Problems in Practice: Critiquing on Thermochromic based Displays for Representing Skin Conductance

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ABSTRACT

Increasing HCI work on affective technologies is using different materials to represent biosensory data. We explored several thermochromic, heating, and insulation materials to represents skin conductance data through abstract and ambiguous representations. We report on the development of three prototypes to represent emotional arousal using different colors, patterns, and shapes. By critically reflecting on our experience, we highlight problems in these prototypes and propose design guidelines to inform future research for representing arousal using thermochromic materials.

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KEYWORDS

Biosensing representations; thermochromic displays; skin conductance; arousal; problems in practice

Figure 1: Multilayer fabrication.

BACKGROUND

Over the last decade, we have seen a growing HCI interest in emotional wellbeing and affective health [17] particularly focused on emotional memories [14,15,21,22,23], particularly in old age [18] and end of life care [19], affective representations through smart materials [24], and support for mindfulness [2,20]. With the growing interest in biosensing a growing number of technologies focus on capturing biosensory data such as skin conductance, heart rate variability, breathing rate, movement data, brain activity information [29,30,31,32]. Often such information is displayed through biosensory representations in numerical and graph-based form. However, there are other systems which aim to empower users by employing ambiguous biosensing representations [5,7,11,12,16,24,28] to provoke multiple interpretations of biosensory data. These systems often employ mobile and desktop screens which are not always on sight. However, a growing number of research is trying to use alternative kind of displays using thermochromic materials to represent biosensory information [3,7,24]. Such displays are often integrated into wearables and clothing.

A growing interest in materials research within HCI and interaction design has helped us understand how the qualities of materials unfold when designing and using interactive systems [8,10,27]. They highlight the importance of understanding the aesthetic and experiential qualities of materials. According to Giaccardi and Karana, different individuals experience materials in different ways as: "*properties of a material, the artifact in which a material is embodied, one's previous experience and expectations, and social and cultural values inevitably affect how we experience*" [6]. The framework proposes that materials are experienced at four different levels i.e. sensorial, interpretive, affective and performative level.

We engaged in a material exploration of thermochromic, heating and insulation materials to design and develop such ambiguous representations that can be used in daily life settings. Through our exploration, we analyzed the interplay of these materials, their properties, constraints, and inner working and developed prototypes to represent changes in skin conductance, also a measure of physiological arousal [24]. In previous work we have shown similar such prototypes [24], however among those we have developed, some have been less successful. Such work however is seldom presented in academic writing [4]. Thus, in this paper, we present three discarded prototypes and critically reflect on our approach to highlights problems and unpack the qualities of thermochromic displays representing skin conductance.

FABRICATING THERMOCHROMIC DISPLAYS THROUGH MATERIAL EXPLORATION FOR REPRESENTING SKIN CONDUCTACE DATA

We explored different materials for fabricating thermochromic displays. The approach involved tinkering with materials and trying out different combinations to learn their affordances and constraints [10,13]. We examined materials' resistance, power requirements, actuation temperatures settings, color expressiveness, how they can be cut, bend and shaped together and what combination of materials can be weaved together. We used multi-layered approach [9] Fig. 1

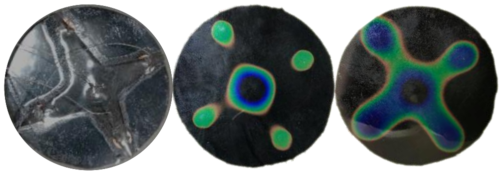

Figure 2: The appearing and expanding dots

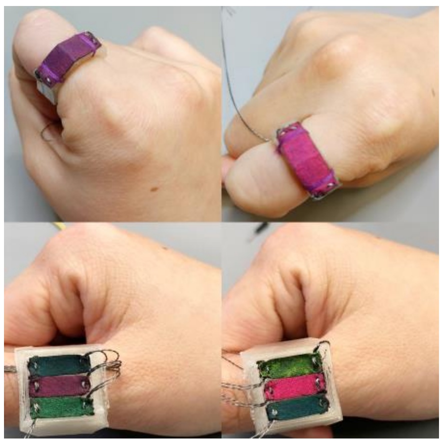

Figure 3: Single and Multi-palette rings changing colors

Figure 4: Rainbow colored display with three colors (light blue, yellow and red) disappearing

for fabricating thermochromic based displays including a thermochromic layer, a heating layer in the middle, and an insulation layer as a substrate. Human skin becomes a better conductor in response to strong stimuli. Skin conductance is often linked to sympathetic arousal which is representative of having strong emotions and cognitive processing [1]. The changes in skin conductance are measured by calculating potential difference between two points of contact on the skin using electrodes. We wanted to represent skin conductance through ambiguous and abstract representations that are wearable and part of clothing or accessories. We used Grove GSR sensor to capture skin conductance data, and Arduino Nano and LilyPad microcontrollers to process the sensor data and actuate the three prototypes shown in Fig 2, 3 and 4.

Thermochromic layer: We explored thermochromic liquid crystal sheets and paints of different actuation temperatures in their ability to visualize color changing effects. We also discarded the ones actuating above 40°C making it safe to use for near body applications. Thermochromic liquid crystal sheets change color to red, green and blue, whereas thermochromic paints transform from one color to another or to clear (no color) when exposed to heat. An additional design layer can be added underneath the thermochromic layer to enhance the aesthetics or reveal hidden information when using color to clear thermochromic paint (Figure 1).
Heating Layer: Heating elements are high resistance materials which produce heat when current is applied through them. We explored a range of materials such as nichrome wire, conductive threads, conductive fabrics, conductive paints, copper and aluminum sheets in terms of the produced heat, speed of heating up and cooling down, power requirements, and ability to bend into different shapes.
Insulation: The heat generated during actuation can be insulated by adding an insulation layer underneath. In some cases, insulation is also required at the top as well. We explored polypropylene sheets, silicon, and polyimide insulation tapes, and epoxy resins as insulation materials.

The Dots: The Dots employ a flexible, plus-shaped conductive fabric flexible, 0.8mm thick which provides a tunable surface resistivity of 8 Ohm/square to 105 Ohm/square. To provide current, we sewed five conductive thread connections (GND in the middle and +Vcc around four corners) into the plus shaped fabric as shown in Figure 2. The insulation layer consists of a clear adhesive tape whereas the top layer is a circular shaped liquid crystal sheet. Increase in arousal is represented by providing current across four terminals one by one with each dot representing the level of heightened arousal. This results in slow appearance and disappearance of dots one by one. As the arousal remain high, the four dots expand forming a plus shape (Figure 2).
The Rings: The Rings uses 10x19mm conductive fabric strips as a heating mechanism powered through conductive threads. We applied 31°C thermochromic paint layer directly on the fabric strips that change color from purple to pink, green to yellow and blue to green upon increase in the

arousal. Once the paints became dry, we attached the strips onto a 3D printed ring which acts as an insulation. Increase in arousal is represented by changes in colors. The three color strips can be actuated in any pattern to represent changes in arousal.

The Rainbow: The Rainbow uses a conductive thread as a heat resistive element. As the current passes through the thread, it heats up. The top layer is a rainbow-colored pattern that only changes three colors: 31°C thermochromic light blue, yellow, and red paints to clear in case of low, medium and high arousal respectively (Figure 4).

DISCUSSION

We now take the critical lens to identify the problems and challenges we faced in prototyping and representing skin conductance in the three thermochromic based displays. By reflecting on the experience, we critique on the design features which the material properties did not support.

Not too expressive: The appearance and disappearance of dots in the Dots display is expressive and open for interpretation. Existing research calls for expressiveness to represent mood [25]. However, increased expressiveness paired with the ambiguity of thermochromic materials can become problematic. Although we designed the display ambiguous to support interactive openness on purpose, its expressive nature adds to the ambiguity, making it hard to interpret the increase and decay of arousal.

Subtle but Perceivable: The Rings use different color thermochromic paints which are directly applied on black fabric strips. Existing work highlights that people value privacy using color coding moreover they also expressed the desire to personalize the colors for representing skin conductance based data [24]. The rings support these important findings however with slow heating of the fabric, the change from one color to another becomes less perceivable. Through experiments, we found that this can be improved by either using large fabric strips or by using thermochromic paints with a contrasting color change.

The Choice of Heating Material is Crucial: The choice of heating material is an important step as it determines the shape, resolution, and speed of actuation of thermochromic display. The choice of conductive thread to actuate a bigger circle in the Rainbow display became problematic. As we used the thread to cover the whole surface area, it became longer in length which in turn reduced the heat and speed of actuation. This resulted in being color unable to disappear as shown in the Figure 4. Prior work only used thermochromic thread to represent color change animations of boundaries and patterns [26]. Therefore, it is important to consider the appropriate choice of the heating element when designing any thermochromic based display.

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REFERENCES

1. Jason J Braithwaite, Derrick G Watson, Robert Jones, and Mickey Rowe. 2013. A guide for analysing electrodermal activity (EDA) & skin conductance responses (SCRs) for psychological experiments. *Psychophysiology* 49, 1: 1017–1034.
2. Claudia Daudén Roquet and Corina Sas. 2018. Evaluating Mindfulness Meditation Apps. *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, ACM Press, 1–6.
3. Laura Devendorf, Joanne Lo, Noura Howell, et al. 2016. I don't want to wear a screen: probing perceptions of and possibilities for dynamic displays on clothing. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 6028–6039.
4. Abigail C Durrant, David S Kirk, Jayne Wallace, Simon Bowen, Stuart Reeves, and Sara Ljungblad. 2017. Problems in Practice: Understanding Design Research by Critiquing Cases. *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, 636–643.
5. Pedro Ferreira, Pedro Sanches, Kristina Höök, and Tove Jaensson. 2008. License to chill!: how to empower users to cope with stress. *Proceedings of the 5th Nordic conference on Human-computer interaction: building bridges*, 123–132.
6. Elisa Giaccardi and Elvin Karana. 2015. Foundations of materials experience: An approach for HCI. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, 2447–2456.
7. Noura Howell, Laura Devendorf, Rundong Kevin Tian, et al. 2016. Biosignals as social cues: Ambiguity and emotional interpretation in social displays of skin conductance. *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, 865–870.
8. Heekyoung Jung and Erik Stolterman. 2012. Digital form and materiality: propositions for a new approach to interaction design research. *Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design*, 645–654.
9. Hsin-Liu Cindy Kao, Christian Holz, Asta Roseway, Andres Calvo, and Chris Schmandt. 2016. DuoSkin: rapidly prototyping on-skin user interfaces using skin-friendly materials. *Proceedings of the 2016 ACM International Symposium on Wearable Computers*, 16–23.
10. Elvin Karana, Bahareh Barati, Valentina Rognoli, Van Der Laan, Anouk Zeeuw, and others. 2015. Material driven design (MDD): A method to design for material experiences. .
11. Madelene Lindström, Anna Ståhl, Kristina Höök, et al. 2006. Affective diary: designing for bodily expressiveness and self-reflection. *CHI'06 extended abstracts on Human factors in computing systems*, 1037–1042.
12. Daniel McDuff, Amy Karlson, Ashish Kapoor, Asta Roseway, and Mary Czerwinski. 2012. AffectAura: an intelligent system for emotional memory. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 849–858.
13. Stefano Parisi, Valentina Rognoli, and Marieke Sonneveld. 2017. Material Tinkering. An inspirational approach for experiential learning and envisioning in product design education. *The Design Journal* 20, sup1: S1167--S1184.
14. Chengcheng Qu and Corina Sas. 2018. Exploring memory interventions in depression through lifelogging lens. *Proceedings of the 32nd British Computer Society Human Computer Interaction Conference*, ACM.
15. Chengcheng Qu, Corina Sas, and Gavin Doherty. 2018. Exploring and Designing for Memory Impairments in Depression. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*.
16. Pedro Sanches, Kristina Höök, Elsa Vaara, et al. 2010. Mind the Body! Designing a Mobile Stress Management Application Encouraging Personal Reflection. *Proceedings of the 8th ACM Conference on Designing Interactive Systems*, 47–56.
17. Pedro Sanches, Axel Janson, Pavel Karpashevich, et al. 2018. HCI and Affective Health: Taking stock of a decade of studies and charting future research directions. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM.
18. Corina Sas. 2018. Exploring Self-Defining Memories in Old Age and their Digital Cues. *Proceedings of the 2018 on Designing Interactive Systems Conference 2018*, 149–161.
19. Corina Sas, Kieran Brahney, Carl Oechsner, et al. 2017. Communication Needs of Elderly at Risk of Falls and their Remote Family. *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, 2900–2908.
20. Corina Sas and Rohit Chopra. 2015. MeditAid: a wearable adaptive neurofeedback-based system for training mindfulness state. *Personal and Ubiquitous Computing* 19, 7: 1169–1182.
21. Corina Sas and Matthew Rees. 2013. AffectCam: Arousal – Augmented SenseCam for Richer Recall of Episodic Memories. *Extended Abstracts on Human Factors in Computing Systems*, 1041–1046.
22. Corina Sas and Steve Whittaker. 2013. Design for forgetting: disposing of digital possessions after a breakup. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1823–1832.
23. Corina Sas, Steve Whittaker, and John Zimmerman. 2016. Design for rituals of letting go: An embodiment perspective on disposal practices informed by grief therapy. *ACM Transactions on Computer-Human Interaction (TOCHI)* 23, 4: 21.
24. Muhammad Umair, Muhammad Hamza Latif, and Corina Sas. 2018. Dynamic Displays at Wrist for Real Time Visualization of Affective Data. *Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility - DIS '18*, ACM Press, 201–205.
25. Torben Wallbaum, Wilko Heuten, and Susanne Boll. 2016. Comparison of in-situ mood input methods on mobile devices. *Proceedings of the 15th International Conference on Mobile and Ubiquitous Multimedia*, 123–127.
26. Yanan Wang, Shijian Luo, Yujia Lu, et al. 2017. AnimSkin: Fabricating Epidermis with Interactive, Functional and Aesthetic Color Animation. *Proceedings of the 2017 Conference on Designing Interactive Systems*, 397–401.
27. Mikael Wiberg. 2014. Methodology for materiality: interaction design research through a material lens. *Personal and ubiquitous computing* 18, 3: 625–636.
28. Graham Wilson, Pietro Romeo, and Stephen A Brewster. 2016. Mapping Abstract Visual Feedback to a Dimensional Model of Emotion. *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, 1779–1787.
29. (r)evolution Board Kit BT. Retrieved February 20, 2019 from https://bitalino.com/en/board-kit-bt.
30. E4 wristband. Retrieved February 20, 2019 from https://www.empatica.com/research/e4/.
31. Feel Wristband. Retrieved February 20, 2019 from https://www.myfeel.co/.
32. Spire Health Research Platform. Retrieved February 20, 2019 from https://spirehealth.com/pages/research-platform.