] showed that some people start collecting data merely because they could, and their goals and information needs become refined once they engage with collected data and understand its limitations.

The agency relationship between data and the person who is tracked is complex, inasmuch as the data and the person co-construct one other. People pick and choose between different trackers to serve their goals [58], building a complex mosaic of data. People dwell in data, making sense of it. In a sense, they become active constructors of data. And at the end, they emerge as changed people, with new attitudes and beliefs about themselves (such is the case of Kaiton Williams, who gives a vivid account of his own self-tracking journey to lose weight [90]). Conversely, data is not merely representational – representing some objective state 'out there' – it intervenes and changes the very activities it represents. This happens in elite sports [82] and everyday usage [58,82]. Like others in the HCI community [51], we are concerned with how biodata is woven into everyday life, which interpretations are afforded by bio-sensing technologies, and how these relate to everyday practices of the users. In this paper, we contribute to growing body of literature on how individuals engage with and ascribe meaning to data about themselves.

We understand data engagement as part of an evolving socio-historical context. For example, Pantzar and Ruckenstein [56], writing about heart rate measurement, note that it took years of technological changes, popular culture, scientific studies showing connections between heart rate, sport recovery, stress or romantic notions such as love to create the current (but ever changing) practice of heart rate measurement. People looking at their heart rate data draw on several resources to make sense of it. These resources come from the image of heart rate in their culture: the idea of a resting heart rate, of a normal heart rate for an age group, or the popular and medical knowledge that the heart is connected to emotion and exertion. Slovak and colleagues [75] look at people sharing heart rate values between each other, exploring a social aspect of tracking. They found that people attach "informational" and "connection" aspects to heart rate, and that how they see and interpret heart rate in each situation leads to different preferences on sharing (who they share with, how they share it). They also underline how multi-faceted the meaning of heart rate is. Another study found that prior beliefs shape how biosignals such as heart rate are interpreted by users [50], for example, calling for designers to pay attention on how they may be training users to associate biosignals to social meanings.

Unlike heart rate, which is a well-known biosignal, skin conductance is still relatively obscure, at least for most end-users. In order to explore it further, we designed a system that shows skin conductance, drawing from earlier designs on the topic. Here we follow on a tradition in HCI of how to do studies of "immature" technologies with the intent of uncovering future design directions. For example, Kuijer and de Jong [39] used a practice-oriented approach that they called "trigger products" to explore which types of uses and practices would emerge around home comfort when a product – a small heat source – was put in a number of households. Jonsson and colleagues [31] explored how heat elements could be used for reinforcing sensory perceptions. Their exploration contributes to the current knowledge on how to design with heat, and point to the importance of some of its qualities: experiential (such as subtleness) and material (such as inertia). Ruckenstein [61] did research on heart-rate variability and found that people engage with their data in a complex, social way, projecting different meanings and with different motivations for engagement.

We used a research through design [93] approach to explore the biosignal of skin conductance, through several design iterations we ended up with the current artifact and put it in the hands of users. It is impossible to disassociate skin conductance itself, the raw signal, from the way that it is presented to users in the artifact we designed. Designing an artifact is a form of communication; the designer shapes materials and scenarios into an object that has a certain shape, reflects a certain position and certain values. The raw biosignal data will be presented in a certain form at the interface to spur certain interpretations, hiding some details of the data, emphasizing others.

Product semantics studies the symbolic qualities of "human-made" forms, taking into account the physical functions of the artifact, and also the social and cultural context (the symbolic environment). Krippendorff [37] describes product semantics not in terms of material objects themselves, but their value in supporting people's construction of motivation and meaning in their social practices. According to product semantics theory, the human-made devices' affordances should account for users' available cognitive models as well as for those emerging through practice. According to product semantic theory, the context of use for innovative products, which do not benefit yet from habitual use can be supported by accounting for the diverse heuristics people employ in constructing the new meanings of such products.

In HCI, it is well known that design artifacts and the social milieu where they are used co-construct each other. For example, the task-artifact cycle describes how artifacts designed for a task can change the task by creating new possibilities or new constraints [10]. This in turn creates new requirements for the re-design of the artifact, in a cyclical relationship. Instead of looking solely at tasks, here we apply a wider lens to look at how people adopt a biosensing technology into their everyday life. For that, we rely on practice theory as a lens to studying and understanding the diversity in meaning making by our subjects.

Practice theorists study the dialectic between social structures and individual actions, namely how social structures shape individual actions and how individuals can change structures or procedures by enacting and re-enacting them continuously. In the context of HCI, the unit of analysis is not just the relationship between the artifact and the users, but rather the practice, and a practice is dependent on a complex assemblage of material environments, contexts, on both micro and macro levels [9]. For social sciences, a focus on practices has been a way to overcome a series of dichotomies such as micro/macro, mind/body or material/social. According to Shove and colleagues [73], a practice can be seen as constituted by *competences*, which are embodied ways of knowing how to perform a task (e.g. knowing how to drive a manual gear car, or knowing road traffic rules in US), *materials*, which are things, artifacts, or infrastructure (e.g. a car, or a multi-lane road), and *images*, which are shared ideas about the meaning of practice (e.g. going from point A to point B, leisure, status). When all these elements are linked successfully, a practice may emerge, such as driving a car. All these elements of practice change over time and space, as driving in early 20th century is different from driving now, or going for a road trip with the family in an automatic car in the US involves related but also dramatically different materials, competences, and images than driving a truck in an ice road in the Artic. When the elements of a practice are not yet linked successfully, we have a *proto-practice*.

Recently, Kutti and Bannon [41] have identified a turn to practice research in HCI, noting that the increasing interest in complex real world problems, on context of interaction, appropriation, materiality and embodiment (particularly when attempting to overcome the divide between mind and body) shows that HCI is slowly moving beyond a sole focus on interaction [22,24,32,69]. The interaction paradigm, as the authors call it, is individually focused on user needs, technology centric and ahistorical. A practice orientation in HCI considers user practices as fully embodied framed in both sociality and historicity. Such an explicit orientation towards practice has been adopted in sustainable HCI [13,40,41], but not in other HCI areas. However, here we show that a turn to practice coupled with using ambiguity (or was we shall discuss below, finding the evocative balance between ambiguity and clarity) as a design resource [19] can illuminate pathways for future research and design for immature

technologies, in particular, biosensing technologies for personal informatics. There is also a growing HCI interest in biofeedback-based interfaces for affective health which explored a range of biosignals as input such as heart rate [91, 103, 153], breathing [63, 165, 168], EEG [72], as well as electro-dermal activity [110] represented on a different interfaces ranging from visual, auditory, haptic or VR-based feedback [64].

Looking at practices surrounding the use of an artifact that relies on skin conductance from the perspective of the cultural narratives surrounding this genre of artifacts, the values it carries, and how the users perceive it allows us to understand the different pathways product semantics can take in future designs.

2.2   Skin conductance

Electrical conductance of the skin is associated with increased arousal, which in turn is associated with increased sympathetic response in the body, reflected in sweat glands. Since its discovery in the 19th century, skin conductance has been increasingly used in psychiatric research [7]. Skin conductance has also been used outside research settings, such as in polygraphs, tools to aid hypnotherapy, or for example as a recruitment tool by the church of scientology. At the same time, there are many examples in HCI [28,35] and Affective Computing (e.g. [4,12,29]) trying to apply skin conductance to different settings.

The skin conductance signal can be divided by frequency in two components: a slow changing one, called the tonic component, which can reflect a person's mood, environmental factors, and temperature regulating mechanisms (such as sweating from exercise) and a fast changing one, called the phasic component, which usually reacts to discrete stimuli related to arousal. This fast-changing component is also called skin conductance response, or galvanic skin response. The responses in skin conductance have been studied quite extensively in psychophysiological laboratory studies [48], and it is found that the best placements to observe skin conductance responses (phasic component) are the forehead, palms of hands and soles of feet [83]. In HCI, skin conductance has been used for a variety of purposes, ranging from games [62], self-reflection [42, 50], arousal detection for interactive systems [55,85], emotion detection for user studies [45], or arts [74]. In order to isolate the phasic component of skin conductance, it is necessary to eliminate all environmental factors, movement noise, as well as the tonic component of skin conductance.

For everyday usage, where it is currently impossible to eliminate all sources of noise, there is no established way of measuring skin conductance. Insofar as it has been used in technology development and adoption by end-users, measurement of skin conductance is considered "immature".

We can identify two main approaches in the design of systems that make use of skin conductance. One approach treats it as a feature for objective detection of arousal, stress or human emotion; systems in this approach typically attempt at detecting arousal states with some degree of accuracy. An example is the FEEL [1] system which uses triggers from mobile phone communications (such as receiving an SMS or an email) to record skin conductance and detect a stress level. Stress levels are then presented to users in a calendar or list view associated with the events that triggered them. Another approach requires users to make their own inferences based on skin conductance, providing instead clues for assisting interpretation [1,5]. Particularly relevant to us are the systems that reflect long-term trends of skin conductance in everyday life. For example, the work by Kocielnik and colleagues [34,35] makes use of Philips' DTI-2 bracelet by to collect skin conductance over long periods with users in work environments. The data is processed to show only the tonic component of skin conductance and mapped to a color scale. To help users interpret the data, the system provides context from the users' calendars, showing meetings, tasks and other work-related activities. Using this type of context scaffolding, users find that skin conductance data over the course of their everyday activities reflects their activities at work, and sometimes find surprising patterns. Our design exploration falls into this approach, but we explore a wider range of contexts in the daily life of users, other than work

environments. To do so, we do not provide as much guidance for users to interpret skin conductance data. Instead, our interface is left purposefully open-ended, as we explain further below. Another system, very similar to ours, is Ripple [28]. Ripple displays skin conductance data through a thermochromic display in a garment. The variations of skin conductance in everyday life and the volatility of thermochromic displays mean that the data is open-ended and ambiguous. Like ours, Ripple was meant to support alternative interpretations and critical questioning of skin conductance data in everyday life. Below we detail how we designed open-endedness into Affective Health through a quality we extracted from previous work [27,63,65,78,80], that we call *evocative balance*.

2.3   The value of open-ended design: evocative balance

In the design of Affective Health we made use of an experiential quality named *evocative balance*, that had been extracted from our previous designs in the same area [26,77,79]. We named it "balance" to capture how an experience of an interaction can resonate on the one hand with given familiar, lived experience – representing ready-made interpretations of what is there that we can recognize and understand – while at the same time being open enough to allow for new interpretations and meaning-making – representing data in a slightly ambiguous manner, evoking new ideas, new interpretations. The gestalt of an interactive system aiming at representing bodily data is quite sensitive to detailed design choices. If the designed expressions are overly literal or unambiguous, there is little room for interpretation, meaning making and growth. On the other hand, if the expressions come across as arbitrary and abstract, there will be no resonance in lived bodily experience and the whole interaction becomes unfamiliar and insignificant. Therefore, the balance between evoking the familiar and evoking the new is a key experiential quality in these designs, especially when seeking for the interpretation to be in the hand of the user. The name 'evocative balance' therefore draws on the dual meaning of the word "evoke" in characterizing the user's sense that data and actions evoke familiar recollections of lived experience yet are open enough to evoke multiple interpretations in an on-going process of co-constructive making of meaning.

The most salient concept resembling evocative balance here is the one of ambiguity. Gaver and colleagues [19] saw ambiguity as an opportunity early on, at a time when ambiguity would generally be seen as a problem in design. They describe how ambiguity can be a resource:

> "Ambiguity can be frustrating, to be sure. But it can also be intriguing, mysterious and delightful. By impelling people to interpret situations for themselves, it encourages them to start grappling conceptually with systems and their contexts, and thus to establish deeper and more personal relations with the meaning offered by those systems." [19:233]

Their interest lies in how ambiguity can be used to positively affect the design of digital systems. The aim is to make the designs evocative rather than didactic, and mysterious rather than explicit. By purposefully creating ambiguous situations, people are more or less forced to participate in meaning-making. This said, ambiguity is not a virtue in itself, but used in the right way ambiguity can provide a frame of reference for people to contribute their own interpretations.

Through engaging with design that balances between being ambiguous vs semantically closed, our aim is not to create poor usability. Instead, our definition of evocative balance aims to capture those experiences that resonate with our lived, everyday, social and bodily experiences. In the next section, we will describe how we used the experiential quality in the form giving of the interface.

3   AFFECTIVE HEALTH SYSTEM

The Affective Health system is a product of several years of research. It originates from experiences and lessons learnt when building and testing Affective Diary (built already in 2005), a tool for reflecting on bodily experiences (captured as biodata alongisde mobile data such as text messaging and

Bluetooth presence). The aim was to provide a scrapbook that would work as a resource for making sense of everyday patterns and remembering the past [78]. Affective Health also builds on previous research where we investigated how to map biodata to color, forms. In that work, we explored different temporal/spatial representations and showed how those representations supported an *evocative balance* between too "closed" representations where users could not inscribe their own interpretation versus too ambiguous representations that could not support meaning-making at all [23,86]. During early stage development of Affective Health, we have also learnt the importance of designing for a sense of fluency and aliveness at the interface, highlighting both real-time responsiveness and the need for short-term historical data, to help users interpret the meaning of biodata in the context of stressful situations [14]. In our process, we have also learnt that biosensor and careful feature selection in biodata also matter when attempting to design for evocative balance [63]. The study presented here extends our previous results by exploring how practices and meaning making may arise from integrating a system like Affective Health with everyday life for a longer time period – highlighting other challenges for measuring and communicating stress patterns in everyday life.

The version of Affective Health system used in this study monitors users' skin conductance related to movement (as picked up by an accelerometer), both displayed in real-time in an app on a smartphone. We used the Philips DTI-2 wristband, which captures and streams real time GSR and accelerometer data via Bluetooth to the phone. The Philips DTI-2 is a research prototype wristband that measures arousal through a skin conductance sensor and movement through a tri-axial accelerometer [34]. The device had been field tested previously [34,54] in work settings. In addition, following an auto-ethnographic approach, members of the Affective Health team had been using and working with the DTI-2 prototype prior to the study presented here. The skin conductance sensor involves two electrodes positioned under the wrist, and three resistors allowing for a stable 1.2 V reference voltage DC current to safety flow through the skin [54]. The device has a separate circuit board for the skin conductance sensor allowing for local filtering, through a 2nd order low-pass Butterworth filter [54], amplification and digitization of this signal.

The LEDs on the device are used to signal the switching on or off the device, i.e., LEDs are lit from the bottom up for ON, and from top to bottom from OFF, and for pairing with the mobile app, i.e., blue LED flashed on the top right corner indicates information is transferred to the mobile app.

In the app on the smart phone the data is shown in the spiraling bar that consists of a background color representing the arousal, which ranges from red, high arousal to blue, low arousal and uses an overlay shape of width for movement (Fig.1).

In the app users can engage in four kinds of activities. First, they can see their real-time data and secondly, the system offers a history where users can see and reflect over their own bodily reactions in relation to their everyday behavior. The system is designed to be used daily over a longer time. The interface on the mobile uses color and animations in a spiral-shaped figure to portray how skin conductance and movement change over time. The most recent data is shown in the square and spirals inwards towards older data. The view can be set to show minutes, hours or days. Second, users can also zoom in time by pinching the data and zoom out by spreading the data. Third, users can choose, for example, a specific hour or day and compare it to seven hours or day in a comparison view. Finally, users can tag data by pinning at a certain point in time and make a notation.

As discussed above, we aimed to design for an evocative balance between representing somatic reactions that users can immediately recognize and understand, while at the same time not closing off the interpretation. Users should be allowed and even encouraged to create their own stories, which is why we attempted to avoid telling them if the skin conductance level was good or bad. A red color can be seen as a representing a high level of negative stress, but it can also be the color of an intense positive, engaging, passionate experience. Let us explain in more detail how we designed with color here.
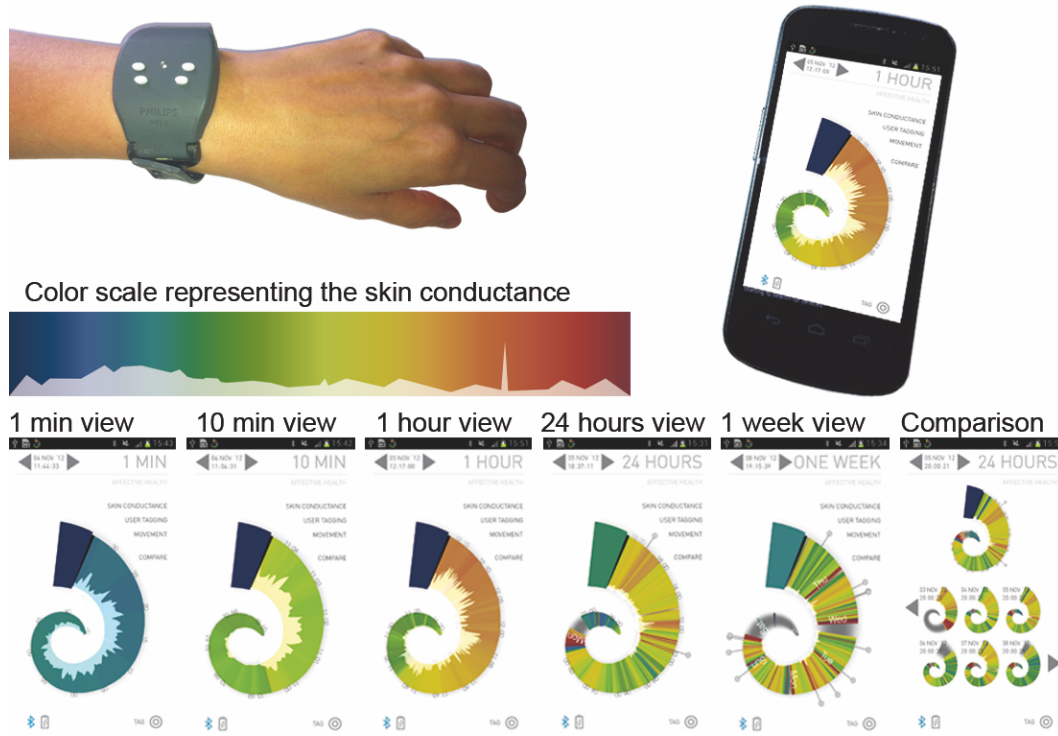
Fig. 1 Affective Health bracelet and application

3.1   Form-giving of Affective Health

To portray skin conductance through evocative balance we were inspired by color psychology and color theory [94]– the higher temperature/energy level of the color, the more arousal. This was explored in on our previous design and study of a system [76] where we used color in relation to expressing skin conductance. Red was mapped to the highest value of skin conductance, and then using a scale down to blue for the lowest. We sought to evoke a feeling of familiarity and recognition with how stress, excitement or physical effort is experienced in our bodies.

Movement was mapped to area size; the more movement the accelerometer picked up, the more space it took up in the interface. First, we hypothesized that movement would be best visualized through a pulsating animation, increased movement rendered higher change in frequency. The square shaped part in the interface represents the real-time biodata (the present now), which flows into and builds up the spiral with colors of skin conductance data. Accelerometer data is shown as a semi-transparent shape along the border, changing in height depending on the data fed in. Colors and the shape feed into the representation, creating a feeling of aliveness as it keeps changing when new data flows in at the top of the circle, while old data moves further into the shell-shaped circle, becoming more and more compacted, finally disappearing into the tail (from where it can be retrieved by pinching it or scrolling back in time). The choice of laying the data out in a shell-shaped spiral is twofold; first, it builds from the metaphorical view of time as circular [92]; second, it made screen space available for other functions.

Users can scroll back in time by sliding their finger counter clockwise on the spiral; the part representing the present then gets disconnected from the rest of the spiral, indicating that they are not fluently connected anymore. The scrolling in time can also be done as zooming into different views: from a one-minute view to a 10-min view, one-hour view, a six-hour view, a 24-hours view and a week view. Moving in between these states can be done by pinching around the time one wants to zoom into or vice versa by spreading. Comparing data can be done in the same zooming states, so the time of the hour the user looks at can be compared to the same hour for the last 6 days, or the last 6 days can be compared. Users can also tag the data, helping them to remember what was happening at the time. Tagging is done through attaching a small pin, where notations can be added. A certain pin can then at a later stage be clicked and the user can read the tag they put in there. If there is a loss of data from e.g. taking the wristband off, this is visualized as a gray shadow of the spiral, but the space it takes up is equal to how long it was off.
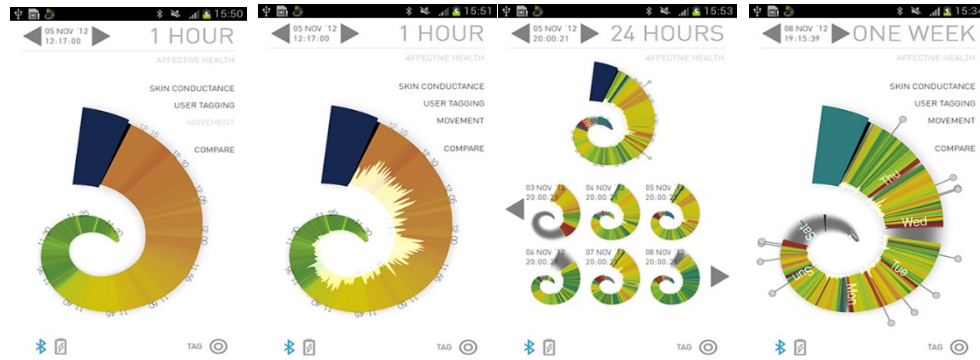
Fig. 2. Affective Health interface showing a) skin conductance with no movement, b) skin conductance with movement data c) comparison view and d) tagging

3.2 Skin conductance in Affective Health

Based on our previous work on visualizing skin conductance [76] we knew that the translation of data into a representation would not be a simple one-to-one mapping. Skin conductance is not a measurement that would make sense to users in its raw form: it contains a lot of noise and varies a lot. The raw signal often oscillated wildly due to variations in contact, pressure and other factors.

To stabilize the skin conductance signal received from the DTI-2 bracelet, a median filter was implemented in the Affective Health application in addition to the filtering already done in the bracelet [54]. A window was created around the signal, where the edges of the window are copies of the signal passed through a low frequency filter. The low frequency filter has the effect of making only the long-term trends of the signal visible, i.e. *the tonic component of skin conductance*. This filtered signal is then transposed twice to form two bounds of a window: one is the maximum value of conductance and the other is the minimum value over a period of approximately one minute. The edges of the window became the edges of the color scale: the lower bound was mapped to the blue and higher bound was mapped to the red in our color scale. This algorithm achieved smooth transitions and responsive color changes. This algorithm was initially developed through a research through design approach, using our own data, where we repeatedly tested the timing of color changes, transitions and further refined them through testing them on ourselves [63]. For example, the experienced changes in our bodies could influence the time duration of a specific color transition depending on which colors were blending. For example, getting frightened is a quick reaction and therefore the color transition should be

shorter/quicker, while relaxing or falling asleep is experienced as a slower change and should then allow for a longer/slower color transition.

4   STUDY SETUP

After testing the interface in smaller studies [14,63], we wanted to take the Affective Health system all the way into "the wild" [57]. We wanted users to experience the system as part of their everyday life, finding trends and interpretations beyond first initial impressions from using it for a day or so. We decided to deploy the system for about a month, following how participants' interpretations changed from one week to the next.

4.1   Participants

We recruited a group of 23 people (13 male, 10 female), combining purposeful and opportunistic sampling. The participants we purposefully recruited came from two settings: a large telecom-company in Sweden (9 participants, 6 male and 3 female) and an elite athlete team in orienteering (7 participants, 3 male and 4 female). The opportunistic sampling contributed the last 7 participants (3 male and 4 female). They had spontaneously contacted us after seeing the system mentioned in Swedish media or hearing a talk about it. Let us briefly describe each group in some more detail.

IT-professionals: The IT-company was a partner in the project at that time and the project representative expressed interest in trying the system with colleagues (who were not working with us but came from a different department). These participants were all engineers. Their main motivation to participate was that they had been developing similar bio-sensor-based applications. From our perspective, it was important to have this group of participants as they were familiar with other bio-data systems and would know what to expect. These recruited participants were also curious to see what they would gain from biosensor-data from their everyday life. These participants were all very technically savvy and all had their own smart phone. Unfortunately, the type of smart phone that this group had was not the most compatible with the system. This meant double the amount of technical issues than the other two groups. The main problem area was the time for transmission on data, as the wristband would not collect data at the same time as sending it. It took so long for data to transfer that it meant that they lost valuable data while the wristband was sending data to the application. There was also loss of data if they did not remember pair the wristband and application before the wristbands' battery died.

Elite athletes: The Swedish national team in orienteering had contacted prior to this study, as they were curious about our biosensor experiments. We decided to recruit them as participants as they would have a different and strong motivation to use the system compared to, e.g., people with stress issues. They all had university degrees and were working or studying full time alongside practicing their sports. They were a very analytic group, all of them had a least one GPS and pulse watch, some also measured sleep and recorded training sessions with video. They all expressed a sense of obligation to finish what they started once they had entered this study. They all used it every day; two athletes also wore the system at night. These athletes do not earn a lot of money from their sport. They rarely have the possibility to get a personal coach for their personal development. Instead, they depend mainly on their own ability to coach themselves. All of the athletes told us that they spend a lot of time self-reflection, not only physically but also mentally. And they also spend a lot of time exchanging experiences and knowledge with other athletes. They express that this type of knowledge sharing between athletes to be a huge contribution to their own development as athletes. Overall reflections of motivation to participate in the trials were that they are always looking for new ways to develop their training. This system was an addition to the continuous reflection they are already doing. However,

they were lacking knowledge of time in between training sessions and were mostly interested if this system could tell them more about what they referred to as recovery.

Mixed group interested in stress management: The last group of participants can best be characterized as generally interested in stress management. They all had university degrees except for one who was a teenager, attending high school. They were all strongly motivated, career-driven individuals. Two of these participants were married and were interested in comparing their data with one-another. In this group, one of the female participants discovered that she was getting ill from all the stress in her life, and was able to pull the breaks in time. She claimed that she would not have done so if it had not been for using the system.

In the analysis, we do not make any difference between these three groups of participants, even if on and off it is clear that some of them are keener to engage with optimizing their physical performance as they are doing sports while others are more concerned with caring about their emotional wellbeing.

4.2   Procedure

The participants were told that they were being given a tool that – quoting from the instruction manual given to each participant on paper – would "*help [them] reflect on [their] bodily and emotional reactions and perhaps even start to change some of them*".

They were instructed that skin conductance is a measure of how much once sweats, indicating emotional reactions as well as physical reactions. With respect to the color, they were told that the scale goes from low/blue to high/red, and the higher the value, the most intense bodily reaction, so high and low skin conductance readings are not to be read as good or bad, but their value is to be judged in the context that triggered them. About skin conductance specifically, we stated: "*if a value of high or low is positive or negative is up to [the participant] to interpret]*". No specific use was specified or set of recommendations given for how to use the system, other than instructions for caring for the battery of the device, and how to upload data from the bracelet to the mobile device.

Regarding movement, participants were instructed that the thickness of the inner part of the visualization shows how much one has moved, the thicker the line, the more movement. They were familiarized with the real time- and historic view of data and how to switch between the two views, and that the numbers along the spiral indicates time. They also were instructed on how to use tags linked to current time for entering short comments about what is happening at present moment.

Each participant was asked to use the system during 4 to 8 weeks. We deemed that this length of the study was appropriate for the participants to get used to the system and for it to be domesticated and adopted into their everyday practices – or be dismissed if it had no relevance to them.

Semi-structured interviews were held with each of the participants once a week. The duration of each interview was approximately one hour. The participants were asked to talk through their everyday use of system, where deepening questions were asked in order to clarify usage. The participants were asked to show specific data related to the episodes reencountered in the interviews in the app. While these interview sessions can be seen as inappropriate interventions, obscuring the interpretation of how users will engage with Affective Health if we had not been around, we see them as part of the use situation. If Affective Health would ever become a commercial product, for example, handling stress management, users would meet up with therapists regularly to get help in setting strategies and interpreting their data.

The interviews were transcribed. Most participants were Swedish-speaking and their quotes have been translated. The participants all signed an informed consent form. Below, we will refer to them by their initials to preserve some degree of anonymity.

4.3   Method of analysis

The transcribed interviews went through a qualitative content analysis [70], and code reduction was achieved deductively. First, we got acquainted with the data by inductively coding five randomly selected participants. The underlying question we repeatedly asked ourselves in selecting the codes was "*what are the underlying beliefs about skin conductance shown through this statement?".* Then, we matched those codes with practice theory concepts, thereby reducing the number of codes to those that were relevant to us. Finally, we made use of these codes to understand which sub categories that could be matched to specific product semantics. From the five randomly selected participants, we achieved the nine tagging codes shown in Table 1.

Based on these nine codes, two of the authors deductively and independently coded all transcribed interviews, sentence by sentence. The two analysts regularly met and discussed to achieve consensus in coding. The nine codes can be divided into two sets: those mainly to do with skin conductance-interpretation, irrespective of existing products and those that might have been influenced by tools and products on the market, such as therapy-methods or other existing practices. The latter includes: *stress management* tools, *sports performance*, *life-logging*, *personality representation*, *emotion tracking*, and finally, any attempts to engage in *behavior change* due to their interpretation.

Categories not explicitly referring to existing practices include: noting effects of *social* settings and how they give rise to higher skin conductance[1], speculations on how other *bodily factors* may influence the conductance readings (a warm room, putting on a sweater, going out into the cold weather, being dehydrated), and of course in general being *confused* about what skin conductance is and how to interpret the data.

Once we had coded all the interviews, the two coders individually summarized which codes could be attributed to each participant. They also made a high-level interpretation of each participant's overall pattern in terms of main and secondary practices used to make sense of Affective Health. The participants were not explicitly asked about their product associations. Instead this classification was deduced from their accounts of interacting with Affective Health.

Proto-practice	Meaning
Stress management	Referring or alluding to psychological stress affecting (or surprisingly not affecting) skin conductance
Sports performance	Attempts at performing in an optimal way through finding the 'right' skin conductance-level appropriate to the activity at hand
Life-logging	Documenting or logging activities, places, times through their effects (or lack of effects) on skin conductance-readings
Personality representation	Referring to general personality traits confirmed (or not found in) through skin conductance-patterns
Emotion tracking	Specific emotions such as happiness, anger, or sadness, being reflected (or not) in skin conductance-patterns

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[1] We will not dwell on this here, but it is interesting to note how many of our participants were confused by how social settings create skin conductance readings that go up and down in rapid succession. When you reflect on it, it is not so strange that this happens – social settings are demanding in terms of attention and focus, even when we enjoy them – but to our subjects this sometimes came as a surprise.

Behavior change	Willingness to change a behavior pattern in their life to improve an identified skin conductance-pattern that they think is negative (or should be strengthen as it is positive)
Social	Encounters with people, friends or work meetings, affecting (or not) skin conductance
Contextual	Environmental factors contributing to skin conductance, such as a warm room or putting on a sweater
Confused	Not making sense of the skin conductance readings

Table 1. Proto-practices relating to participants' interpretation of the meaning of the skin conductance readings

5   RESULTS

Before we go into the results of the study, we would like to acknowledge the richness of what participants shared with us. We were let into people's lives and they shared very personal, intimate aspects of their lives with us. Reducing all that richness into the patterns of a few proto-practices does not give their full use experience justice. That said, what intrigued us in the interview data was how often our participants were ignoring whole chunks of data or where their preconceived ideas about the product category entirely governed their use and meaning-making processes. While we had expected that users would make their own, individual interpretations of the data – as the whole point was to leave aspects of the interface open-ended and ambiguous to invite interpretation and reflection vis-à-vis their own lives – we had not understood how strongly this would be associated with practices or products already available on the market. It was not until we started to see the influence from already existing product categories in the society that we could make sense of what was going on. Below, we unpack some of these. We consider these to be *proto-practices*, i.e. practices where the links between *materials*, such as technologies like Affective Health or representations of skin conductance, *images*, such as ideals about stress and performance, *competences*, such as reflection, or meditation skills [66] are not yet linked and stable [56] for our participants.

The examples were picked to illustrate how participants can struggle with defining aspects of system usage. In table 2 we portray how each of our participants interpreted their data. One participant, GB, was never able to interpret the data and gave up using the system, so the table and analysis below refers only to 22 participants. The first column shows whether the participant at all discussed this way of reading their skin conductance-data. The second column shows which interpretation was their main understanding and take-away of the system.

Table 1 Proto-practices where Affective Health was adopted by 22 participants [a]

Proto-practice	Main interpretation	Part of interpretation (excl. main)
Stress management	11	7
Sports performance	7	2
Life-logging	2	6
Personality representation	0	6

Emotion tracking	1	7
Behavior change	1	15

5.1   Stress Management

Eleven participants saw the system mainly as a stress management system. Of those, six became highly engaged with the data and saw a potential for changing how they reacted to stressful situations in their life, actively working with the data in their everyday lives to achieve such a behavior change. Participant PR, for example, talks about how the system made her aware of how stressed she was (and she went on sick leave due to stress during the period she used the system):

> "*Yes, but I can say... I think this has helped me after all. It helped be pull the brakes and it helped me to tell myself that I can do something about it. Because I can see results. So that I must, I am very grateful that I had this because otherwise it would not have been blatant. That I think I can say. Because stress comes creeping up on your and you have such weird feelings, but these measurements (of sweat) are not so obvious (to you). You do not go around all day thinking about how sweaty the palms of your hands are. Or that you... that your heart is pumping in 190 even though you are not really doing anything. Sure, you think about it, but you have so much stuff in your head that you do to really register it, because you are so hang up on all that other stuff.*" (PR)

PR is a particularly interesting case, as she did not initially engage much with the data. She started by questioning it, noting that it would show red when it was hot (and she was sweating), and then went on to use it playfully, stating that it was a fun way of seeing stressful vs. calm days in general, but was not able to detect short period of stress. However, after going through a particularly stressful couple of weeks she decided to take her skin conductance data seriously. Crisis periods like this can be described as breakdown periods [3], where people periods of uncertainty or conflict prompt reflection. She figured out that "*when there is a long period of orange and [she does] not do anything physically, then there is something else that's wrong*". By the end of the study, PR purchased a lifelogging camera called Memoto, using it in conjunction with Affective Health, and joined lifelogging online communities to share data with others.

A couple of the six highly engaged participants had previous experience of stress illness and had learnt how to face stress in a more deliberate manner already from the start. They had knowledge on how to manage negative emotions or how to counteract stressful periods. One of our participants, for example, spoke about her horse and horseback riding as a space where she would get energy and could focus. She checked the system to see if her ideas about horseback riding were correct. These highly aware and knowledgeable users could easily create their own practice around the system as they had the knowledge and tools needed.

Others amongst these six participants, however, who tried to engage with their skin conductance to manage their stress, expressed disappointment and failed at deriving any meaningful benefits. They

expected the system to be able to differentiate between "good" and "bad" stress and noted that the red spikes were not always reliable for identifying negative stress.

These comments are not so different from the initial comments from PR, who ended up engaging with her data only after her difficult stress period. Stress is a complex phenomenon [87], in parts a socially-constructed term associated with culturally-determined symptoms. This is where issues regarding practice evolving around tools like Affective Health are most acutely missing. Noticing that there is a problem, getting it documented in data, reflecting on it, is not enough. This was clear by some accounts of PR:

> "*you have so much stuff in your head that you don't really register it, because you are so hang up on all that other stuff.*" (PR)

The final five out of the eleven who mainly associated Affective Health with stress management claimed that they did not see a need for such a system for themselves, but that it would be particularly useful for others, e.g. "*irritable people*" (KK). Participants who had not experienced illness due to stress often came with such ideas for how "others" could benefit from tools like Affective Health. Typical beliefs would be that simply understanding the source of stress and reflecting on that would counteract the negative consequences. The physical impact on the body, the time it takes to recover and the difficulties in changing behaviors, emotions and reactions to situations, was not something they knew about or reflected much upon, and also something that we did not provide as functions or lessons in the system.

Moving from a proto-practice to a mature stress management practice requires that users be provided with a whole apparatus of competence for understanding the difficulties of stress and how to counteract negative effects. Those who had experienced stress problems and learnt how to deal with them had all those skills needed to make good use of the system. Those who never had experienced real stress problems relied on "folk" interpretations of what they assumed stress problems would be.

What is interesting to note here is that those eleven participants who associated Affective Health mainly with stress management products and practices, did not see opportunities for using it to track their physical activities and performance. Our manual clearly stating that the system can mirror both bodily and emotional reactions, but somehow, their associations to the stress management practices precluded engagement with physical activities. It is particularly interesting as stress research show strong relationships between training practices and stress relief [15]. It is as if once a user is forced to take a stance to which product or practice association they make with the ambiguous, open-ended design such as Affective Health, other interpretations are precluded.

5.2 Improving sports performance

In contrast to the fifteen participants who did not at all discuss their physical movements as mirrored in the movement and skin conductance data, there were seven participants who focused mainly on physical performance. Six of them were from the orienteering athlete user group. It is therefore not surprising that they were looking for anything that could improve their physical performance. But it is interesting to note that only one of these athletes focused on stress and emotional stability as part of maximizing her physical performance. The other six did not see the system at all as a stress management tool, or as a tool for tracking emotions – they focused solely on the relation between sweat and exertion. They would probably all agree that their physical performance is strongly linked to their emotional wellbeing, as this is much discussed in sports, but still they did not look for this connection in the data at all.

The only participant who engaged with the system in both ways, linking ways of improving her sports performance with stress management, was TA. She believed she should be able to improve her performance in competitions through controlling her stress levels in general:

> "*I have been checking out what stress level makes me most efficient and so, and [makes me] do stuff. I've come to the conclusions that is about yellow,*

> *then I usually, … yes, when it is about yellow, that seems to be a good stress*
> *level for me [to perform].*" (TA)

TA was highly engaged with the data, looking for patterns, and open to interpreting unexpected patterns as relating to her experiences. In our first interview with TA, she was showing us her data, talking through a situation that she had thought of as a calm relaxing moment, but looking at the data she afterwards realized she was stressed and thinking about all the things she should be doing:

> "*Yes, we were here when we sat to have a coffee break. At that point I was*
> *very surprised by how red it was. We just sat there, having a coffee really,*
> *but then I remember that I was sitting there thinking about all the stuff I*
> *should be doing and how I will manage to deal with all of it. We were really*
> *taking things quite slowly, but I was thinking about that stuff.*" (TA)

She explained later in the interview, that this was a new insight to her. She had not understood before that she could be stressed even when she was sitting down calmly, just thinking about tasks to be done. She then showed us another example when she was on the way to a training camp. Her data was red all the way up until they started to drive the car and then suddenly she turned to blue (see Fig.3):

> "*[…] at one occasion, I was on my way to a training camp. When we are*
> *about to leave, we had to sit and wait in the car and we were waiting for a*
> *long time as some of the others had to pack stuff into the car. Some skis and*
> *stuff. It was pretty cold there, in the car, and during the waiting period I*
> *was very red. Then you could see that right when we started going, it went*
> *down to blue.*" (TA)

She continues to explain that she didn't think of it as she was being stressed, but when she looks back she probably was, because she wanted to leave. This insight made her start altering her behavior, trying to calm herself down in situations where she was only "thinking" about stressful tasks or situations rather than being in them. This in turn, she linked to her ability to perform well in competitions. She spoke about one training session for orienteering when she got lost in the woods and she could not find her way back. The system was then red for a short while both before the competition started and then again when she got lost.

Fig. 3. Leaving with car screenshot from TA

Through putting these events together, she started to form ideas about how to take control over what she thought of as "mental stress" with how to achieve "optimal performance". Her idea was that

by sticking to an optimal stress level – both when training and when not doing much – she would be able to take better control also in those situations where it mattered to her.

But the other six who focused solely on improving their sports performance also made good use of the system. What is interesting is how they had to invent explanations and ways of interpreting data that would otherwise be associated with a more mature practice. Take, for example, the experiences of EO, one of the athletes. Since the onset of the experiment, his interpretation of the data was that it was correlated with his energy level:

> "*I think it might be relatively correlated to the energy level or the effort put in during the day. You are a little bit more tired in the evening and not as enthusiastic or up and running for it.*" (EO)

Continuing to articulate his energy level metaphor, he attempted to explain the colors shown to him as being related to how "warm" or "cold" his body was, and how it can be correlated with the metabolic rate. In one occasion, he compared his data with the data of another participant of this study, and was one of his training partners, where he explains the data using concepts like temperature, training hours, and eating schedules:

> "*Well, yes, Peter was a little bit warmer than me all the time. What we put in there, as a reflection is that I am a person who tends to get cold easily. I run just as much, in terms of time I workout very similar to Peter, but I eat less and get cold much more often than Peter does. Peter eats more, is almost always warm…so that is a difference. It is almost like he has a higher metabolism than me, the basic metabolism kind of.*" (EO)

When asked about the purpose of the system, EO said that for someone like him, the system could give an indication of sports *recovery* – a concept that reoccurred with several of the participants in this group. The idea is that if you train too much, without letting your body recover, you will be 'over-trained' and underperform. But how do you know if you have been training too much? And how do you recover? These participants hoped to see those patterns in their data. But as there was not a clear established practice for how to interpret skin conductance data from a recovery-perspective – no baseline, no numerical values to adhere to – they struggled. Take for example the experiences of PO, an athlete who competes internationally. He uses different kinds of devices when training, such as a GPS and a watch that shows his heart rate. Training is for him already a data-enriched practice; he uses data to reflect on his past trainings and to find ways of improving. He attempted using the system as part of his training, but it failed to provide him with the kind of data that he expected. He would have liked to have access to the "value", so that he could plot it in a graph to check his own performance over the time.

> "*Yes, right, for example do a variability graph, yeah, that could be a cool test to do.*" (PO)

Another user, BES was not an athlete, but he also used the system as a kind of sports device. Unlike PO, who was only interested in his own values, he wanted to know what a "normal" jog was for a "typical guy", so he could compare himself to some kind of reference value:

> "*when you get a population, then you do like, but here is a typical guy who runs to the bus, here is a meeting where you have an engaged discussion, and here you are out running or jogging.*" (BES)

It is clear how other sports tracking devices, such as pulse meters or step counters, allow for these kinds of comparisons. Once participants latch on to the idea that Affective Health is a sports device, these interpretations come easily. Unfortunately, some of those sports equipment-based practices require a type of precision that Affective Health does not provide. With current technology and scientific knowledge, skin conductance measured from the wrist is not associated with markers of performance, nor is there a normalized way of using it to exercise. In fact, skin conductance is so prone to environmental variation that an effort to produce such a device would have to rely on more than one

type of sensor to cancel out noise. Nevertheless, some participants did believe that such accuracy was perhaps possible, and noted the lack of expected features in Affective Health. Their expectations came from using other sports products. Extensive validation on research and technological development, as well as marketing, have made e.g. steps as markers of physical activity [84] or target heart rate zones as household concepts for most people who exercise. Participants referenced a number of products that they either used or were aware of, that were able to measure and provide a type of certainty that they expected from Affective Health. The fact that the wrist-worn Affective Health looked like many of the current exercise watches made it so that our product was interpreted as one of these, by some participants.

In summary, similar to the stress management situation, moving from a proto-practice to a mature practice for improving your sports performance with a system like Affective Health, would require that users are provided with a whole apparatus for understanding what skin conductance really says about performance, recovery and fitness. Probably we also need more research in order to understand how skin conductance can be linked to improving performance. Tholander and Nylander [82] uncover two distinct dimensions in self-tracking in sports: measured sense of performance and lived sense of performance. Physical performance can be social, even in softer experiential perspectives. While a measuring perspective can require a "reference population" or other kinds of comparisons, softer goals can afford a co-located interaction where "energy levels" represented by skin conductance data through colors can be playfully compared between friends or training partners, supporting physical exercise as a co-present [49] activity. This was a role that Affective Health fulfilled to some of our participants.

Pertaining to our main argument in this paper – that participants sometimes do not even see data that speaks of other processes, like emotion, stress or simply events in your life – it is very clear how this was enacted for everyone in this group – except TA.

5.3   Life-logging

Our participants often told us stories about their lives while looking back over the data in Affective Health. To two of the participants this became their main use of the system. To them the system became like a diary where they could go back and remember what had happened without really looking for ways of managing stress, increasing performance or handling emotions. This type of usage is similar to what Rooksby and colleagues call documentary tracking [58].

For example, JM uses the system to recount when he was at work, when he was spending time with the kids and so on. While he notes that there was a week that was particularly stressful, he does not see stress as a problem to him. In general, he did not really feel a need to change himself or any pattern in his life. Instead, after testing the system extensively to make sure that it actually worked as said, Affective Health became as a diary to him.

Lifelogging or keeping a diary is often a way to process events in the past. Remembering, re-framing, re-experiencing as a way to process or even alter memories [76]. Throughout the years with Affective Health we have met many who believe that logging body data would reveal something about them that they do not yet know understand. By returning to past events, looking at their bio-signals, their bodies would be able to speak to them, telling them something. In this study, some participants, like BX, simply noted that they could use Affective Health to help them remember past activities.

"It's quite easy by looking at that to identify how, the time that I was walking around or moving or doing something." BX

Others, like HH, preferred to reminisce on moments that they enjoyed, associating these with colors such as yellow or green, reflecting their general mood:

"I'm definitely green, it's like Saturday morning, we start the day usually with coffee, […] I'm not in a hurry going anywhere. You don't have to do any obligations, the things we sit, have a big breakfast, not as

big as in a lot, but more as a long breakfast. We play music, I play music and then I play different songs, then that is like also calm feeling, like yellowish" HH

Overall, life-logging is probably the most well-established practice that a system like Affective Health could latch onto. Several life-logging tools share properties with Affective Health. As discussed by Sellen and Whittaker, lifelogging tools are supporting the five r:s: "*recollecting, reminiscing, retrieving, reflecting, and remembering intentions*" [71]. None of these uses require any behavior change but are more concerned with ways of understanding yourself. Using Affective Health as a life-logging tool is therefore, in some ways, less demanding than using it to detect negative stressful behaviors and alter them, or improve performance.

Using Affective Health as a life-logging tool would of course be much improved if the system had also provided logs of where events took place or integrating the data with other memory cues such as photos, calendar data or messages sent/received.

5.4   Personality representation

Six participants explicitly mentioned their personality in relation to their system encounters. Most referred to how calm and collected they typically are. In a sense, they are influenced by some of the socio-cultural ways of speaking of personality traits. 'Personality' is often interpreted as some stable traits that do not change throughout your life. While these participants might be willing to change their behaviors around training or habits, they do not see personality as a trait than can be changed. Many who speak explicitly about their personality traits maintain very strong beliefs about their stability: I am a calm person; therefore, I cannot make sense of any data that speaks against this view. TS, for example, one of our elite athletes, had this particular view. He associated Affective Health mainly with stress management (not with sports performance despite being an athlete). As he believes he has a calm personality and despite claiming that he is interested in learning about his own stress patterns, he is not really learning anything, at least not anything he is reporting on in the interviews. Whenever red arousal peaks appear in his data, he dismisses them as technical glitches:

> "*Now, do you see, a small red thingy. Can you see it, right after the yellow? Below that yellow, there is a small, small red thing [...] most of those I interpret as a [technical] glitch, that the wristband is not properly attached. Or maybe some fluid entered [between wrist and wristband], it usually is*" (TS)

While his interpretation might be correct – it might be that those are technical glitches – it might also be that he is missing out on a learning possibility. Maybe those small red arousal peaks show a pattern of situations where he is not so calm. This contrasts with other research in skin conductance displays in everyday life [28], where participants did not question the authority of the data. Here, we hypothesize that the prior beliefs that people have about themselves and the context they are in is weighed against the data offered by the device, and some participants trust their own prior believes over the data they see. But just because you believe you have a particular personality that belief not necessarily preclude changing and learning. Perhaps most interesting here is BX who learnt that he had more patience than he believed he was capable of:

> "Interviewer: Generally, then, do you feel that it really reflected you in the system? [..] BX: *Some of them were a little surprising but that was good, because I would love to see surprises, and the surprises also helped me understand myself a little bit better. So as I was telling NN, initially I thought I would have quite a lot of arousals when I was, when I tried to keep patient with the kids, but it didn't show up like lot of arousals. Which might mean that I could, I had better patience than I thought. So there are always some limits that I could probably push even further. And those are quite good findings that I had about myself. [..] Yeah, so for example talking*

> *about the patience with kids, and lots of times I felt I was already pissed off*
> *and I tried to keep calm, but I guess it was far, still far from the red so I*
> *could keep calm for a little longer time I think.*" (BX)

Here, BX is also hinting that this insight about his own patience might even help him change to become even more patient. Later in the interview, he mentions that Affective Health would have been even more useful to a younger version of himself who did not know how to control his temper. He is happy to see how he is now a much calmer person.

But is personality tracking a proto-practice? We have very little data here (only six mentioned their personality at all and none of them used it as their main product categorization). Nobody explicitly mentioned any other products to do with personality tracking (such as the Big Five personality model [95] or the numerous popular social media tests of your personality). To us, what is more interesting is what set ideas about personality traits enables or precludes. Once a participant is set on re-confirming what they already see as their personality, they are not open to any other interpretations – even if the data speaks of other reactions than those they expect. And vice-versa, if they are actively trying to change themselves, then they look for data to support the change process.

5.5   Emotion tracking

As skin conductance is otherwise so strongly related to emotional arousal (as in the lie detector machines) it was a surprise to us that so many of our participants did not associate data to emotions at all in Affective Health. Out of the 23 participants, only 8 spoke of emotions in relation to the data. (We do not count stress as an emotion). In addition, emotions mentioned were limited to either anger or happiness. And even if we extend this category to also include mood, there is almost no mention of moods either.

But there are a couple of instances that show that Affective Health could potentially develop into an emotion-tracking tool. One of our participants, GZ, used the system very much in this manner. She kept looking back over the data to find a pattern that was unexpected, where her body was responding in ways she was not expecting. Often, she failed to find anything that surprised her, which made her disappointed in the system. But she also looked for the happy moments, aiming to relive those positive moments, as a reminiscing tool. In particular, she relishes the moments when she picks up her kids at Kindergarten:

> *"…I think several occasions I was very red was when I was really happy to*
> *see [child's name] or [other child's name] after kindergarten. …because*
> *when I picked him up he, he calls mamma, mamma, hugs me, look at me,*
> *hugs me so it's a really nice feeling*" (GZ)

One of our participants, CL, even used Affective Health as a way to look back over her dates with a man she was dating and when the skin conductance-readings showed high arousal during the first dates, she took this as confirmation of her romantic feelings – that the spark was there. Her she notes that the system displays red not only when meeting but also when talking about him with others:

> "*Yes, I thought it was kind of fun to see. And kind of right when I have*
> *spoken about him, told someone else about him, then I react the same. It*
> *sounds promising.*" (CL)

Just as with representing personality traits, it is perhaps hard to speak of emotion tracking as its own practice. Even if we often discuss our emotions with one-another and probe our own feelings in diaries and through life-logging systems, there are almost no products on the market specifically targeting emotion tracking [42]. There are no ready-made product categories to latch on to or even structured practices that help us follow emotion changes in our daily life. This said, emotion tracking was seen on and off in our data.

5.6   Behavior change

Most participants (16) mentioned how the system could be used to encourage behavior change in their lives, either by helping them to maximize their physical performance, or in dealing with negative emotions or stressful situations. Not all of them succeeded in finding something they explicitly addressed and changed. And even when they found something they wanted to change, it is not easy to change or even know what a relevant change would be.

But some (7) of the participants did make use of the system to train themselves – both in identifying patterns and then trying to change them, or in the moment, in a real-time feedback loop with the system. For the latter, for example, CL discusses how the system confirmed her ability to react in a better way to stressful situations:

> "*I was going to have lunch with a friend. We were going to a place… I had not been there before. I knew where it was, but not exactly where to enter. That often happens to me that if I go out to have lunch I am a bit stressed and … yes if you want to sit for a while and so. We were wandering around and it was pretty cold outside and so, we were [wondering] "but where do you enter?". Then once we found it, I went to the ladies first. And then I said, aloud, to myself, that, "well it is not dangerous, is it?! Now I need to slow down a bit". Then it [the system] reacted here, right away, kind of…*" (CL)

Here CL is happy to see that the system confirms how she immediately calms down after explicitly telling herself to relax. She looks at the system in the moment, at the ladies, and gets confirmation that she is indeed able to calm herself down.

Sometimes change is not so much behavior change as an attitude change – as for PR that we discussed above. Her use of the system was quite detached during the first weeks. But as she discovered that she was getting ill from the stress in her life, her attitude to and what she saw in the data changed dramatically.

For those who mainly aimed to improve their sports performance, we were intrigued to see how they tried a whole range of hypotheses. This type of usage can also be called diagnostic tracking, where participants try to find correlations between things [58]. EOI hypothesized that he needed to drink more water in between training sessions and also let his body recover better, in order to improve his performance as he conjectured that he was not sweating enough. MM focuses on identifying the calm periods as she was hoping to improve her ability to recover better between the training sessions. EO spoke about his body temperature and how he should eat more to become warm.

Whether these hypotheses are at all related to skin conductance is a matter of debate and much more research as well as development of shared practices would be needed to really know. But our point here is not so much whether these are correct interpretations of skin conductance. Instead, what we noted, over and over, in the interview data, is the need for a strong reason to engage all the way from looking at the data, making sense, reflecting on what they mean, to actually setting goals and persistently attempting to change. Behavior change is notoriously difficult [21]. In Shove's practice theory terminology [73], as discussed in the background, you need both competence (as in knowing how to handle the technology, how to interpret the data, or what to do to achieve change) and images (meanings, shared ideas of what the system is for), alongside the technology (Affective Health in this case) in order to create for a sustained practice. Here, we clearly see the need for such shared images of what Affective Health could support.

6   DISCUSSION

As we have shown, skin conductance data, as measured and presented by Affective Health, fitted different proto-practices, some partially overlapping, others dramatically unalike: managing stress, enhancing sports performance, logging life's events, confirming personality traits or tracking different emotions, or providing a basis for changing behavior. Based on these, we now turn towards implications for design and possible future re-design of Affective Health. Or perhaps more importantly,

not only the re-design of the system as such, but what it might mean to deliberately 'design' the overall practice, i.e. moving from proto-practices towards practices. We then argue that the whole process, from design to study to analysis, shows an important possibility through this combination of an open-ended, ambiguous design and practice theory. Finally, we discuss our experiences of using practice theory as a lens to analyzing rich data as the one at hand.

6.1   Proto-practices around skin conductance

We do not claim that this is an exhaustive list of possible skin conductance applications, but the proto-practices we presented in this paper show possible pathways for designing products that seek to weave skin conductance biofeedback applications into everyday life practices. They are related but are more than "folk theories" [32], i.e. lay perceptions of what skin conductance is and what it can be used for. This is because, to explore proto-practices, not only the users' everyday experience with data needs to be considered, but also the product semantics of Affective Health, as well as the users' assumptions and motivations for using this technology, as we can see a priori that the different user groups at recruitment had different expectations for using Affective Health.

Our findings indicate the importance of open design for the emergence of proto-practices associated with current relevant goals. For example, we have seen how many athletes focused on sport performance that is their most relevant goal. While their prior experience with tracking devices meant that they could transfer expertise so that they coped well with an ambiguous interface, others such as GB could not. This suggests the tension when designing for proto-practices between too little openness, preventing system's appropriation for goals not explicitly supported in the system, versus too much openness, leading to either frustration or disengagement. We can think of new design principles [68]for novel classes of technologies supporting proto-practices which should aim to balance the tradeoff between ambiguity and scaffolding. This can be done through participatory design approaches, and the provision for the option to select a decreased level of ambiguity of the interface design.

People engage with the data through the associations they make with these different product categories, showing that engagement with data is not detached or objective, in line with other research in personal tracking in everyday life [59]. According to Feinberg [10], even "just using" data requires conceptual framing to imbue data with meaning. Users' perception of semantics of the product that produces and displays data is an important piece of that conceptual framework. Skin conductance can acquire a variety of meanings depending on how it gets interpreted, associated with different images and beliefs, and integrated or rejected in different practices. Based on our data analysis, we note that users' interpretation and usage is not only a matter of what we told them the system could do or whatever signs and signals are communicated in the Affective Health interface and in the shape and form of the bracelet. We could see that our participants did not look at the data in a value-free manner, from a clean-slate perspective, just trying to make sense of it 'objectively' and systematically. Instead, they made sense of it against a backdrop of beliefs about arousal, personality, emotion, stress and physical performance, as well as other products and practices. Our findings are in line with other research with skin conductance displays. For example, if skin conductance is displayed alongside contextual information from the workplace, such as meetings [21], then data is going to be interpreted as stress levels, but if it is displayed in other contexts such as social situations, then it gets interpreted differently, for example, as emotional engagement with others [28]. If we were to launch Affective Health as a commercial product, the different proto-practices we described would be pointing to different market segments. Depending on which one we choose, further work would be needed to support the shift from proto-practice to a functioning practice. If we aim for those interested in stress coping mechanisms, it might be good to provide stress management exercises in the system. For improving sports performance, we would have to make further studies into what other sensors could be used to deliver a more stable interpretation of what improves performance – or what improves

"recovery". For life logging, other contextual data should be integrated in the Affective Health interface, designing to support memory retrieval cues [71].

But what our study shows, is that changing the system is only one piece in the puzzle. What is also needed is 'competence' in handling the technology, in everything from charging batteries to making sense of data patterns. Users also need to set goals – or create 'images' of where they are heading and how to integrate these processes with their everyday life – which could be done through sharing practices and ideas in on-line forums. The study by Boman and Sanches [6] shows how Fitbit users make sense of their tracked step data by sharing practices in the online forums, not only by helping each other making sense of data, but also by finding alternative practices using the step counter (e.g. in a bicycle), or together developing solutions for when the device is found to be incorrectly making calculations. Similar to how many know that they are supposed to walk 10.000 steps per day and that step counters can help keep track, normative statements about stress or performance around skin conductance data might have to be communicated. The problem here, of course, is that stress, sports performance, recovery, are in themselves very complex phenomena where normative statements do not make much sense in an objective sense.

For sports performance, we note, for example, that skin conductance as measured by the Philips DTI-2 bracelet and communicated through the Affective Health interface, does not deliver the precise measurements needed to optimize performance. To achieve those, a considerable amount of work would need to be done in order to develop standardized measuring practices, ways of cancelling out contextual factors, and only then it would have been possible to represent the data in the more familiar semantics of fitness trackers.

Similarly, for stress management, the complexity of the stress phenomena requires a sophisticated understanding of the mechanisms behind stress illnesses and ways of recovering. We noted above how those who already had experienced stress problems had a much more informed stance, making better use of the system. But first they had to *make space to engage with data*. Making the data offered by these systems an embodied part of themselves (as so elegantly shown by Kaiton Williams in his study of weight reducing technologies [53]), requires 'work'. Participants who were looking for clear cut patterns did not find any, but those who had motivation, and were able to find time to deal with personal stress issues used the data as an aide to go through periods in their life. Data on its own did not mean anything, but together with memories of events it can be used to tell a story, and sometimes to reappraise feelings attached to past events. It is through that process, supported by skin conductance data but by no means defined just by it, that some of our participants were able to identify and take measures towards improving their lives. (Those with less experience had naïve ideas about how stress manifests itself and what to do about it, and were consequently not able to interpret the data or engage with it, in manners that could help to prevent stress problems.)

In summary, to turn the current version of Affective Health into a useful and viable product requires picking one, or several, product segments, and then actively re-designing both the system but also the whole 'practice', including communicating competence, ideals and ways of 'making space' for engagements with the system and the surrounding conceptualizations.

6.2 Evocative balance as part of a methodology to co-construct semantics

A question we might ask is whether ambiguous designs are a viable path to richer engagements with technology? What we would like to argue based on the results of this study, is that they serve (at least) two possible, and important, purposes.

The first purpose is to interrogate a design space, serving as a probe. As noted above, lately there have been fewer publications [28] where skin conductance is used as an ingredient in user-facing applications. With this study, we, in a sense, are opening this design space, pointing to several different possible product possibilities. In general, combining an open-ended design with a study along the lines presented here, might be a helpful path to discovering new practices or reconfiguring existing ones.

Ambiguity really arises in the relationship between the user and the system. In many ways, the process of altering Affective Health into a commercial product is similar to designing systems like step counters or pulse meters. The underlying data used, steps and pulse, are akin to skin conductance, ambiguous. It is not until there is a practice (as we argued in the introduction) that helps end-users to make sense of the ambiguity against whatever aims/goals/images they have that a proper practice can develop. Framings such as "you need to walk 10.000 steps every day" help shape the practice. Commercially, there is a potential to further explore these different product categories and engage with shaping the overall practice where a system like Affective Health would fit. This practice design needs to go all the way from marketing, to support systems, choice of terminology, on-line forums, and collaborations with e.g. therapists, health or sports experts, surrounding the new product. We might need a smaller group of users, from some marginal practice to take on the system and use it for a while before we can shift it to a larger community [46].

The second reason why ambiguous designs should be one tool in the toolbox of a designer is to provide better, truer accounts of what the system is providing when the data itself can be interpreted in so many different ways as skin conductance. Furthermore, skin conductance is just one variable, measuring one bodily process. It would be reductionist to claim that arousal is solely what a skin conductance measurement shows. The richness of the accounts in our interview study tells us that the ambiguity in our design, and the striving for an evocative balance, touching processes that feel familiar to us, was a successful, even if demanding, path to engage end-users with richer accounts of what was going on than solely what a straight skin conductance measurement would provide for.

Notwithstanding many possible interpretations of skin conductance in everyday life, a question that can be raised is the one of ethics and designer responsibility in ensuring that correct interpretations of biodata are made. Should designers prevent erroneous interpretations of biodata? Biodata is never neutral, and it changes how people relate to their own [91] as well as other's bodies, when seen through the lens of biodata [33]. For example, quantified data on babies health can affect how families relate to their offspring, and misguided trust on data can be an added source of anxiety [89]. However, preventing erroneous interpretations of biodata may not be feasible, as it would be impossible to envision all the settings and contexts around the use of the designed product, sensor failures, and how they are appropriated in every-day life. While there are contexts where authoritative systems may be beneficial, such as critical healthcare or emergency systems which pose unique ethical challenges [8], in the space of personal technologies for everyday life, we argue that there is a space for systems that critically engage users themselves in meaning-making. Within HCI, the growing interest in the human body [24,25,52], has started to shape designers' need for better communicating and understanding of the internal, felt qualities of bodily experiences [47]; therefore we further argue that users benefit from an increased bodily literacy in situations where it increases body awareness and aesthetic sensorial appreciation. As more and more data-intensive and wearable systems enter our everyday lives, it becomes critical to better communicate how sensor-based systems sense us and to, at times, include users in interpretation, decision making, but perhaps more importantly, enjoying and caring for the body.

6.3 Practice as a lens for designing for everyday life

There are, as far as we know, not many practice-based studies of open-ended, ambiguous, systems such as Affective Health. A similar approach was taken with the trigger-products by Kruijer and colleagues [40], but their approach takes an existing product, instead of designing for an entirely novel category of use. Gaver and colleagues have performed studies of several of their ambiguous designs in situ (e.g. [16–18,20]), as well as Hutchinson and colleagues [30]. In these studies, participants have engaged in ways that makes sense to them – not always what the designers had expected – and depending on which narratives they have used, different forms of use have resulted, or different requirements. But they have not used practice theory to analyze their results, as we did here. Their focus was on

individual interactions with systems, rather than more systematically unpacking wider narratives surrounding the systems they deployed, as we did here. To us, the practice theory lens helped see how new designs enter into a complex world of preconceived notions, product categories, social rhetoric, adding interpretations that go well beyond the design of the particular system, and this unpacking gave us a richer picture of what would be required to move from the ambiguous design towards viable commercial products – an aim that Gaver and colleagues are not necessarily engaging with.

In our analysis, practice theory became a helpful framework to understand what was going on in our data. It helped explain why different participants had so different interpretations and why some seemed to be entirely uninterested in (or unable to detect) certain interpretations. By seeing Affective Health as an artifact not yet linked to particular 'competences' or 'images', made us better equipped to make sense of what different participants were doing. It allowed us to detect the proto-practices in formation. As the results showed, skin conductance data, as measured and presented by Affective Health, fitted different proto-practices, some partially overlapping, others dramatically unalike: a measure of stress, useful for enhancing physical performance, logging life's events, mirroring different emotions, or personality.

7   CONCLUSIONS

The study presented here presents possibilities for designs of technologies with skin conductance. As Krippendorff and Butter [18] stated "*What we need are research methods that will not restrict us by saying what is right and wrong, but will show us where the range of practical options lie.*"

Through the lens of practice theory, we have analyzed the data from a month-long study with 23 participants using a skin conductance-based tool. What we found were entanglements of socio-cultural rhetoric, effects of the design itself, participants' experiences and competence. Our study analysis shows how bio-data engagement is not detached and rational, but an ongoing lived emotional experience that can only be understood in a specific socio-historical context, against the backdrop of product categorization. Our analysis also shows the importance of widening the scope of what we mean by designing and validating design. While we all might be fully aware that the design process does not end once the system is launched as a product, providing the practice theory framework may help us continue the designing activity throughout the whole process – beyond the surface signs and signals of the design itself. This can work as a catalyst in opening up for unexpected use areas while at the same time get detailed input of what how to tailor the system to better fit a specific use. As HCI-researchers we need to move beyond designing interactions with technology itself, to instead designing practices [38], activities [88], considering systemic factors and dynamic factors at play in everyday life, that the applications we design will be part of.

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