Emotional Biosensing: Exploring Critical Alternatives

NOURA HOWELL, University of California, Berkeley, USA
JOHN CHUANG, University of California, Berkeley, USA
ABIGAIL DE KOSNIK, University of California, Berkeley, USA
GREG NIEMEYER, University of California, Berkeley, USA
KIMIKO RYOKAI, University of California, Berkeley, USA

Emotional biosensing is rising in daily life: Data and categories claim to know how people feel and suggest what they should do about it, while CSCW explores new biosensing possibilities. Prevalent approaches to emotional biosensing are too limited, focusing on the individual, optimization, and normative categorization. Conceptual shifts can help explore alternatives: toward materiality, from representation toward performativity, inter-action to intra-action, shifting biopolitics, and shifting affect/desire. We contribute (1) synthesizing wide-ranging conceptual lenses, providing analysis connecting them to emotional biosensing design, (2) analyzing selected design exemplars to apply these lenses to design research, and (3) offering our own recommendations for designers and design researchers. In particular we suggest humility in knowledge claims with emotional biosensing, prioritizing care and affirmation over self-improvement, and exploring alternative desires. We call for critically questioning and generatively re-imagining the role of data in configuring sensing, feeling, 'the good life,' and everyday experience.

CCS Concepts: • **Human-centered computing → Interaction design theory, concepts, and paradigms**

KEYWORDS: Biosensing; critical alternatives

ACM Reference format:
Noura Howell, John Chuang, Abigail De Kosnik, Greg Niemeyer, and Kimiko Ryokai. 2018. Emotional Biosensing: Exploring Critical Alternatives. In *Proceedings of the ACM on Human-Computer Interaction*, Vol. 2, CSCW, Article 69 (November 2018). ACM, New York, NY. 25 pages. https://doi.org/10.1145/3274338

1 INTRODUCTION

Fig. 1. Leaf Urban, Spire, and Microsoft Band (from left) promote: "Elegance matters. Health even more" [158]. "Give the gift of calm" for Valentine's Day [51]. "Live healthier and achieve more" [159]. These advertisements shape our desires toward a particular normative vision of the good life. How can emotional biosensing support alternative ways of living and feeling?

2573-0142/2018/11 – ART69 https://doi.org/10.1145/3274338

Biosensing technologies track many aspects of daily life, including emotions, in sometimes unexpected ways. For example, video surveillance can be used to 'detect' percentages of joy, contempt, or anger [160], 'hostile intent' threats at airports [161], or heartrate [99]. Heartrate can be linked to stress [87] or future involvement in violent crime [71]. Mobile phone and Instagram data can be linked to depression diagnoses [19,105]. Abilify, a new medication for depression, bipolar, and schizophrenia, tracks whether patients ingest it to ensure compliance [156,162]. It is difficult to know or manage how we will be categorized from the seemingly innocuous data we give off by appearing on surveillance cameras or using a mobile phone, or how these correlative categorizations might masquerade as authoritative predictive insights.

For those of us not (yet) categorized as 'crazy' or 'criminal,' or those deemed 'healthy,' consumer products urge self-improvement via algorithmically generated behavioral adjustments [113]. Microsoft Band promises, "This device can know me better than I know myself, and can help me be a better human" [154:2], with "actionable insights" to help "live healthier and achieve more" [163:2]. Wristband sensor Feel claims to be the "world's first emotion sensor and well-being advisor" [164]. Clip-on breath monitor Spire offers to help "gift wrap peace of mind this Christmas" [50], reducing stress and improving mindfulness [165]. Certainly we all need help emotionally sometimes, and these technologies may help some people. Yet, these devices illustrate a prevalent approach to emotional biosensing that is far too limited.

In "Fitter, Happier, More Productive: What to Ask of a Data-Driven Life," Elsden et al. question the normative values of helping individuals be fitter, happier, and more productive. They argue that prevalent approaches to self-tracking are too limited. They call for broadening the design space to explore, "moving beyond an individual, trajectories and temporalities, and alternative representations of data" [31:46]. Focusing on emotional biosensing, this paper builds on these questions and helps broaden the design space by locating emotion beyond the individual, exploring alternative material data displays, and highlighting epistemic tensions.

CSCW challenges notions of individualism with its longstanding focus on collaboration, alongside a growing body of design research and art exploring such questions. Sharing and interpreting biosensory data, Slovák et al. studied social connection [125,126], Snyder et al. combined pair's data into a single display [127], Elsden et al. explored social performance [30] and memorabilia [29], Merrill and Cheshire investigated trust [89], and Kaziunas et al. [64] and Pina et al. [103] studied emotional aspects of family health tracking. Unfit Bits challenge step counts [14], plenty of work supports personal and social reflection [58,91,110,111,128] or social sharing in video or fashion [33,118,139,147], and somaesthetic design attunes bodies to sensing themselves [56]. Still more work explores immersive meditation [140], emotional meaning making and performativity [73,74,143], privacy [150], mindfulness [2], design fictions of BCI APIs and labor [149], or relationality [83,93] with biosensing.

We reflect on industry zeitgeist and draw from ongoing alternative explorations to outline how prevalent approaches with emotional biosensing are too limited: They promote individuality and optimization, and claim data can capture and represent emotion extracted from context. We leverage strands of critique from design research, feminist new materialisms, and (post-) biopolitics to suggest generative alternative approaches for design researchers.

How we approach emotional biosensing has intrinsic consequences for vital ethical and political questions and shifts [107]. What are or will be "the actors and authority involved in the production of 'self'-knowledge" [55:2], who is granted the authority to speak what truth, and what ways of knowing the self are considered valid? With self-tracking, "At stake are the very

lenses we use to see ourselves and others" [97:10]. With emotional biosensing in particular, at stake are ways of feeling and the emotional experience of everyday life.

Our contribution prioritizes open-ended generativity. We do not propose a new research agenda or ethical guidelines for emotional biosensing. Instead, we (1) curate and synthesize a set of wide-ranging conceptual lenses, and unpack how these can shift design research with emotional biosensing. (2) We select and analyze design exemplars to concretize concepts. (3) Throughout we offer reflections and recommendations for emotional biosensing design. In particular we call for humility in emotional knowledge claims, prioritizing care and affirmation over self-improvement, and exploring alternative desires. In the spirit of Law's reflections on method and messiness [72], we put these lenses into conversation without flattening messiness to acknowledge the complexity of affect, feeling, and emotion, and reflect on how each lens crafts reality slightly differently. Rather than providing answers, we wend pathways for asking:

How can emotional biosensing be reconfigured away from commodity lifestyle and self-optimization toward alternative ways of feeling and living?

2 CURRENT APPROACHES ARE TOO LIMITED

Fig. 2. Consumer products Feel [164], Moodmetric [157], and Spire [166] (from left) provide categorical, quantitative, and comparative representations of emotion and suggest behavioral adjustments. They emphasize particular ways of knowing emotion and the self, locating emotion at the level of the individual and valuing scientific objectivity as a means of knowing the self. We argue that Feel's discrete emotional categories (e.g., joyful, sad, content, distressed) flatten richness and complexity of feeling while ignoring context, and its Mood Booster exercises suggest we should desire an 'upward' trajectory. Moodmetric's scale from 0 to 100 also flattens mood along a single axis. Considering context, how might Spire's suggestion of a "quick breathing exercise" be received during a hectic morning vs. a family emergency?

Here we outline how emotional biosensing products are too limited in their emphasis on the decontextualized individual, workplace productivity, and data as an authoritative way of knowing. These limitations are opportunities to explore alternatives.

2.1 Prevalent Current Approaches

Affective Computing quantifies emotion into discrete categories based on patterns of participants' physiological signals. As an overly simplistic example, if most participants respond to a calming experimental stimulus like gentle ocean waves with a particular pattern of physiological signals, then this pattern is associated with calm. Experiments often include participant self-report of emotion as a kind of 'ground truth' to validate results, but the eventual goal is often framed as 'accurately' 'detecting' or 'predicting' emotions in daily life without needing self-report. Some claim this can provide more 'natural' experiences with technology or even detect deception. The goal is often to find generalizable categories of emotion that are

universal and transcend sociocultural context [18]. Yet, methods not only describe but also help craft reality [72]. Affective Computing creates the categories it seeks and reifies particular approaches to emotion that influence industry and enthusiast emotional biosensing.

Drawing from Affective Computing, consumer and enterprise products quantify emotion into standardized categories used to offer behavioral suggestions for self-improvement and workplace productivity. Feel, Spire, Oura, Moodmetric, and Leaf Urban track physiological signals (e.g., skin conductance, breath, EEG) to produce quantitative or categorical representations of emotion, and suggest behavioral adjustments for emotional wellness like reducing stress and improving productivity [158,165,167–169]. Affectiva uses facial video analysis to produce percentage representations of discrete categories like anger, fear, and joy, to help advertisers and developers make products more appealing [160]. Humanyze offers workplace tracking of "objective, complete data" like employee chat messages and meeting durations to "improve productivity, cost-savings, and employee satisfaction using the proven science of our people analytics platform" [170]. Muse Lowdown Focus uses EEG to help improve cognitive performance [171]. These products put Affective Computing into practice, claiming scientific authority for their insights and suggestions about everyday emotional experience.

Enthusiast practices also use quantification and behavior change for self-improvement and productivity, but with more individual flexibility on what to measure, what it means, and what to do about it. Self-described 'biohackers' track mood, heartrate, steps, etc. They seek behavioral adjustments in diet, lifestyle, and medication to improve professional performance, health, and wellbeing (e.g., [151,152]). Quantified Self enthusiasts also self-track mood in often creative and reflective ways (e.g., [172]). They often manually record data, offering flexibility and reflexivity in measurement and meaning making. Quantified Self may be a form of "soft resistance" against "dominant practices of firms and institutionalized scientific production" [96:1784], and a way to resist social norms [121]. Broadly, these practices emphasize self-knowledge and self-improvement via individual data tracking, data analysis, and behavior change. While commercial products provide an intended use case or kind of desirable behavior change, biohackers and Quantified Selfers usually decide for themselves what to track and what to do about it.

Of course, there are many practices of emotional biosensing not discussed here. We focus specifically on these practices because they align with a prevalent cultural imagination around data, where data is framed as having the authority to deliver promising insights. Reflexively, we as authors are especially attuned to Silicon Valley cultural imagination due to our location.

2.2 Potential and Limitations

There is positive potential in these approaches. For example, Feel executives hope their product will destigmatize mental health issues and make therapy more affordable [135]. For some, Spire does help manage stress throughout daily life as an alternative to medication [165]. Bio-hackers and Quantified Self enthusiasts share stories of how their practices have greatly helped them (e.g., [151,152,172]). Our critique is to call out what these approaches normalize or promote, outlining those as limitations to seek alternative approaches. While acknowledging that users may adapt products to their own purposes, our critique focuses on the approaches put forth by product companies, because these marketing materials influence our social and cultural imagination about what emotional biosensing can and should do.

These devices and practices focus on the individual as the site of sensing and behavior change. An individual focus on wellness can distract from and normalize structural issues, like stress due

to race, poverty, or gender discrimination, as outlined by Lupton and others [3,44,45,45,82]. These devices and practices join a broader biomedical move around risk and responsibility: Health is framed as constantly at risk, and it is the individual's responsibility to mitigate risk. One should seek a normative 'good life' via informed decisions and individual behavior changes relying on data [27,28,106,108,113,114,131]. Self-tracking products frame wellness as never-ending self-optimization, promote the "commodification of daily living," and "give far too much power to those who decide what is worth measuring and who measures up" [97:6–7].

A focus on workplace productivity, and health for the sake of work, is prevalent. Employers are beginning to push for tracking workplace and fitness activities with the aim of increasing productivity and reducing insurance costs. Some insurance programs reward 'healthy' behavior as determined by Fitbit [7]. In the U.S., West Virginia teachers went on strike partly in response to insurance changes requiring fitness activities as tracked by Fitbit and other means [11,37]. Big Health offers sleep tracking and apps for improving mental health; while acknowledging potential benefits, this is marketed as a way employers can reduce health insurance costs [173]. Even mindfulness gets framed as a tool for improved productivity and reduced stress [2].

These devices emphasize particular ways of knowing emotion and the self. Many devices treat emotion as something that can be put into discrete categories that transcend context, neglecting the socioculturally situated nature of emotion [10]. Cultural and new media scholar Hong describes how these technologies promote particular ways of knowing: "the idea that machines will know us better than we know ourselves, a kind of 'knowing' that embraces modernity's epistemic virtues of accuracy and objectivity" [55:2]. This points to opportunities for emotional biosensing to support other ways of knowing and other values.

3 SEEKING ALTERNATIVES VIA THEORY

Theory can help explore alternatives, not by presenting explicit design directives, but rather by helping see things through different lenses and suggesting different areas of focus. Critically oriented work seeks to question and reimagine our everyday interactions, often drawing from theory. These approaches may not lead to solutions immediately, but they offer better understanding of the problem space. These approaches embrace critique as opportunity for further research [39,102]. Our strategy for critique draws from Nafus quoting Latour in her introduction to *Quantified: Biosensing Technologies in Everyday Life* [95]: The critic can be "not the one who lifts the rug from under the feet of the naïve believers, but the one who offers the participants arenas in which to gather" [70:246]. We offer 'arenas' by grouping together different theories and projects and putting them in conversation with one another. The selection of theories and projects stems from our own design research with emotional biosensing. These are the lenses that are especially generative for our own work. These are the design exemplars we find useful for discussing these lenses with interdisciplinary groups of biosensing researchers.

The theories presented here speak to one another but do not reach perfect consensus. They are presented as separate, but different boundaries could be drawn. Instead of a cohesive summary of relevant theories, we sketch an (artificially linear) series of conceptual moves that suggest generative directions for a growing, dynamic design space. Reflecting on how these theories have informed particular design exemplars makes this engagement with theory more concrete. Reflexively acknowledging shortcomings or enduring tensions of these designs generates opportunities for further exploration. Methods and theoretical lenses are intertwined, and as Law argues they not only describe reality but also help craft reality [72]. With alternative lenses

CSCW design researchers can craft alternative realities for emotional biosensing, ways of feeling, and ways of knowing and configuring the self and social relationships.

3.1 Affect, Feeling, and Emotion

How do we define affect, feeling, and emotion in the first place? These definitions influence emotional biosensing designs. For example, distinguishing affect, feeling, and emotion suggests designing for more affective embodied experience, personal interpretation of feelings, or social interpretation of emotions. To explore alternatives with emotional biosensing, we consider how affect, feelings, and emotion have been distinguished in different fields (e.g., [6,65,68,100]).

One view from media and cultural studies outlines a progression: *Affect* is seen as pre-cognitive or more embodied, before conscious identification by the person experiencing it. These can become *feelings* when consciously recognized by the person. These can become *emotions* when mapped to words or concepts that are culturally recognizable by others [123].

Psychology takes various approaches to understanding affect, feeling, and emotion: For instance, while social appraisal theory emphasizes the role of interpretation in orienting ourselves toward the world, processes like mimicry, contagion, and empathy focus more on "direct embodied" transfer without interpretation [100:6]. Design could draw inspiration from processes of mimicry or social synchronization of physiological signals (e.g., [126]). Drawing from psychology, Affective Computing "hope[s] to build computer systems that can automatically recognize emotion by recognizing patterns in these sensor signals" [49:1].

In sum, different distinctions rely on different framings of self, embodiment, and consciousness. Not taking a hard stance on these distinctions in this paper, we acknowledge the variety of distinctions at play in the variety of work related to biosensing, mood, feeling, affect, and emotion. This variety indicates not a lack of rigor, but rather is an expected outcome of drawing from a variety of disciplinary approaches to the complexity of human experience.

3.2 From Digital to Material Data Representations

Fig. 3. Material representations can invite different meaning-making associations and engagements with data. (from left) Devendorf et al.'s slow, subtle color-changing fabric data displays evoke personal style associations [24]. Ryokai et al.'s chocolate bar graphs represent moments of laughter as biosensory data, inviting celebration and cherishing [109,110]. Fox's bioluminescent algae displays the viewer's real time heartrate, creating an experience of cross-species connection [36]. How else can material representations invite different ways of engaging and knowing with biosensory data?

One way of exploring alternatives with emotional biosensing is to reconsider the way this data is represented (e.g., [36,90,110,125,127]). Material displays of data invite particular engagements in particular sociocultural contexts, and can evoke different associations that can influence interpretation. Most emotional biosensory data displays show time series graphs, or logs of

emotional states over time, on digital light-emitting screens (e.g., [164,174–176]). Sometimes a more abstract animation is displayed on a screen such as a growing tree [153]. A digital time series graph supports seeking patterns over time, while material representations offer other kinds of interpretations. For example, Miller's Conflict Sculptures represent family shouting incidents with playdough balls [90]; playdough could support kids rearranging, comparing, and analyzing the data. Showcase fashion uses LEDs, actuation, and fiber optics for expressive, dramatic biosensing garments (e.g., [4,34,38,48,118,119,147,148,177]). Data physicalization can support embodied interpretation [62].

Data is often treated as intangible, yet we only ever encounter it in material form, whether as a graph on a light-emitting screen or on paper. Digital 0s and 1s are fuzzy abstractions used to describe physical electrical properties. Vallgårda et al. introduce *computational composites* and material strategies for combining computational and material properties for interaction design [136,137]. Latour frames data not as a given but rather as an achievement, something actively constructed and transformed from each material representation to the next [69]. Dourish and Mazmanian [26] describe how the materials used to present data—whether as a log of discrete emotional categories on a light-emitting mobile phone screen [164], or playdough balls [90]—"shape the questions that can be easily asked of it, the kinds of manipulations and analyses it supports, and how it can be used to understand the world" [26:8].

For design researchers engaging materials with emotional biosensing, we highlight Giaccardi and Karana's framework of *materials experience*. They outline *sensorial*, *interpretive*, *affective*, and *performative* levels of experience with materials [41]. We apply this to analyze a design exemplar, Ryokai et al.'s chocolate laughter representations (Fig. 3) [109,110]. *Sensorially* chocolate can evoke pleasure, representing the pleasure of (most) laughter. *Interpretively* the chocolate shapes enable counts and comparisons of moments of laughter. *Affectively* the box of chocolates culturally suggests a special gift, commemorating moments of shared laughter. *Performatively* it suggests giving the gift and sharing the memories. On multiple levels, then, chocolate is a sensible choice for designing with the emotional biosensory data of laughter.

3.2.1 Recommendations. At a higher level, we call for design researchers working with emotional biosensing to **engage materials because doing so invites attunement to specificity and embodiment**. Affect, feeling, and emotion are embodied and situated in particular social and cultural contexts. This makes data physicalization a sensible choice because it can support embodied interpretation. Materials can make themselves present in a specific context, encouraging contextually situated interpretation. Physical artifacts are laden with social and cultural meanings that designers can leverage to craft particular avenues of open-ended interpretation. Materials can refer back to the context and process of their creation. In experiencing a crafted artifact we might wonder whose stories and whose bodies are wrapped up in its creation leading up to our own embodied engagement. Yet, already we are breaking our own categories and pointing to how materials have agency (Section 3.5) and become part of social performances (Section 3.3, 3.4).

3.3 From Representation to Performativity

Fig. 4. Beyond representing biosensory data, biosensing technology, garments in these cases, can both sense and help enact performances of emotion. (From left) Farahi's Opale uses video-based emotional facial analysis to expressively alter the garment, in this case sensing and expressing strength or aggression [34]. Gadani's Porcupine Dress senses the emotionally pertinent movement of hunching over in fear or self-defense, extending quills in response [38]. Hartman et al.'s Monarch uses EMG sensors on the arm to create an expressive gesture of flexing and taking up more space [48,155]. What might more everyday expressions of and performances with emotional biosensory data look like?

In tandem with materiality, CSCW has seen a broad shift from representation toward performativity. Instead of claiming that data capture reality and data displays represent or mirror reality, an alternative is to frame data and data displays as material responses to reality. These responses are shaped by data, humans, and materials and in turn they also shape reality [8]. For example, Leahu et al.'s Freaky performs fear instead of just representing it. It senses heartrate to predict fear in the person carrying it, then responds by 'freaking out' with noise and vibration that are clearly visible to others. Rather than attempting to represent the human's state, Freaky enacts an empathetic response, creating a shared human-machine performance of fear [74]. Flex-N-Feel senses and re-enacts emotionally pertinent data about hand flexing for long distance couples [124]. Performative engagements with biosensory data call attention to different aspects of data and context, such as the performative, embodied, and socially emergent nature of emotion. Similarly, AI and Ubicomp have discussed moving away from attempts to completely represent reality toward ad-hoc, situated representations and actions [75,130].

Sensing and display are not passive, neutral, or removed acts of observation; rather, they actively re-shape the world and experience. Verbeek describes this as *technological mediation*: "When a technological artifact is used, it facilitates people's involvement with reality, and in doing so it co-shapes how humans can be present in their world and their world for them… Technological artifacts are not neutral intermediaries, but actively co-shape people's being in the world: their perceptions and actions, experience and existence" [138:6].

Somaesthetic design leverages sensing and feedback as technological mediators to attune bodies to sensing themselves and help people articulate nuances of their ongoing experience [56]. The *somatic connoisseur* is an important human mediator who facilitates sessions in paying attention and bringing insights out of that into daily life [112]. Wilde, Schiphorst, and Klooster describe applying somatic principles throughout the design process of participatory biosensing installations [112,144,145]. These practices are just a few of many ways of knowing the self and emotion through the body, through movement, and with expert guidance—all appearing in sharp relief against the current moment favoring 'objective' data-driven insight.

For designers of more everyday experiences, performativity calls attention to ongoing practices rather than static states of context or emotion. Kuijer and Giaccardi describe how human and artificial agents combine in practice to shift what is seen as appropriate practice. Rather than

designing 'smart' agents that try to replicate human capabilities and replace human decisions, they call for nonhuman agents that complement the unique capabilities of humans in collaborative *co-performance* [67].

3.3.1 Recommendations. Applying *co-performance* to emotional biosensing, we suggest embracing and leveraging capabilities of many humans to interpret their own and others' feelings and emotion in context. **Instead of training algorithms to categorize emotion, emotional biosensing can provide resources for reflection, prompts for social sharing, or guides that leave space open for human adaptation**, as many cited examples already do. More broadly, synthesizing these rich strands of research, we argue designs with emotional biosensing should **treat affect, feeling, and emotion as embodied, dynamic, and fluid rather than abstract, static, discrete categories**. Emotional biosensing designs do not represent emotion, they respond to and influence ongoing performances of emotion.

3.3.2 In relation to other lenses. With performativity, materiality is no less important, as performances unfold through bodies, materials, time, and space. Post-anthropocentric moves in design research emphasize the agency of materials, collaborating with humans in creating forms, such as with 3D printing [23,25]. Performativity and materiality can attune us as design researchers to similar aspects of biosensory data and display, but with a slightly different focus. For example, revisiting the chocolate laughter representations [109,110] (Section 3.2, Figure 3), materiality as a lens emphasizes the tangible qualities of the chocolates. One can compare the heights of different pieces of chocolate or associate the pleasurable taste of chocolate with the pleasurable memory of the laughter. Performativity as a lens emphasizes the practices surrounding the chocolate, such as gift-giving. Of course there is overlap here. Both materials and performances can evoke meaning-making associations or invite particular kinds of engagement or practices. Material or artificial agencies can shape the development of appropriate ways of feeling and expressing emotion, individually and as part of social performance (Section 3.4). Designers working with emotional biosensing should leverage sensing and display to enact active, adaptable choices that reshape emotional experience.

3.4 From Machines Knowing to Humans Interpreting, Individually and Socially

Reflective design calls for foregrounding the role of human interpretation in meaning making [115,117]. Rather than emotional biosensing devices that try to tell people how they are feeling in terms of discrete emotional categories extracted from context, emotional biosensing devices can invite people to reflect on their own feelings. Rather than seeking to build computational systems that provide unambiguous machine-driven interpretations of emotional states, ambiguity is leveraged as a resource that encourages people to take a more active role in interpretation [40]. Self-tracking technologies can in some sense delegate responsibility for self-knowledge away from the self to devices, as machines claim to 'know' more and more aspects of our daily lives [113]. Alternatively, there is an opportunity for emotional biosensing to encourage humans to take a more active role in emotional meaning making and self-knowledge.

In a performative move, Boehner et al. critique Affective Computing's representationalist approach to emotion [9]. They argue that much Affective Computing research treats *affect-as-information*, something that can be measured by sensors and algorithmically interpreted into discrete categorical representations of emotion. Sensors and algorithms are used to detect and categorize emotions into discrete symbolic categories like "happy," "angry," "sad," etc. They measure emotion on the level of the individual. "Happy" in one context is modeled as equivalent

to "happy" in any other context. This approach treats emotions as pre-existing in individuals and able to be algorithmically detected independent of context [10]. For example, present day self-trackers Feel [164] and Spire [175] arguably treat affect-as-information: Both encode the user's internal state into discrete individual categories regardless of sociocultural context, displaying states such as "happiness" (Feel) or "calm" (Spire). Boehner et al. critique such approaches for reinforcing older models of cognition and ignoring the socioculturally constructed and performative nature of emotion [10].

Fig. 5. Boehner et al. describe how affect-as-information treats emotion like any other kind of computational state or variable. Sensors and algorithms are used to 'detect' discrete categorical emotions like "happy" or "stressed," locating emotion in the individual. Context can be flattened here, where "happy" in one context is modeled the same way as happy in any other context. As an alternative, they propose affect-as-interaction, which treats emotions as emergent from interactions between people and contextually situated in interaction. Rather than teaching machines to detect and categorize feelings, the goal shifts to supporting emotional reflection and interpretation by humans [10]. Diagram is our own.

They propose an alternative lens which treats *affect-as-interaction*, emphasizing how emotion is situated in and arises from sociocultural context. This lens shifts the goal of affective systems away from algorithmic interpretation toward supporting human interpretation of (their own and others') emotion in context. With affect-as-interaction, sensors, algorithms, and displays provide open-ended resources for emotional reflection and enactment. Emotion is not directly represented 'in' the machine but emerges through interaction [10].

Affect-as-interaction has already seen uptake in design. Affector used abstract distortions of video feed to prompt open ended emotional interpretation [116]. Sanches et al. intentionally avoided 'detecting' stress, instead using abstract visuals to prompt interpretation [111]. Slovák et al. studied couples' interpretations of a laptop heartrate display, finding the display was seen to provide a sense of social connection [125]. Howell et al. studied how pairs of friends, having a conversation while wearing thermochromic t-shirt displays of their skin conductance, enrolled the display in social meaning-making and self-presentation [57]. At a speed dating event, participants introduced themselves using hand-drawn graphs of their data [30]. These projects mark a shift away from attempts by machines to 'know' emotions as discrete categories, toward re-introducing biosensory data into social contexts for human interpretation.

Höök et al. extend *affect-as-interaction* into *affective loop experiences* with considerations for embodiment, privacy, and autonomy. They emphasize the embodied nature of perception, mind, and emotion, and call for *affective loops* that not only present emotionally pertinent displays but also invite user reflection and active feedback into the system. For example, Affective Diary combined personal notes and sensor data into a resource for personal reflection with visualizations that suggest affective bodily expressions [128]. EMoto used expressive gestural input to add emotional yet abstract visual cues to text messages [32]. Relying on humans rather

than machines to form emotional meaning gives users more autonomy and more privacy in deciding how they feel, and how or what to share with others.

Affect-as-interaction also informs social science. Merrill and Cheshire studied social interpretations of heartrate in vignette [88] and trust game [89] experiments. Combining quantitative and qualitative results, the interactional lens supports both rigor and common sense in their analysis, as they discuss how people formed emotional interpretations around heartrate while drawing on social context. Liu et al.'s studies, of people interpreting another's brainwaves or of socially sharing heartrate, also consider how biosensory data displays can take on social meaning [79,80]. For social science as well as design research, an interactional lens for emotional biosensing shifts attention to social context and human interpretation.

3.4.1 Recommendations. **We call for humility in the emotional knowledge claims made by machines with emotional biosensing, leaving more open to contextual interpretation, adaptation, and contestation by humans**. This is easier said than done, as even a highly ambiguous and intentionally inaccurate display can be granted a concerning degree of authority by some [58]. Designing not just for personal and social reflection and interpretation but also for *contestability* [53] merits further exploration. Hirsch et al. propose contestability based on their work designing a machine learning system for the highly sensitive context of assessing psychotherapists, where therapists' careers and patients' wellbeing are at stake [53]. Emotional biosensing can produce sensitive data suggesting users are emotionally unwell or have a recognized condition (e.g., inferring depression from mobile phone movement data [19]). Given that such inferences may or may not be accurate, and given that different interventions might work better for different people, being able to *contest* such inferences becomes essential.

3.4.2 In relation to other lenses. Thus far we have seen how materials (including our bodies), performativity, and sociality are all tangled up with affect, feeling, and emotion. Materials invite different ways of engaging with emotional biosensory data and evoke different kinds of emotional meaning. Performativity calls our attention to emotion as embodied experience and ongoing (inter)personal activity, where even data displays become part of this performance. Considering sociality attunes us to emotion as socioculturally situated, performed, and interpreted, rather than treating emotion as discrete abstract categories. We synthesized this rich history of prior design research and called forth generative new directions for further exploration for emotional biosensory designs in particular.

Our next and final three conceptual shifts draw from feminist new materialism, biopolitics, and cultural theory. The rich histories here come from a little further afield relative to design research. We contribute to ongoing pathmaking efforts showing how these lenses are generative for design research, especially for emotional biosensing.

3.5 From Things to Phenomena, or, from Inter-Action to Intra-Action

Taking materiality and performativity further, Barad argues for a shift from thinking about *interaction* to *intra-action* with her theory of *agential realism*. We apply this to emotional biosensing, deconstructing typical notions of sensor, data, and display, and reconceptualizing these as ongoing series of material transformations. Agential realism centers phenomena (which are performed) rather than things (which are represented). Though her argument draws from Bohrian quantum physics to make fundamental onto-ethico-epistemological claims, here we focus on how it reframes thinking about emotional biosensing.

3.5.1 What is agential realism? While actor-network theory acknowledges the agency of things as well as people (e.g., [17,63]), Barad's agential realism accounts for material agency while dismantling the presupposed divide between individual things or people. While interaction assumes separate things (including people) as a given and then looks at actions across this separation, intra-action acknowledges the fundamentally entangled nature of matter, including our bodies with the environment. This suggests attending to *phenomena,* not things or individual people, as the basic unit of analysis. Within phenomena, *agential cuts* enact local separations that define components. We can then reason about these components as the 'subject' or 'object' of a relation, or as 'cause' and 'effect.'

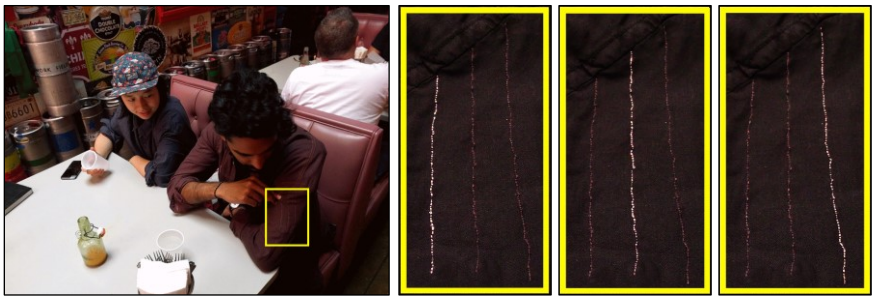

Fig. 6. Where is the data in this entangled sensing and display phenomenon? Barad's agential realism [5] reframes the act of measurement, and the resultant data, as a series of material transformations. Environment and social context influence a pair of friends at lunch, influencing his emotions and body, influencing a skin conductance sensor, sending electrical signals to a microcontroller, discretized into a digital sensor value, run through a low pass filter to detect spikes, sending battery power to the threads, changing color one by one, seen and socially interpreted by the friends at lunch [58].

3.5.2 Reframing emotional biosensing. We outline how agential realism can profoundly shift how we think about biosensing. Biosensory data is co-created by phenomena of intra-acting body, responsive circuitry, electrical signals, and digital signals. These components are locally separable via agential cuts, but they are also inextricably interconnected as phenomena. This lens contrasts the conceptualization suggested by commercially available biosensing devices such as Feel or Spire [164,175]. There, biosensors are framed as extracting physiological signals as pre-existing entities from humans, and then further 'detecting' pre-existing categorical emotional states in humans. Agential realism deconstructs any canonical notion of data. It forces careful attention to intra-actions of measurement and transformation, ongoing responses and becomings of reality rather than attempts to representationally mirror lived experience.

Socially as well as materially, agential realism shifts attention away from the individual toward interconnectedness. While many emotional biosensing devices invite a single user to interpret their own data, people often socially reflect on their feelings with friends and family. Aside from social verbal reflection, psychology studies how we also physically and emotionally respond to others without conscious or rational intention (e.g., [100]). Our feelings, meaning-making processes, and identities are not so inherently separate from one another. Drawing agential cuts invites us as designers to reconsider what we choose to treat as separate.

3.5.3 A case in point. We analyze Howell et al.'s emotional biosensing garments Ripple [58] through the lens of agential realism (Figure 6). The design's "multifaceted ambiguity" [58:5] makes it difficult to disentangle emotional biosensory data from other intra-acting factors. The clothing-based thermochromic display changes color in respond to digital biosensory data but

also in response to heat from the body or sunlight. Furthermore their skin conductance sensor and algorithm are "intentionally crude" [58:4] and also respond to sweating from physical exertion. Thus the design befuddles attempts to separate cause and effect, or data from display. These design decisions are explained as attempts to support *contestability* [53] (described further at the end of Section 3.4). Though it is perhaps remarkable that the system was interpretable at all, Howell et al. self-critically reflect that for some participants the display seemed to hold a concerning degree of authority [58] (we return to issues of authority in Section 3.7).

Agential realism helps analyze Ripple as a series of material transformations along agential cuts. Physical and sociocultural environment intra-act with the body. Affect, feeling, and emotion intra-act with physical responses on the skin. These electrodermal changes intra-act with a sensor, transforming them into analog electrical signals along a wire. These signals are digitized into numeric sensor readings. These feed into a spike detection algorithm. In response to a spike, the algorithm sends current from a battery to the thermochromic threads. The current transforms across resistance into heat. The heat slowly transforms the light-reflecting properties of the thermochromic pigment. Light reflecting off the subtle color-changing threads reaches the eyes of the wearer and other socially collocated people. The display influences sociocultural interpretation and performance, influencing emotional response and feeding back again. This, or environmental heat or physical exertion could be part of other entangled phenomena. It is difficult to locate the 'data' in this system. Rather, we argue that Ripple treats emotional experience, sensing, data, and display as ongoing, entangled phenomena.

3.5.4 Recommendations. Beyond this example, agential realism wends new pathways for design research with emotional biosensing. For example, Tholander et al. draw from agential realism in analyzing how materials shape design thinking [132]. **We suggest using agential realism throughout the design process to attend to how materials shape meaning-making and to prompt reflexivity about which materials, roles, people, or categories are treated as separate in the first place. What if designers working with emotional biosensing stopped treating data as an inherently abstract, insight-laden 'thing' and instead turned their focus to phenomena of continually transforming materials and meaning?** To make this shift, one useful starting point could be to apply the previously discussed lenses of materiality, performativity, and social interpretation specifically to the materials, practices, and social meanings of measurement and sensing. This can also lead to reconfiguring what counts as measurement and sensing. For example, smudges on a door from people's hands can be seen as an accumulated material measure and display of passerby count or group activity level. Depending on context and subject position, this might be related to, for example, a stressful busy night in a restaurant kitchen or a joyful exciting celebration occurring at the restaurant.

Not just a creative tactic, for designers especially agential realism presents an ethical imperative of "being accountable to marks on bodies" [5:824]. For example, Introna's critical analysis of surveillance cameras and plagiarism 'detection' software provides a lucid, tractable engagement with agential realism. The analysis uses agential realism to trace agential cuts like roles and categories constructed in part by the surveillance camera technology. It also traces ethical consequences like how the software constructs 'plagiarism' in a way that disproportionately marks non-native language speakers as plagiarists [61]. Design is in some sense a process of formgiving and markmaking, and it is worth being critical of our own and others' work by tracing the effects of these marks onto bodies.

3.5.5 In relation to other lenses. Overall, agential realism underscores the importance of materials, performativity, and social interpretation to emotional biosensing (Sections 3.2-3.4) while deepening critiques of Affective Computing. *Affect-as-interaction* [10] (Section 3.4) might seem to conflict with *intra-action* [5], but we see this as mostly a difference of nomenclature. Both concepts emphasize the inextricable interconnectedness of ourselves with the world, and shift the focus from attributes of an individual subject or object toward performances or phenomena as ongoing and emergent. **We argue that biosensory data and surrounding emotional interpretations are fundamentally not discoveries of internal state that can be extracted and displayed unchanged. Rather, every measurement or transformation along an agential cut changes the potential meanings of emotional biosensing and enacts different marks on bodies**.

3.6 (Post-)Biopolitics: Reducing Authority and Leveraging Negative Affect as a Resource

Now we turn to issues of authority to further engage political and ethical questions regarding emotional biosensing. Biopolitics considers what counts as legitimate knowledge and ways of knowing. Drawing from Rabinow and Rose, *biopower* considers "truth discourses" regarding human life, "authorities considered competent to speak that truth," and strategies for life and health relating to those discourses, whether individual, governmental, or cultural [104:197]. *Biopolitics* refers to contestations around those discourses, authority, and what counts as legitimate knowledge [104]. Artifacts have politics and "can embody specific forms of power and authority" [146:121]. Many emotional biosensing devices play up their authority, promising consumers actionable insights and positive behavior changes (e.g., [154,163,164,168,169,175]). Hong calls for greater attention to "who–and what–is given which kinds of authority to speak the truth of the 'self'" with self-tracking technologies [55:1].

Emotional surveillance via video facial analysis could spread via technologies like Affectiva [174] and Google Glass [134]. Using Google Glass as a case study, Noble outlines harms of the surveillance gaze across race, socioeconomics, and gender [98]. Buolamwini analyzes racial harms of the 'coded gaze' [15,16,178]. Foucault's analysis of internalized self-discipline in view of an all-seeing authority [35] has been applied to self-tracking (e.g., [81,92,96,120,122]). Yet, Schüll describes how self-tracking devices that suggest behavioral adjustments in some sense *externalize* self-discipline [113]; others look to Schüll as well [122]. For example, responsibility to care for the self by drinking enough water can be delegated to Mother sensing technology [114,179]. Spire reminds one to pause for a breathing exercise to reduce stress [175]. Other devices remind people to exercise and sleep [180], eat slowly [181], or take their medicine [156,162]. Schüll suggests that in some ways the constant feedback and modulation based on information flows might resemble Deleuze's control society [21,113]. Through this lens, emotional biosensing products can be seen as modulating our emotions according to feedback systems and algorithms created by designers and technologists.

Lindtner and Avle discuss the economization of everyday life and of citizenship and critique CSCW's complicity with Silicon Valley's visions of individual self-improvement and productivity [78]. Till drawing from Lupton describes how self-tracking technologies extract economic value from non-work behavior like physical exercise in the form of data [133]. Emotional biosensory data is already being monetized (e.g., [174]). Rose describes how *somatic ethics* are shifting and influenced by capitalism. For example, concern for one's physical health might have previously

seemed narcissistic but is now seen as an expected way to feel better, be morally better, and be a better worker [107]. We speculate, as emotional norms become embroiled in data and market logics, will negative affect be seen as a moral failure?

3.6.1 Recommendations. Returning to *co-performance* (Section 3.3), Kuijer and Giaccardi raise essential ethical and political considerations for design in how artificial agents can shift norms of appropriate practice. They outline how these norms can be hard to contest because (i) the newly appropriate practice may depend on the nonhuman agent, (ii) artificial agents often claim the authority of scientific evidence, or (iii) designs can inflexibly embed decisions. When artificial agents are designed to too closely mimic human agents, designers often wield too much power in shaping norms of practice via embedded design decisions. To avoid these issues, *co-performance* leaves more flexibility in shaping practices open to humans [67].

Applying *co-performance* [67] to emotional biosensing, we call on designers to critically reflect on the emotional practices and norms suggested by designs. Machines need not model or 'know' emotion in the same way that humans do. Instead, avoiding authoritative knowledge claims about emotion can help designs make space for humans to adapt emotional experience and practices for themselves. Designing for *co-performance* [67] and *contestability* [53] with emotional biosensing might also open space for alternative politics and voices about the meanings and roles of biosensory data in daily life. For example, biosensing responsive garment Ripple was designed to "seem unauthoritative to invite critical questioning" [58:4]. With the touted authority of biosensory data, and known critiques of Western cultural narratives of the authority of data more broadly (e.g., [12,13,20,42,43,54,59,94]), **perhaps biosensory data displays with intentionally *reduced* authority are worth exploring**. We frame this as only the beginning to exploring: **Instead of valorizing accuracy, objectivity, and data as authoritative ways of knowing with emotional biosensing, how can designs make space for alternatives?**

A design exemplar in affirming negative affect, Imhotep et al. created the Bank of Hysteria for black women to call in and share their frustration and hysteria to "invest in [their] rage" as a collective bank of support and force for change [52,60]. Negative affect is a valid response to societal issues. Designing a quick breathing exercise (e.g., Fig. 2) might legitimately reduce tension in the short term, but it is essential to not locate approaches to social issues only in the individual. An overly individual focus can marginalize someone's experience by implying they are the only one experiencing this problem, or suggest they are solely responsible for dealing with the negative effects, and it can downplay the need for structural change. Instead, **emotional biosensing designs can leverage negative affect as a resource for building community, support, and collective action**.

3.6.2 In relation to other lenses. Biopolitics in emotional biosensing design research engages performativity and social interpretation (Sections 3.3-3.4). Performativity and biopolitics combined help question and critique what practices emotional biosensing designs foreground, and who gets favored or excluded by those practices. Social interpretation and biopolitics help question and critique who gets to make social interpretations that are considered valid.

3.7 From Affect to Desire, and from Individual to Pre-Individual

Considering affect and desire through different lenses helps chart what goals emotional biosensory data is enrolled to serve and how that might be reimagined. These conceptual shifts invite questions like, instead of locating emotion in individuals, how might sensors tune in to

broader emotional flows through society? Some work has looked at collective audience response (e.g., [101,141]), but what are other possibilities? **Instead of considering emotion as arising in a particular moment, what about tracing flows of desire motivating emotional trajectories?**

3.7.1 From affect to desire. At an individual level, affect can be seen as a response or orientation with regard to the social or material world (e.g., I feel angry at a rude comment, or I feel happy about the weather). Desire can also be seen as orienting oneself to the world, pointing toward a desired object, person, activity, or cultural signifier. Desires can carry different emotional valences like romantic attraction, professional ambition, or a desire to help a friend. Considering affect can call our attention to moments of action/reaction. Without claiming any firm causal relationship between affect and desire, considering desire can call our attention to underlying drives motivating affect and orienting actions/reactions.

For emotional biosensing design, this could shift the focus from prompting reflection on the question, "How am I feeling?" to "What do I desire?" These questions are closely related but desires point to motivation (e.g., I feel angry at a rude comment because I desire respect). **Rather than emotional biosensing designs imposing normative desires of self-improvement, users' desires could point in more personally relevant directions.** For example, desiring respect might be more related to social and structural issues than an individual need to improve, and anger could be productively shared as a resource (Section 3.7.3).

3.7.2 From individual to pre-individual affect. While Affective Computing locates affect in individual bodies [18], and affect-as-interaction locates affect as emergent from culture and social interaction [10], treating affect as pre-individual helps consider structural forces shaping emotion and the self. For example, in *Affective Economies* Ahmed describes circulating affect around charged issues like terrorism and immigration and how people position themselves with regard to these issues [1]. Stewart's poetic *Ordinary Affects* describes moments of surging affect arising from events or places; the individual subject is constructed by engaging with these pre-individual affects [129]. Massumi draws from Spinoza to describe affect as a kind of pre-personal intensity, something at the interface between our bodies and the world, in that moment of affecting and being affected. Once we start interpreting it to understand how we feel, or decide what socially recognizable emotions those feelings might be, something gets lost—affect is that noisy buzzing intensity before interpretation [86].

For emotional biosensing design, attending to pre-individual affect can, we argue, help consider broader societal issues and forces shaping emotion. For example, Kozel's AffeXity [66] explores affect as flowing through the city and personally embodied through dance. Drawing from Spinoza, Massumi, and Ahmed's approaches to affect, AffeXity explores how, "Urban dwellers are ever increasingly affectively manipulated by political and economic forces without the scope to *not* be affected" [66:77–78].

3.7.3 From individual to pre-individual desire. Deleuze & Guattari see desire *not* in the Lacanian sense of an individual's affinity toward an object of desire, but as pre-individual driving forces that move across and through individuals [22,77]. "Desire is instrumental for Deleuze and Guattari because they locate within it the possibility for political, social, and economic transformation" [77:365]. Yet, we also draw inspiration from Haraway's earthy attunement to the desires of individual critters [46], and acknowledge potentially unresolved tensions between these approaches. Again, as designers we must sensitively treat individuals' feelings and desires while also acknowledging structural forces.

Desire as pre-individual helps consider structural forces shaping desire. For example, the Situationists critiqued how capitalism directs our desires toward commodity goods, and sought instead to "produce a different kind of social practice for expressing the encounter of desire and necessity, outside of power as representation and desire as the commodity form" [142:47]. Through *détournement* they sought to reroute existing capitalist cultural media toward new purposes. More recently, Neff and Nafus among others describe the "commodification of daily living" through data [97:7]. Self-tracking products suggest we should desire individual self-improvement via data-driven insight and behavioral adjustment.

As designers working with emotional biosensing, we should critically reflect on the desires promoted by our projects. For example, emotional biosensing designs might tackle stress at work. A conventional approach could be to detect stress at the level of the individual and help reduce that stress through individual behavioral changes like taking breaks or meditation. This could address desires for reduced stress, improved workplace performance, and company profit. An alternative approach could be to leverage the negative affect of stress as a resource (Section 3.6.1), collecting data on workplace stress for collective action like negotiating for better workplace conditions or more reasonable deadlines. This could address desires for reduced stress while challenging notions that workers should constantly strive to improve their performance and that company profit should be optimized.

More broadly, **how can design reroute normative societal desires of emotional biosensing toward alternative ends?** One example is Queer AI [76,84,85], a manifesto and critical computing art project whose "first chatbot will be trained on erotic literature, feminist and queer theory, and an ethics of embodiment" for "the advancement of new eroticisms" [85]. Different training sets of emotional biosensory data could help shift design.

3.7.4 Recommendations. Even as our projects try to serve the existing desires of users, they also construct desiring users [47]. As designers working with emotional biosensing, **we should critically reflect on the desires our designs legitimize, and on the societal structures that make those desires seem appropriate**. We can make designs adaptable so humans can shape norms. Furthermore **we can start from different sets of norms and legitimize different desires.** For engaging different desires, **we suggest starting from a basic belief in the validity of our own and others' experiences**, even and especially when they do not align with established norms or our own expectations. Humility in emotional knowledge claims and adaptability in design (Section 3.4) can help designs respectfully engage difference. **We suggest giving and receiving care and affirmation as desires to legitimize.** These suggestions may seem obvious, but they contrast products pushing self-improvement, which can engage insecurity or suggest that one is not 'good enough.' Care, affirmation, respect, and recognition for human experience are promising generative design directions, especially for what is not well understood by normative categories or seen as optimal by normative desires. More broadly, **we call for emotional biosensing designs to explore a wide range of alternative desires.** By synthesizing and outlining different lenses, and advocating for already-begun but not-yet-mainstream directions, we push CSCW to continue exploring emotional biosensing, broadening the design space to include richer alternatives.

4 CONCLUSIONS

Emotional biosensing technologies promote a particular normative vision of 'the good life' limited by a focus on individual wellness, self-improvement, and workplace productivity. While

there is positive potential here, these limitations point to opportunities for broadening the design space with emotional biosensing. We sketched how a broad shift from abstract representationalism to sociomaterial performativity opens critical alternatives for emotional biosensing: (Section 3.2) Rather than treating data as something immaterial to be represented, attending to the materiality of data sensing and display opens new possibilities for interpretation and experience. (3.3) Building on interpretation and experience, treating sensing/display not as passive representations but as active performances or responses offers opportunities for social meaning making and experiential, expressive displays. Emotional biosensing designs should treat affect, feeling, and emotion as embodied, dynamic, and fluid rather than abstract, static, discrete categories. (3.4) Continuing this performative shift, reframing affect from a kind of abstract information to affect as socially enacted in interaction adds sociocultural nuance to emotional biosensing. We call for humility in the emotional knowledge claims made by design, leaving more open to human interpretation, adaptation, and contestation.

(3.5) Shifting further to posthumanist performativity, we outline how agential realism can help emotional biosensing designs attend to how materials shape meaning-making and prompt reflexivity about which materials, people, or categories are assumed to be separate. Attending to biopolitics (3.6) calls for embracing a diversity of voices and ways of knowing with emotional biosensing. We suggest designs with intentionally reduced authority are worth exploring, and that emotional biosensing designs can leverage negative affect as a resource for building community, support, and collective action. (3.7) Finally, reframing affect and desire as pre-individual, we call for emotional biosensing designers to critically reflect on the desires our designs legitimize, and on the societal structures that make those desires seem appropriate. We argue that emotional biosensory designs should prioritize care, affirmation, respect, and recognition over self-improvement. Designs can encourage people to trust themselves to be 'emotionally good/safe enough' with room to explore and change rather than only seek self-improvement according to predefined norms. More broadly, designs should explore a wide range of alternative desires with emotional biosensing. Finally, with the help of these conceptual shifts and our recommendations, we call for CSCW to continue exploring:

How can desiring with and through data be reconfigured away from commodity lifestyle and self-optimization toward alternative ways of feeling and living?

ACKNOWLEDGMENTS

Thank you to the reviewers, whose thoughtful commentary greatly strengthened the paper. Thank you to Nick Merrill and Richmond Wong for constant dialogue and working through ideas. Thank you to Meena Natarajan and Paul Duguid for teaching Re-Imagining the Body: Design, Data, Values and Intersectionality.

REFERENCES

[1] Sara Ahmed. 2004. Affective Economies. *Soc. Text* 22, 2 (May 2004), 117–139.

[2] Yoko Akama, Ann Light, and Simon Bowen. 2017. Mindfulness and Technology: Traces of A Middle Way. In *Designing Interactive Systems*, 345–355. DOI: https://doi.org/10.1145/3064663.3064752

[3] Kathryn Freeman Anderson. 2013. Diagnosing Discrimination: Stress from Perceived Racism and the Mental and Physical Health Effects. *Sociol. Inq.* 83, 1 (February 2013), 55–81. DOI: https://doi.org/10.1111/j.1475-682X.2012.00433.x

[4] Rain Ashford. 2014. Baroesque barometric skirt. In *Proceedings of the 2014 ACM International Symposium on Wearable Computers: Adjunct Program (ISWC'14 Adjunct)*, 9–14. DOI: https://doi.org/10.1145/2641248.2641271

[5] Karen Barad. 2003. Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter. *Signs* 28, 3 (2003), 801–831. DOI: https://doi.org/10.1086/345321

[6] Lisa Feldman Barrett. 2009. Variety is the spice of life: A psychological construction approach to understanding variability in emotion. *Cogn. Emot.* 23, 7 (November 2009), 1284–1306. DOI: https://doi.org/10.1080/02699930902985894

[7] Tara Siegel Bernard. 2015. Giving Out Private Data for Discount in Insurance. *The New York Times*. Retrieved April 17, 2018 from https://www.nytimes.com/2015/04/08/your-money/giving-out-private-data-for-discount-in-insurance.html

[8] Kirsten Boehner. 2009. Reflections on representation as response. *interactions* 16, 6 (November 2009), 28. DOI: https://doi.org/10.1145/1620693.1620700

[9] Kirsten Boehner, Rogério DePaula, Paul Dourish, and Phoebe Sengers. 2005. Affect: from information to interaction. In *Proceedings of the 4th decennial conference on Critical computing: between sense and sensibility (CC'05)*, 59–68. DOI: https://doi.org/10.1145/1094562.1094570

[10] Kirsten Boehner, Rogério DePaula, Paul Dourish, and Phoebe Sengers. 2007. How emotion is made and measured. *Int. J. Hum.-Comput. Stud.* 65, 4 (April 2007), 275–291. DOI: https://doi.org/10.1016/j.ijhcs.2006.11.016

[11] Charlie Boothe. 2018. Potential teacher strike looms over West Virginia. *Bluefield Daily Telegraph*. Retrieved March 28, 2018 from http://www.bdtonline.com/news/potential-teacher-strike-looms-over-west-virginia/article_32f4a9f4-04a1-11e8-99f2-7f31dc816267.html

[12] Chris Bopp, Ellie Harmon, and Amy Voida. 2017. Disempowered by Data: Nonprofits, Social Enterprises, and the Consequences of Data-Driven Work. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (CHI '17), 3608–3619. DOI: https://doi.org/10.1145/3025453.3025694

[13] danah boyd and Kate Crawford. 2012. Critical Questions for Big Data: Provocations for a cultural, technological, and scholarly phenomenon. *Inf. Commun. Soc.* 15, 5 (June 2012), 662–679. DOI: https://doi.org/10.1080/1369118X.2012.678878

[14] Tega Brain and Surya Mattu. *Unfit Bits: The Guide*. Retrieved April 17, 2018 from http://www.unfitbits.com/assets/UnfitBits-FullGuide-WebDownload.pdf

[15] J. Buolamwini and T. Gebru. 2018. Gender Shades: Intersectional Accuracy Disparities in Commercial Gender Classification. In *Proceedings of Machine Learning Research*, 77–91.

[16] Joy Buolamwini. 2016. The Algorithmic Justice League. *MIT Media Lab*. Retrieved June 24, 2018 from https://medium.com/mit-media-lab/the-algorithmic-justice-league-3cc4131c5148

[17] Michel Callon. 1984. Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St Brieuc Bay. *Sociol. Rev.* 32, 1_suppl (May 1984), 196–233. DOI: https://doi.org/10.1111/j.1467-954X.1984.tb00113.x

[18] Rafael Calvo, Sidney D'Mello, Jonathan Gratch, and Arvid Kappas (Eds.). 2015. *The Oxford Handbook of Affective Computing*. Oxford University Press. Retrieved May 18, 2016 from http://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780199942237.001.0001/oxfordhb-9780199942237

[19] Luca Canzian and Mirco Musolesi. 2015. Trajectories of Depression: Unobtrusive Monitoring of Depressive States by Means of Smartphone Mobility Traces Analysis. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing* (UbiComp '15), 1293–1304. DOI: https://doi.org/10.1145/2750858.2805845

[20] Kate Crawford, Mary L. Gray, and Kate Miltner. 2014. Critiquing Big Data: Politics, Ethics, Epistemology. *Int. J. Commun.* 8, 0 (June 2014), 10.

[21] Gilles Deleuze. 1992. Postscript on the Societies of Control. *October* 59, Winter (1992), 3–7.

[22] Gilles Deleuze and Félix Guattari. 1987. *A thousand plateaus: capitalism and schizophrenia*. University of Minnesota Press, Minneapolis.

[23] Laura Devendorf, Abigail De Kosnik, Kate Mattingly, and Kimiko Ryokai. 2016. Probing the Potential of Post-Anthropocentric 3D Printing. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems* (DIS '16), 170–181. DOI: https://doi.org/10.1145/2901790.2901879

[24] Laura Devendorf, Joanne Lo, Noura Howell, Lin Lee Jung, Nan-Wei Gong, M. Emre Karagozler, Shiho Fukuhara, Ivan Poupyrev, Eric Paulos, and Kimiko Ryokai. 2016. "I don't want to wear a screen": Probing perceptions of and possibilities for dynamic displays on clothing. In *Proceedings of the 34th Annual ACM Conference on Human Factors in Computing Systems (CHI'16)*.

[25] Laura Devendorf and Kimiko Ryokai. 2015. Being the Machine: Reconfiguring Agency and Control in Hybrid Fabrication. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (CHI '15), 2477–2486. DOI: https://doi.org/10.1145/2702123.2702547

[26] Paul Dourish and Melissa Mazmanian. 2011. Media as material: Information representations as material foundations for organizational practice. In *Third International Symposium on Process Organization Studies*.

[27] Natasha Dow Schüll. 2016. Sensor technology and the time-series self. *continent.* 5, 1 (January 2016), 24–29.

[28] Joseph Dumit. 2012. *Drugs for life: how pharmaceutical companies define our health*. Duke University Press, Durham.

[29] Chris Elsden, Abigail C. Durrant, David Chatting, and David S. Kirk. 2017. Designing Documentary Informatics. In *Proceedings of the 2017 Conference on Designing Interactive Systems Pages*, 649–661. DOI: https://doi.org/10.1145/3064663.3064714

[30] Chris Elsden, Bettina Nissen, Andrew Garbett, David Chatting, David Kirk, and John Vines. 2016. Metadating: Exploring the Romance and Future of Personal Data. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (CHI '16), 685–698. DOI: https://doi.org/10.1145/2858036.2858173

[31] Chris Elsden, Mark Selby, Abigail Durrant, and David Kirk. 2016. Fitter, Happier, More Productive: What to Ask of a Data-driven Life. *interactions* 23, 5 (August 2016), 45–49. DOI: https://doi.org/10.1145/2975388

[32] Petra Fagerberg, Anna Ståhl, and Kristina Höök. 2004. eMoto: Emotionally Engaging Interaction. *Pers. Ubiquitous Comput* 8, 5 (September 2004), 377–381. DOI: https://doi.org/10.1007/s00779-004-0301-z

[33] Behnaz Farahi. 2015. *Caress of the Gaze*. Retrieved November 3, 2017 from http://behnazfarahi.com/caress-of-the-gaze/

[34] Behnaz Farahi. 2017. *Opale*. Retrieved November 3, 2017 from http://behnazfarahi.com/opale/

[35] Michel Foucault. 1995. *Discipline and punish: the birth of the prison* (2nd Vintage Books ed ed.). Vintage Books, New York.

[36] Tyler Fox. 2014. *Biolesce*. Retrieved August 31, 2017 from http://www.tylersfox.com/487

[37] Jonah Furman and Dan DiMaggio. 2018. West Virginia Teachers Launch Statewide Strike. *Labor Notes*. Retrieved March 28, 2018 from http://www.labornotes.org/2018/02/west-virginia-teachers-launch-statewide-strike

[38] Amisha Gadani. 2010. *Porcupine Defensive Dress*. Retrieved December 15, 2017 from http://www.amishagadani.com/Work/porcupine/index.html

[39] William Gaver. 2012. What Should We Expect from Research Through Design? In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '12), 937–946. DOI: https://doi.org/10.1145/2207676.2208538

[40] William W. Gaver, Jacob Beaver, and Steve Benford. 2003. Ambiguity As a Resource for Design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '03), 233–240. DOI: https://doi.org/10.1145/642611.642653

[41] Elisa Giaccardi and Elvin Karana. 2015. Foundations of Materials Experience: An Approach for HCI. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (CHI '15), 2447–2456. DOI: https://doi.org/10.1145/2702123.2702337

[42] Lisa Gitelman (Ed.). 2013. *"Raw data" is an oxymoron*. The MIT Press, Cambridge, Massachusetts; London, England.

[43] Charles Goodwin. 1994. Professional Vision. *Am. Anthropol.* 96, 3 (September 1994), 606–633. DOI: https://doi.org/10.1525/aa.1994.96.3.02a00100

[44] Carol Graham. 2017. *Happiness for All? Unequal Hopes and Lives in Pursuit of the American Dream*. Princeton University Press, Princeton.

[45] Kathleen Green. 2002. Stress Management Ideology and the Other Spaces of Women's Power. In *Hop on Pop: The Politics and Pleasures of Popular Culture*. Duke University Press, 670–679.

[46] Donna Jeanne Haraway. 2016. *Staying with the trouble: making kin in the Chthulucene*. Duke University Press, Durham.

[47] Jean Hardy and Silvia Lindtner. 2017. Constructing a Desiring User: Discourse, Rurality, and Design in Location-Based Social Networks. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing* (CSCW '17), 13–25. DOI: https://doi.org/10.1145/2998181.2998347

[48] Kate Hartman, Jackson McConnell, Boris Kourtoukov, Hillary Predko, and Izzie Colpitts-Campbell. 2015. Monarch: Self-Expression Through Wearable Kinetic Textiles. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction* (TEI '15), 413–414. DOI: https://doi.org/10.1145/2677199.2690875

[49] Jennifer Healey. 2015. Physiological Sensing of Emotion. In *The Oxford Handbook of Affective Computing*, Rafael Calvo, Sidney D'Mello, Jonathan Gratch and Arvid Kappas (eds.). Oxford University Press. Retrieved May 18, 2016 from http://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780199942237.001.0001/oxfordhb-9780199942237-e-023

[50] hello@spire.io. 2017. Gift-Wrap Peace of Mind This Christmas.

[51] hello@spire.io. 2018. A Valentine's Day Gift of Calm.

[52] Angela Helm. 2017. Black Women, Don't Throw Up Hands—Call the Bank of Hysteria to Vent. *The Root*. Retrieved June 23, 2018 from https://www.theroot.com/black-women-don-t-throw-up-hands-call-the-bank-of-hys-1821047581

[53] Tad Hirsch, Kritzia Merced, Shrikanth Narayanan, Zac E. Imel, and David C. Atkins. 2017. Designing Contestability: Interaction Design, Machine Learning, and Mental Health. 95–99. DOI: https://doi.org/10.1145/3064663.3064703

[54] Bjørn Hofmann. 2001. The technological invention of disease. *Med. Humanit.* 27, 1 (June 2001), 10–19. DOI: https://doi.org/10.1136/mh.27.1.10

[55] Sun-ha Hong. 2016. Data's Intimacy: Machinic Sensibility and the Quantified Self. *Commun. 1* 5, 1 (September 2016), 1–36. DOI: https://doi.org/10.7275/R5CF9N15

[56] Kristina Höök, Martin P. Jonsson, Anna Ståhl, and Johanna Mercurio. 2016. Somaesthetic Appreciation Design. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (CHI '16), 3131–3142. DOI: https://doi.org/10.1145/2858036.2858583

[57] Noura Howell, Laura Devendorf, Rundong (Kevin) Tian, Tomás Vega, Nan-Wei Gong, Ivan Poupyrev, Eric Paulos, and Kimiko Ryokai. 2016. Biosignals as social cues: Ambiguity and emotional interpretation in social displays of skin conductance. In *Designing Interactive Systems (DIS)*.

[58] Noura Howell, Laura Devendorf, Tomás Vega Gálvez, Rundong Tian, and Kimiko Ryokai. 2018. Tensions of data-driven reflection: A case study of real-time emotional biosensing. In *SIGCHI Conference on Human Factors in Computing Systems*.

[59] Andrew Iliadis and Federica Russo. 2016. Critical data studies: An introduction. *Big Data Soc.* 3, 2 (November 2016), 1–7. DOI: https://doi.org/10.1177/2053951716674238

[60] Malika Imhotep, Jess Liu, Becca Milman, and Phyllis Thai. 2018. *The Bank of Hysteria*. Retrieved June 23, 2018 from http://bcnm.berkeley.edu/news-research/2355/malika-imhotep-and-the-bank-of-hysteria-featured-on-the-root

[61] Lucas Introna. 2014. Towards a post-human intra-actional account of sociomaterial agency (and morality). In *The moral status of artefacts*, Peter Kroes and Peter-Paul Verbeek (eds.). Springer, Dordrecht, 31–53.

[62] Yvonne Jansen, Pierre Dragicevic, Petra Isenberg, Jason Alexander, Abhijit Karnik, Johan Kildal, Sriram Subramanian, and Kasper Hornbæk. 2015. Opportunities and Challenges for Data Physicalization. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (CHI '15), 3227–3236. DOI: https://doi.org/10.1145/2702123.2702180

[63] Jim Johnson. 1988. Mixing Humans and Nonhumans Together: The Sociology of a Door-Closer. *Soc. Probl.* 35, 3 (1988), 298–310. DOI: https://doi.org/10.2307/800624

[64] Elizabeth Kaziunas, Mark S. Ackerman, Silvia Lindtner, and Joyce M. Lee. 2017. Caring Through Data: Attending to the Social and Emotional Experiences of Health Datafication. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing* (CSCW '17), 2260–2272. DOI: https://doi.org/10.1145/2998181.2998303

[65] R. Ketal. 1975. Affect, mood, emotion, and feeling: semantic considerations. *Am. J. Psychiatry* 132, 11 (November 1975), 1215–1217. DOI: https://doi.org/10.1176/ajp.132.11.1215

[66] Susan Kozel. 2012. AffeXity: performing affect using augmented reality. *Fibreculture J.* 21, (2012), 72–96.

[67] Lenneke Kuijer and Elisa Giaccardi. 2018. Co-performance: Conceptualizing the Role of Artificial Agency in the Design of Everyday Life. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (CHI '18), 125:1–125:13. DOI: https://doi.org/10.1145/3173574.3173699

[68] Jo Labanyi. 2010. Doing Things: Emotion, Affect, and Materiality. *J. Span. Cult. Stud.* 11, 3–4 (September 2010), 223–233. DOI: https://doi.org/10.1080/14636204.2010.538244

[69] Bruno Latour. 1999. Circulating Reference: Sampling the Soil in the Amazon Forest. In *Pandora's Hope: Essays on the Reality of Science Studies*. Harvard University Press, 24–79. Retrieved from http://www.amazon.ca/exec/obidos/redirect?tag=citeulike09-20&path=ASIN/067465336X

[70] Bruno Latour. 2004. Why Has Critique Run out of Steam? From Matters of Fact to Matters of Concern. *Crit. Inq.* 30, 2 (January 2004), 225–248. DOI: https://doi.org/10.1086/421123

[71] Antti Latvala, Ralf Kuja-Halkola, Catarina Almqvist, Henrik Larsson, and Paul Lichtenstein. 2015. A Longitudinal Study of Resting Heart Rate and Violent Criminality in More Than 700 000 Men. *JAMA Psychiatry* 72, 10 (October 2015), 971–978. DOI: https://doi.org/10.1001/jamapsychiatry.2015.1165

[72] John Law. 2004. *After method: mess in social science research*. Routledge, London ; New York.

[73] Lucian Leahu, Steve Schwenk, and Phoebe Sengers. 2008. Subjective Objectivity: Negotiating Emotional Meaning. In *Proceedings of the 7th ACM Conference on Designing Interactive Systems (DIS'08)* (DIS '08), 425–434. DOI: https://doi.org/10.1145/1394445.1394491

[74] Lucian Leahu and Phoebe Sengers. 2014. Freaky: performing hybrid human-machine emotion. In *Proceedings of the 2014 conference on Designing interactive systems (DIS'14)*, 607–616. DOI: https://doi.org/10.1145/2598510.2600879

[75] Lucian Leahu, Phoebe Sengers, and Michael Mateas. 2008. Interactionist AI and the Promise of Ubicomp, or, How to Put Your Box in the World Without Putting the World in Your Box. In *Proceedings of the 10th International Conference on Ubiquitous Computing* (UbiComp '08), 134–143. DOI: https://doi.org/10.1145/1409635.1409654

[76] Ben Lerchin. Retrieved June 22, 2018 from http://benlerchin.com/

[77] Robert Leston. 2015. Deleuze, Haraway, and the Radical Democracy of Desire. *Configurations* 23, 3 (October 2015), 355–376.

[78] Silvia Lindtner and Seyram Avle. 2017. Tinkering with Governance: Technopolitics and the Economization of Citizenship. *Proc ACM Hum-Comput Interact* 1, CSCW (December 2017), 70:1–70:18. DOI: https://doi.org/10.1145/3134705

[79] Fannie Liu, Laura Dabbish, and Geoff Kaufman. 2017. Supporting Social Interactions with an Expressive Heart Rate Sharing Application. *Proc ACM Interact Mob Wearable Ubiquitous Technol* 1, 3 (September 2017), 77:1–77:26. DOI: https://doi.org/10.1145/3130943

[80] Fannie Liu, Laura Dabbish, and Geoff Kaufman. 2017. Can Biosignals be Expressive?: How Visualizations Affect Impression Formation from Shared Brain Activity. *Proc. ACM Hum.-Comput. Interact.* 1, CSCW (December 2017), 1–21. DOI: https://doi.org/10.1145/3134706

[81] Deborah Lupton. 2012. M-health and health promotion: The digital cyborg and surveillance society. *Soc. Theory Health* 10, 3 (August 2012), 229–244. DOI: https://doi.org/10.1057/sth.2012.6
[82] Deborah Lupton. 2016. *The quantified self: a sociology of self-tracking*. Polity, Cambridge, UK.
[83] John MacCallum and Teoma Naccarato. 2015. The Impossibility of Control: Real-time Negotiations with the Heart. In *Proceedings of the Conference on Electronic Visualisation and the Arts* (EVA '15), 184–191. DOI: https://doi.org/10.14236/ewic/eva2015.19
[84] Emily Martinez and Ben Lerchin. 2018. *Queer AI*. Retrieved June 22, 2018 from http://somethingnothing.me/queerai.html
[85] Emily Martinez and Ben Lerchin. 2018. Queer AI Manifesto. Retrieved June 22, 2018 from http://www.queer.ai
[86] Brian Massumi. 1995. The Autonomy of Affect. *Cult. Crit.* 31 (1995), 83–109. DOI: https://doi.org/10.2307/1354446
[87] D. McDuff, S. Gontarek, and R. Picard. 2014. Remote measurement of cognitive stress via heart rate variability. In *2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, 2957–2960. DOI: https://doi.org/10.1109/EMBC.2014.6944243
[88] Nick Merrill and Coye Cheshire. 2016. Habits of the Heart(Rate): Social Interpretation of Biosignals in Two Interaction Contexts. In *Proceedings of the 19th International Conference on Supporting Group Work* (GROUP '16), 31–38. DOI: https://doi.org/10.1145/2957276.2957313
[89] Nick Merrill and Coye Cheshire. 2017. Trust Your Heart: Assessing Cooperation and Trust with Biosignals in Computer-Mediated Interactions. 2–12. DOI: https://doi.org/10.1145/2998181.2998286
[90] Jill Miller. *Conflict Sculptures*. Retrieved March 28, 2018 from https://www.jillmiller.net/
[91] Ine Mols, Elise van den Hoven, and Berry Eggen. 2016. Technologies for Everyday Life Reflection: Illustrating a Design Space. In *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction* (TEI '16), 53–61. DOI: https://doi.org/10.1145/2839462.2839466
[92] Phoebe Moore and Andrew Robinson. 2016. The quantified self: What counts in the neoliberal workplace, The quantified self: What counts in the neoliberal workplace. *New Media Soc.* 18, 11 (December 2016), 2774–2792. DOI: https://doi.org/10.1177/1461444815604328
[93] Teoma Jackson Naccarato and John MacCallum. 2016. From representation to relationality: Bodies, biosensors and mediated environments. *J. Dance Somat. Pract.* 8, 1 (June 2016), 57–72. DOI: https://doi.org/10.1386/jdsp.8.1.57_1
[94] Dawn Nafus. 2014. Stuck data, dead data, and disloyal data: the stops and starts in making numbers into social practices. *Distinktion J. Soc. Theory* 15, 2 (May 2014), 208–222. DOI: https://doi.org/10.1080/1600910X.2014.920266
[95] Dawn Nafus. 2016. Introduction. In *Quantified: Biosensing Technologies in Everyday Life*, Dawn Nafus (ed.). MIT Press.
[96] Dawn Nafus and Jamie Sherman. 2014. Big Data, Big Questions| This One Does Not Go Up To 11: The Quantified Self Movement as an Alternative Big Data Practice. *Int. J. Commun.* 8, 0 (June 2014), 11.
[97] Gina Neff and Dawn Nafus. 2016. *Self-tracking*. MIT Press.
[98] Safiya Umoja Noble and Sarah T. Roberts. 2016. Through Google-Colored Glass(es): Design, Emotion, Class, and Wearables as Commodity and Control. *Media Stud. Publ.* (2016).
[99] A. Osman, J. Turcot, and R. E. Kaliouby. 2015. Supervised learning approach to remote heart rate estimation from facial videos. In *2015 11th IEEE International Conference and Workshops on Automatic Face and Gesture Recognition (FG)*, 1–6. DOI: https://doi.org/10.1109/FG.2015.7163150
[100] Brian Parkinson. 2015. Emotions in Interpersonal Life. In *The Oxford Handbook of Affective Computing*, Rafael Calvo, Sidney D'Mello, Jonathan Gratch and Arvid Kappas (eds.). Oxford University Press. Retrieved May 18, 2016 from http://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780199942237.001.0001/oxfordhb-9780199942237-e-023
[101] Rosalind W. Picard and Jocelyn Scheirer. 2001. The Galvactivator: A glove that senses and communicates skin conductivity. In *Proceedings from the 9th International Conference on Human-Computer Interaction*, 1538–1542.
[102] James Pierce, Phoebe Sengers, Tad Hirsch, Tom Jenkins, William Gaver, and Carl DiSalvo. 2015. Expanding and Refining Design and Criticality in HCI. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (CHI '15), 2083–2092. DOI: https://doi.org/10.1145/2702123.2702438
[103] Laura R. Pina, Sang-Wha Sien, Teresa Ward, Jason C. Yip, Sean A. Munson, James Fogarty, and Julie A. Kientz. 2017. From Personal Informatics to Family Informatics: Understanding Family Practices Around Health Monitoring. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing* (CSCW '17), 2300–2315. DOI: https://doi.org/10.1145/2998181.2998362
[104] Paul Rabinow and Nikolas Rose. 2006. Biopower Today. *BioSocieties* 1, 2 (June 2006), 195–217. DOI: https://doi.org/10.1017/S1745855206040014
[105] Andrew G Reece and Christopher M Danforth. 2017. Instagram photos reveal predictive markers of depression. *EPJ Data Sci.* 6, 1 (December 2017). DOI: https://doi.org/10.1140/epjds/s13688-017-0110-z
[106] Nikolas Rose. 2001. The Politics of Life Itself. *Theory Cult. Soc.* 18, 6 (December 2001), 1–30. DOI: https://doi.org/10.1177/02632760122052020

[107] Nikolas Rose. 2008. The value of life: somatic ethics & the spirit of biocapital. *Daedalus* 137, 1 (January 2008), 36–48. DOI: https://doi.org/10.1162/daed.2008.137.1.36

[108] Minna Ruckenstein and Natasha Dow Schüll. 2017. The Datafication of Health. *Annu. Rev. Anthropol.* 46, 1 (October 2017), 261–278. DOI: https://doi.org/10.1146/annurev-anthro-102116-041244

[109] Kimiko Ryokai, Elena Duran, Dina Bseiso, Noura Howell, and Ji Won Jun. 2017. Celebrating Laughter: Capturing and Sharing Tangible Representations of Laughter. In *Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems* (DIS '17 Companion), 202–206. DOI: https://doi.org/10.1145/3064857.3079146

[110] Kimiko Ryokai, Elena Duran, Noura Howell, Jonathan Gillick, and David Bamman. 2018. Capturing, Representing, and Interacting with Laughter. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*.

[111] Pedro Sanches, Kristina Höök, Elsa Vaara, Claus Weymann, Markus Bylund, Pedro Ferreira, Nathalie Peira, and Marie Sjölinder. 2010. Mind the Body!: Designing a Mobile Stress Management Application Encouraging Personal Reflection. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems* (DIS '10), 47–56. DOI: https://doi.org/10.1145/1858171.1858182

[112] Thecla Schiphorst. 2011. Self-evidence: Applying Somatic Connoisseurship to Experience Design. In *CHI '11 Extended Abstracts on Human Factors in Computing Systems* (CHI EA '11), 145–160. DOI: https://doi.org/10.1145/1979742.1979640

[113] Natasha Dow Schüll. 2016. Data for life: Wearable technology and the design of self-care. *BioSocieties* 11, 3 (September 2016), 317–333. DOI: https://doi.org/10.1057/biosoc.2015.47

[114] Natasha Dow Schüll. 2017. Algorithmic Selves: Sensory Technology and the Mediation of Sentience. Retrieved December 14, 2017 from http://cstms.berkeley.edu/current-events/datasense-sensor-technology-and-the-mediation-of-sentience/

[115] Phoebe Sengers, Kirsten Boehner, Shay David, and Joseph "Jofish" Kaye. 2005. Reflective Design. In *Proceedings of the 4th Decennial Conference on Critical Computing* (CC '05), 49–58. DOI: https://doi.org/10.1145/1094562.1094569

[116] Phoebe Sengers, Kirsten Boehner, Simeon Warner, and Tom Jenkins. 2005. Evaluating Affector: Co-Interpreting What "Works." In *CHI 2005 Workshop on Innovative Approaches to Evaluating Affective Interfaces*.

[117] Phoebe Sengers and Bill Gaver. 2006. Staying Open to Interpretation: Engaging Multiple Meanings in Design and Evaluation. In *Proceedings of the 6th Conference on Designing Interactive Systems (DIS'06)* (DIS '06), 99–108. DOI: https://doi.org/10.1145/1142405.1142422

[118] Sensoree (Collective), Kristin Neidlinger, Scott Minneman, Anthony Asterisk, and Erik Johnson. *GER Mood Sweater*. Retrieved March 21, 2016 from http://sensoree.com/artifacts/ger-mood-sweater/

[119] Sensoree (Collective), Kristin Neidlinger, Grant Patterson, Nathan Tucker, and Machinic (Collective). *NEUROTiQ*. Retrieved March 21, 2016 from http://sensoree.com/artifacts/neurotiq/

[120] Tamar Sharon. 2017. Self-Tracking for Health and the Quantified Self: Re-Articulating Autonomy, Solidarity, and Authenticity in an Age of Personalized Healthcare. *Philos. Technol.* 30, 1 (March 2017), 93–121. DOI: https://doi.org/10.1007/s13347-016-0215-5

[121] Tamar Sharon and Dorien Zandbergen. 2017. From data fetishism to quantifying selves: Self-tracking practices and the other values of data. *New Media Soc.* 19, 11 (November 2017), 1695–1709. DOI: https://doi.org/10.1177/1461444816636090

[122] Jamie Sherman. 2015. How Theory Matters: Benjamin, Foucault, and Quantified Self—Oh My! *EPIC*. Retrieved May 2, 2017 from https://www.epicpeople.org/how-theory-matters/

[123] Eric Shouse. 2005. Feeling, Emotion, Affect. *MC J. J. Media Cult.* 8, 6 (2005). Retrieved December 17, 2016 from http://journal.media-culture.org.au/0512/03-shouse.php

[124] Samarth Singhal, Carman Neustaedter, Yee Loong Ooi, Alissa N. Antle, and Brendan Matkin. 2017. Flex-N-Feel: The Design and Evaluation of Emotive Gloves for Couples to Support Touch Over Distance. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing* (CSCW '17), 98–110. DOI: https://doi.org/10.1145/2998181.2998247

[125] Petr Slovák, Joris Janssen, and Geraldine Fitzpatrick. 2012. Understanding Heart Rate Sharing: Towards Unpacking Physiosocial Space. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '12), 859–868. DOI: https://doi.org/10.1145/2207676.2208526

[126] Petr Slovák, Paul Tennent, Stuart Reeves, and Geraldine Fitzpatrick. 2014. Exploring skin conductance synchronisation in everyday interactions. In *Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational (NordiCHI'14)*, 511–520. DOI: https://doi.org/10.1145/2639189.2639206

[127] Jaime Snyder, Mark Matthews, Jacqueline Chien, Pamara F. Chang, Emily Sun, Saeed Abdullah, and Geri Gay. 2015. MoodLight: Exploring Personal and Social Implications of Ambient Display of Biosensor Data. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing (CSCW'15)*, 143–153. DOI: https://doi.org/10.1145/2675133.2675191

[128] Anna Ståhl, Kristina Höök, Martin Svensson, Alex S. Taylor, and Marco Combetto. 2009. Experiencing the Affective Diary. *Pers. Ubiquitous Comput* 13, 5 (June 2009), 365–378. DOI: https://doi.org/10.1007/s00779-008-0202-7

[129] Kathleen Stewart. 2007. *Ordinary affects*. Duke University Press, Durham, NC.

[130] Lucille Alice Suchman. 2007. *Human-machine reconfigurations: plans and situated actions* (2nd ed ed.). Cambridge University Press, Cambridge ; New York.

[131] Melanie Swan. 2012. Health 2050: The Realization of Personalized Medicine through Crowdsourcing, the Quantified Self, and the Participatory Biocitizen. *J. Pers. Med.* 2, 3 (September 2012), 93–118. DOI: https://doi.org/10.3390/jpm2030093

[132] Jakob Tholander, Maria Normark, and Chiara Rossitto. 2012. Understanding Agency in Interaction Design Materials. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '12), 2499–2508. DOI: https://doi.org/10.1145/2207676.2208417

[133] Chris Till. 2014. Exercise as Labour: Quantified Self and the Transformation of Exercise into Labour. *Societies* 4, 3 (August 2014), 446–462. DOI: https://doi.org/10.3390/soc4030446

[134] Alice Truong. 2014. This Google Glass App Will Detect Your Emotions, Then Relay Them Back To Retailers. *Fast Company*. Retrieved June 24, 2018 from https://www.fastcompany.com/3027342/this-google-glass-app-will-detect-your-emotions-then-relay-them-back-to-retailers

[135] Haris Tsirmpas and Panagiotis Fatouros. 2018. Feel. Berkeley, CA.

[136] Anna Vallgårda, Laurens Boer, Vasiliki Tsaknaki, and Dag Svanaes. 2016. Material Programming: A New Interaction Design Practice. In *Proceedings of the 2016 ACM Conference Companion Publication on Designing Interactive Systems* (DIS '16 Companion), 149–152. DOI: https://doi.org/10.1145/2908805.2909411

[137] Anna Vallgårda and Johan Redström. 2007. Computational Composites. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '07), 513–522. DOI: https://doi.org/10.1145/1240624.1240706

[138] Peter-Paul Verbeek. 2006. Materializing Morality: Design Ethics and Technological Mediation. *Sci. Technol. Hum. Values* 31, 3 (May 2006), 361–380. DOI: https://doi.org/10.1177/0162243905285847

[139] Jo Vermeulen, Lindsay MacDonald, Johannes Schöning, Russell Beale, and Sheelagh Carpendale. 2016. Heartefacts: Augmenting Mobile Video Sharing Using Wrist-Worn Heart Rate Sensors. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems* (DIS '16), 712–723. DOI: https://doi.org/10.1145/2901790.2901887

[140] Jay Vidyarthi, Bernhard E. Riecke, and Diane Gromala. 2012. Sonic Cradle: Designing for an Immersive Experience of Meditation by Connecting Respiration to Music. In *Proceedings of the Designing Interactive Systems Conference* (DIS '12), 408–417. DOI: https://doi.org/10.1145/2317956.2318017

[141] Chen Wang, Xintong Zhu, Erik Geelhoed, Ian Biscoe, Thomas Röggla, and Pablo Cesar. 2016. How Are We Connected? - Measuring Audience Galvanic Skin Response of Connected Performances: 33–42. DOI: https://doi.org/10.5220/0005939100330042

[142] McKenzie Wark. 2013. The Revolution of Everyday Life. In *The Spectacle of Disintegration* (First edition). Verso, Brooklyn, New York, 49–60.

[143] Stephen Wensveen, Kees Overbeeke, and Tom Djajadiningrat. 2000. Touch Me, Hit Me and I Know How You Feel: A Design Approach to Emotionally Rich Interaction. In *Proceedings of the 3rd Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques* (DIS '00), 48–52. DOI: https://doi.org/10.1145/347642.347661

[144] Danielle Wilde. 2010. Swing That Thing: Moving to Move. In *Proceedings of the Fourth International Conference on Tangible, Embedded, and Embodied Interaction* (TEI '10), 303–304. DOI: https://doi.org/10.1145/1709886.1709954

[145] Danielle Wilde, Thecla Schiphorst, and Sietske Klooster. 2011. Move to Design/Design to Move: A Conversation About Designing for the Body. *interactions* 18, 4 (July 2011), 22–27. DOI: https://doi.org/10.1145/1978822.1978828

[146] Langdon Winner. 1980. Do Artifacts Have Politics? *Daedalus* 109, 1 (1980), 121–136.

[147] Anouk Wipprecht. 2014. *Synapse*. Retrieved July 28, 2016 from https://i.materialise.com/blog/wearable-tech-just-got-smarter-anouk-wipprechts-intel-edison-powered-3d-printed-synapse-dress-logs-your-mood/

[148] Anouk Wipprecht. *Spider Dress 2.0*. Retrieved December 26, 2015 from http://www.anoukwipprecht.nl/

[149] Richmond Y. Wong, Nick Merrill, and John Chuang. 2018. When BCIs have APIs: Design Fictions of Brain-Computer Interface Adoption. In *Designing Interactive Systems*.

[150] Richmond Y. Wong, Ellen Van Wyk, and James Pierce. 2017. Real-Fictional Entanglements: Using Science Fiction and Design Fiction to Interrogate Sensing Technologies. 567–579. DOI: https://doi.org/10.1145/3064663.3064682

[151] Geoffrey Woo. *Biohacking in Silicon Valley ft. Melia Robinson*. Retrieved October 28, 2017 from https://www.youtube.com/watch?v=q9EmairJAXU

[152] Geoffrey Woo. *Biohacking for Self-Actualization ft. Serge Faguet*. Retrieved October 28, 2017 from https://www.youtube.com/watch?v=mNb5rB5at78

[153] Bin Yu, Mathias Funk, Jun Hu, and Loe Feijs. 2017. StressTree: A Metaphorical Visualization for Biofeedback-assisted Stress Management. In *Designing Interactive Systems*, 333–337. DOI: https://doi.org/10.1145/3064663.3064729

[154] 2014. Microsoft Band 2 Advertisement. Retrieved August 25, 2017 from https://i.imgur.com/tiC9ufb.jpg

[155] 2014. Prosthetic Technologies of Being: Monarch. *Social Body Lab*. Retrieved March 30, 2018 from https://www2.ocadu.ca/research/socialbody/project/prosthetic-technologies-of-being
[156] 2017. Otsuka and Proteus® Announce the First U.S. FDA Approval of a Digital Medicine System: Abilify MyCite® (aripiprazole tablets with sensor) - Proteus Digital Health. Retrieved December 14, 2017 from http://www.proteus.com/press-releases/otsuka-and-proteus-announce-the-first-us-fda-approval-of-a-digital-medicine-system-abilify-mycite/
[157] 2018. PART 4: The Moodmetric ring stress measurement and understanding the data -. Retrieved March 28, 2018 from http://www.moodmetric.com/stress-measurement-data/
[158] Leaf Urban: The evolution of well-being. *Bellabeat*. Retrieved March 30, 2018 from https://webshop.bellabeat.com/pages/leaf-urban
[159] Microsoft Band. Retrieved March 30, 2018 from https://www.microsoft.com/en-us/band
[160] Affectiva Developer Portal: Metrics. Retrieved May 2, 2017 from http://developer.affectiva.com/metrics/
[161] Department of Homeland Security Future Attribute Screening Technology Mobile Module (FAST M2) Overview. *Public intelligence*. Retrieved March 1, 2018 from https://publicintelligence.net/dhs-future-attribute-screening-technology-mobile-module-fast-m2-overview/
[162] *Press Announcements - FDA approves pill with sensor that digitally tracks if patients have ingested their medication.* Retrieved December 14, 2017 from https://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm584933.htm
[163] Microsoft Band 2. Retrieved January 11, 2016 from https://www.microsoft.com/microsoft-band/en-us/features
[164] Feel. *World's first Emotion Sensor & Well-being Advisor*. Retrieved January 12, 2016 from http://www.myfeel.co/
[165] Spire Mindfulness. *Spire*. Retrieved September 14, 2016 from http://www.spire.io
[166] Spire Healthtag. *Spire*. Retrieved March 28, 2018 from https://spire.io/pages/healthtag
[167] Feel: How it works. Retrieved March 22, 2018 from https://www.myfeel.co/how-it-works
[168] Oura: The Smart Ring That Helps You Get More Restorative Sleep. Retrieved March 6, 2018 from https://ouraring.com/
[169] Moodmetric: Simplest solution to measure stress and recovery. Retrieved March 6, 2018 from http://www.moodmetric.com/
[170] Humanyze - People Analytics. Better Performance. *Humanyze*. Retrieved March 28, 2018 from https://www.humanyze.com/
[171] lowdown focus. *Muse: the brain sensing headband*. Retrieved April 17, 2018 from http://www.choosemuse.com/lowdown-focus/
[172] mood Archives. *Quantified Self*. Retrieved March 25, 2018 from http://quantifiedself.com/mood/
[173] Big Health. *Big Health*. Retrieved March 28, 2018 from https://www.bighealth.com/
[174] *Affectiva*. Retrieved from http://www.affectiva.com/
[175] Spire. *Spire*. Retrieved September 19, 2017 from http://www.spire.io
[176] E4 wristband. *Empatica Store*. Retrieved September 18, 2017 from https://store.empatica.com/products/e4-wristband
[177] Hussein Chalayan and Intel take stress tracking accessories to Paris Fashion Week. *Wareable*. Retrieved August 25, 2017 from https://www.wareable.com/fashion/hussein-chalayan-paris-fashion-week-wearable-tech-889
[178] The Algorithmic Justice League. Retrieved June 24, 2018 from https://www.ajlunited.org/
[179] Mother: Sen.se. Retrieved December 14, 2017 from https://sen.se/store/mother/
[180] Fitbit One™ Wireless Activity + Sleep Tracker. Retrieved December 14, 2017 from http://www.fitbit.com/one
[181] HAPIfork: Eat slowly, lose weight, feel great! Retrieved December 14, 2017 from https://www.hapi.com/product/hapifork

Received April 2018; revised July 2018; accepted September 2018.