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Di Lodovico, Chiara; Colombo, Sara; Rapp, Amon

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Ambiguity for Social Self-tracking Practices: Exploring an Emerging Design Space

Chiara Di Lodovico*
Politecnico di Milano,
Design Dept.
Milan, Italy
chiara.dilodovico@polimi.it

Sara Colombo
Delft University of Technology,
Sustainable Design Engineering Dept.
Delft, the Netherlands
sara.colombo@tudelft.nl

Amon Rapp
University of Torino,
Computer Science Dept.
Torino, Italy
amon.rapp@unito.it

ABSTRACT

Ambiguity is gaining attention in self-tracking research as a means to go beyond the mere quantification of body signals. Recent research has suggested that ambiguity can be used even to enable social connection mediated by personal data. To explore this design space more widely, we organized two design workshops with a total of 67 participants. In this paper, we present three design concepts, as outcomes of the workshops, which use ambiguity to enable social self-tracking practices. We then discuss how these concepts demonstrate the potential of ambiguity to encourage collective sense-making, directly impact the user's social relationships, and offer multifaceted perspectives on reality.

CCS CONCEPTS

• **Human-centered computing → Collaborative and social computing**.

KEYWORDS

Ambiguity; Social relations; Biosensing technologies; Social self-tracking; Design workshop

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1 INTRODUCTION

Commercial self-tracking and biosensing wearable technologies are attracting considerable attention from Human-Computer Interaction (HCI) and Computer Supported Cooperative Work (CSCW) researchers for their potential to capture streams of data from the wearers' bodies and turn biosignals, movements, behaviors, and mental states into actionable information for the purposes of self-improvement, self-discipline, and self-knowledge [8, 17, 30]. This information is usually delivered to the users in form of screen-based quantified representations, graphs and recommendations conveying an apparent accurate representation of an individual's status [28]. Quantified data displayed by these commercial devices are mostly meant to be accessed privately, whereby "social self-tracking", namely, the social dimension of tracking, is often considered as a supplementary feature that people may use to share their information with the purpose of letting other users know their activities and achievements, or competing with them [10, 25]. Likewise, much academic research in this field focuses on the private dimension of self-tracking, with only a few studies exploring social, collaborative and shared tracking practices [9] in domains like fitness [20], sleep [24], health [4], food [21] and workplace [31], or among members of informal communities of trackers, like the Quantified Selfers [3]. This kind of research points out that data sharing can be used as a means to compare and compete with peers [20], as a motivational lever to perform a certain behavior [29], as a medium to "connect with others" [15], and even as a surveillance and biopolitics tool for normalizing bodies [37].

The majority of these studies, however, investigate people's sharing practices while using existing commercial self-tracking tools, where data are displayed through visualizations emphasizing objectivity, clarity and the rational examination of the tracked parameters [30]: here, sharing data is also considered as a means to transmit precise and unambiguous information. Nevertheless, an emerging stream of research has recently highlighted the limits of such visualizations, which may lack meaning for the user [16, 27], and has started exploring the design opportunities opened by considering self-tracking data beyond quantification and rationality [26]. For example, Rapp and Tirassa [30] presented a theory of the self based on the phenomenological and constructivist traditions, which aims to move the self-tracking discourse from behavior and objective data to the self and subjective meanings. This alternate line of investigation – which includes social biosensing [5] and expressive biosignals [18] research - may emphasize the active role of self-tracking data in enabling novel social interaction trajectories, pointing to an alternative design space [12, 14, 39]. Particularly relevant in this stream of research are recent research-through-design contributions using ambiguous - rather than clear – data representations to stimulate multiple, open-ended, heterogeneous, and unexpected interpretations of data, beyond utility and rationality [11, 35]. For instance, *Animo* [19], *Hint Shirt* [13], and *Ripple* [12] explore biosignals (such as heart rate and skin conductance) displayed in ambiguous visualizations as social cues for interpersonal relationships. These systems show the value of ambiguity as a conversation trigger that can encourage reflection and self-expression, enhance engagement and enable social connection. In the same vein,

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Table 1: Workshops features and details

Features	Workshop 1	Workshop 2
Venue	Politecnico di Milano/Hybrid	Umeå Institute of Design/In person
Duration	2 weeks	Two days
Timeline	February 2022	March 2023
Facilitators	3	1
Participants	61 Master level design students	6 HCI Researchers
Number of Groups/Outcomes	11	2
Selected design proposals	2 (The Void, MatchMe)	1(Noisides)

other studies explored whether sharing ambiguous data representations of biosignals can affect trust and cooperation dynamics [23], as well as the understanding of others [18]. Despite these studies being a source of inspiration for us, no research until now seems to have widely and openly explored the multiple opportunities arising from using ambiguity in the design of social self-tracking practices: here, ambiguity may refer to both representation and interpretation of data, and may be intentionally elicited through design to open new opportunities for social connecting through personal data. To explore this emerging design space, we conducted two design workshops (see Table 1) inviting participants to use ambiguity to imagine novel self-tracking devices. The workshop's outcomes show that ambiguity may be a design resource to open innovative design research trajectories in social self-tracking practices, enabling collective interpretations, eliciting reflection on one's own social relationships, and allowing for the confrontation of multiple perspectives. The study contributes to the CSCW community by highlighting that ambiguity may be used for creating diverse "social systems", which encourage sense-making and reflection on the "self" and its relationship with others through means other than rational data examination.

2 METHODOLOGY: DESIGN WORKSHOPS

In this study, we build upon Rosner et al.'s [32] and Elsden et al.'s [7] work, which explored the use of design workshops as a research method for generating new design opportunities, in order to explore the design space of ambiguity for social self-tracking. This study reports on two design workshops (synthesized in Table 1) organized and conducted by the authors, describing and discussing a selection of three design concepts that emerged from the workshops, which show how ambiguity may represent a fruitful design resource for social self-tracking practices. The two workshops have different formats because we wanted to test our method in different conditions and with different constraints.

In both workshops, we asked participants to design a wearable interactive artifact, an interface, and/or a data representation system leveraging ambiguity as a design resource [11]. The workshops aimed to provide a structured process for generating and exploring design concepts that incorporate ambiguity in the context of self-tracking. The workshops consisted of six main stages illustrated below.

- *Introduction to the workshop.* Participants received informative materials on the workshop topics and objectives.
- *Analysis and discussion of tensions of existing self-tracking devices.* We invited participants to discuss several "tensions" in current self-tracking devices, namely apparently unresolved oppositions emerging from their use (e.g., the objective nature of data vs the subjective nature of their interpretations). Such tensions have been defined on the basis of a review of the current literature, which highlights that self-tracking domain is often characterized by polarized opinions, paradoxes, and even unintended effects with respect to the designers' intentions, e.g., [1, 6, 36, 38], and are extensively reported in [6]. To support this activity, participants were provided with a variety of stimuli aimed at eliciting reflections on the tensions [6], like cards prompting questions about controversial aspects of self-tracking (e.g., surveillance, prescriptions of behavior, etc.), and were invited to reflect on their personal experience and use of data tracking devices.
- *Familiarization with ambiguity as a resource.* Our goal was to inspire participants to design solutions that incorporated ambiguity as a resource to mitigate, exaggerate, or explore the tensions they identified. In the first workshop, we relied on Gaver et al.'s [11] ambiguity tactics to help participants understand and practically apply ambiguity in their projects. However, this approach proved to be challenging for some participants, as they were too abstract. Therefore, we created a set of ambiguity tactics for the second workshop, tailored to the self-tracking domain and informed by the review of literature and the first workshop results.
- *Prototyping.* Participants were asked to define a concept and prototype it through bodystorming techniques [34], low-fidelity [22], and experience prototyping [2].
- *Presentation.* Each team was expected to present their project idea and (fictional) prototype, which was discussed with the other workshop participants. They were required to report on its features, the intended users and application context, and how they implemented ambiguity in the data representation or interactive experience. The discussion brought out reflections and questions opened by the prototypes and their possible use.

3 DESIGN CONCEPTS

In this section, we present three design concepts that best address social practices mediated by self-tracking data and best represent three different ways through which ambiguity can "mediate" social relationships: supporting collective interpretations, eliciting

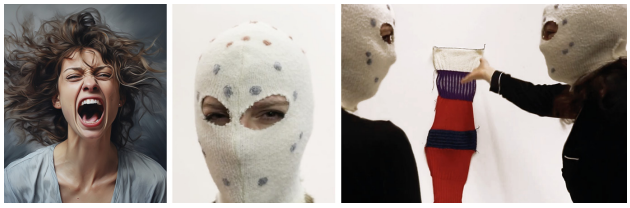

Figure 1: The Void. A visitor's reaction to a screaming woman, and peer-to-peer sharing moment in front of a data knitted piece.

Figure 2: MatchMe. A pair's encounter, and their compatibility assessment through the light-changing heart-like sculpture.

reflection on one's own social relationships, and allowing for the confrontation of multiple perspectives on the same event. For each project, we describe the concepts, provide an account of the tensions inspiring the design, and offer reflections and a series of questions that emerged during the project discussion and may be worth further exploring.

3.1 The Void

Concept. The Void (Fig.1) is a multi-room interactive exhibition that provides an encrypted data physicalization of emotional biosignals, inviting participants to decode the meaning of the data in a social setting. Users wear an electroencephalogram (EEG) and electromyography (EMG) sensor-equipped balaclava (which anonymizes the attendee), while being exposed to four provocative performances (e.g., a person screaming). At the end of the exhibition, each participant receives a data materialization of their own biosignals via a textured, colorful knitted piece hung on the wall, which can be seen as a part of the exhibition, without any information on how to interpret it. The goal is to elicit collaborative decoding through peer-to-peer thought-sharing and comparison, encouraging people to open up about their emotions.

Tensions. The project was inspired by the tension between the claim that commercial wearable devices are capable of detecting complex phenomena, such as stress and emotional states, and the messiness and difficulty of an accurate tracking. The team aimed to reflect on this tension by creating a complex, difficult-to-decipher data representation of emotional biosignals, involving collective interpretations of data.

Reflections and questions. *Collective sense-making and privacy.* As "pieces of art", data materializations become public and open to collective interpretations. Making sense of a difficult-to-interpret data physicalization in a social setting may encourage people to share their feelings to find a plausible explanation and intertwine the representations with meanings arising from collective discussion. Moreover, people may look at others' representations to find similarities or differences to give sense to their own representation. However, even though each visitor's data is accessible to anyone, each visitor may decide whether and how to offer possible explanations of their own data to others. As a result, people may not be sure about the "correctness" of interpretations (an attendee might even lie with respect to their data). While the exhibition invites visitors to talk through their data physicalization of feelings and emotions, may such data and discussions be "deceptive" as it is not possible to reach a "right" interpretation? May the conversations among visitors not be directly related to what the exhibition organisers suggest, entailing a form of technology "appropriation"? Could individuals "force" a person to reveal her emotions to reach the right interpretation of a "piece of art"?

3.2 MatchMe

Concept. MatchMe (Fig.2) is an interactive installation designed to help people find love matches using biosignals. The installation is set up in a performance hall filled with light-changing heart-like sculptures. Participants wear a smart wristband that measures their arousal levels, such as sweat, heart rate, and skin temperature. When two people approach a sculpture, the wristbands sync up, and a collective visual output is generated as a match assessment. The higher the sum of their arousal parameters, the brighter the heart sculpture. People are encouraged to interact with each other and, as they do so, the wristbands keep gathering information, adjusting the visual response in real-time by changing the brightness of the heart sculpture. Then, participants can make their own interpretations of the sculpture response and decide whether or not to engage in further conversations.

Tensions. The project was inspired by technology's significant role in facilitating romantic connections in today's world. MatchMe imagines a future where people may solely rely on technologies and algorithms to find their partners or soul mates. The project intends to explore the tension between trusting the data provided by technology and relying on one's own subjective instincts, exaggerating the technology's capabilities.

Reflections and questions. *Questioning social relationships.* The installation assigns supplementary meaning to biosignals, potentially over-interpreting them as indications of love connections. The installation, however, does not provide a true matching service but rather seeks to provoke participants into reflecting on the role of technology in finding affinities processes. Participants are encouraged to consider whether they should trust data collected by the technology and to what extent this should influence their social relationships. What happens if an existing couple's biosignals don't light up as much as two strangers' biosignals? Will the partners question their feeling and relationship if data go against what they expected? Will people attempt to manipulate their biosignals to increase the brightness of the sculpture? Will visitors still continue the conversation if the heart sculpture isn't bright? Will they question the system's accuracy and argue for the device's limitations?

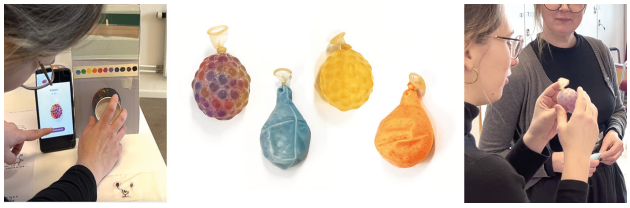

Figure 3: Noisides. Data physicalization system, four people's data physicalizations, and peer-to-peer sharing moment.

3.3 Noisides

Concept. The Noisides project (Fig.3) aims to stimulate various interpretations of bodily signals by giving shape to "gut feelings" through the materialization of an unconventional biosignal – the bowel noise - in order to initiate discussions about personal experiences with peers. The project envisions a group of individuals wearing a belly microphone that detects visceral sounds, which are then translated into one squishy fidget ball per participant containing more particles the noisier the belly is. Each participant can also choose past data connected to some kind of event (e.g., a stressful episode), personalize the colors of the balls, and use it as a trigger to discuss the experience.

Tensions. The project was inspired by the team's personal experiences with self-tracking devices, which showed that when you track your body, you're not just monitoring your own biosystem but also how your biosystem responds and interacts with the environment around you. The team aimed to explore the tension between the inner and outer environment by creating a system where groups of people could combine their individual biodata with contextual information to create a more complete representation of a situation.

Reflections and research questions. *Confrontating multiple perspectives.* Bowel sounds as biosignal are still very little categorized in terms of what they "mean": as there are no conventional meanings ascribed to different bowel sounds (as it happens, e.g., in the case of heart rate, where a fast heartbeat may "mean" agitation, arousal, emotional activation, etc.), they may even be seen as "meaningless." The project prompts reflection on how people "project" into and attribute meaning to an apparently meaningless object and how multiple and even contrasting perspectives on the same event may build a multifaceted perspective on reality. How would a person behave if multiple individuals materialize their bowel sounds in different "objects", which are nonetheless connected to the same event? Would the physicalization highlight the diversity of perspectives on the same experience? Would the data materialization of other's persons influence the understanding of one's own experience of the event? How would people feel by touching another person's physicalization? Would someone consider the data materialization a gift to donate? Would anyone disagree with a representation? What if the data is not understandable at all?

4 DISCUSSION AND FUTURE WORKS

The projects presented in this paper show the potentialities of using "ambiguity" as a design material in self-tracking, making it visible that it may "mediate" social relationships through data, i) enabling collective interpretations, ii) offering opportunities for questioning social relationships enabling novel forms of connectedness, which may create ambiguous and even deceptive interactions, and iii) allowing people to bring together multiple perspectives on the same events creating a multifaceted "view on the world". The projects resonate with previous research acknowledging the inherent multiplicity of meanings of body self-tracked data [12, 13, 18, 19, 33]. Differently from that research, which mainly focused on the potential of ambiguity facilitating self-expression and enabling social connection, we explored more widely the idea of ambiguity for social self-tracking, offering insights on how it may stimulate collaborative, contrasting, or deceptive interpretations, and even impact directly social relations. In future work, we aim to evaluate the prototypes with self-tracking users, to explore whether they can stimulate reflections on their own data, tracking practices, and social relationships enabled by data. Moreover, we are "materializing" the method and materials used in the workshops into a design toolkit aimed at supporting designers in leveraging ambiguity when designing self-tracking wearables.

5 CONCLUSION

This paper explores how to leverage ambiguity as a design material to create social self-tracking devices. The results of this preliminary study contribute to the growing literature on the relational dimension of self-tracking data. While the presented projects are speculative, yet they raise important questions that may be of interest to the CSCW community. In fact, these study findings may open further research lines on how ambiguity can be leveraged to design "social systems" even beyond the self-tracking domain to create novel forms of connectedness and collective sense-making.

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REFERENCES

[1] D. A. Baker. 2020. Four Ironies of Self-quantification: Wearable Technologies and the Quantified Self. *Science and Engineering Ethics* 26, 3 (6 2020), 1477–1498. https://doi.org/10.1007/S11948-020-00181-W

[2] Marion Buchenau and Jane Fulton Suri. 2000. Experience Prototyping. In *DIS '00. Proceedings of the 3rd conference on Designing Interactive Systems. Brooklyn, NY, USA.* ACM Inc., New York, NY, USA, 424–433. https://dl.acm.org/doi/10.1145/347642.347802

[3] Eun Kyoung Choe, Nicole B Lee, Bongshin Lee, Wanda Pratt, and Julie A Kientz. 2014. Understanding Quantified-Selfers' Practices in Collecting and Exploring Personal Data. In *CHI '14: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. April 26 – May 01 2014, Toronto, ON, Canada.* ACM Inc., New York, NY, USA, 1143–1152. https://doi.org/10.1145/2556288

[4] Mayara Costa Figueiredo, Tera L Reynolds, Yunan Chen, Mayara C Figueiredo, Clara Caldeira, Sean Victory, and Kai Zheng. 2018. Self-Tracking for Fertility Care: Collaborative Support for a Highly-Personalized Problem. *Proceedings of the ACM on Human-Computer Interaction* 1, CSCW (11 2018), 21. https://doi.org/10.1145/3134671

[5] Max T Curran and John Chuang. 2022. Social Distancing and Social Biosensing: Intersubjectivity from Afar. *Computer Supported Cooperative Work (CSCW)* (7 2022), 1–34. https://doi.org/10.1007/s10606-022-09428-5

[6] Chiara Di Lodovico. 2023. Exploring the Tensions of Wearable Technologies and Self-Tracking Data Representations through Design. In *Human-Computer Interaction. HCI in Digital Fashion Communication: Thematic Area, HCI 2023, Held as Part of the 25th HCI International Conference, HCII 2023.* Springer International Publishing, Cham, 17.

[7] Chris Elsden, Ella Tallyn, and Bettina Nissen. 2020. When Do Design Workshops Work (or Not)?. In *DIS' 20 Companion. Companion Publication of the 2020 ACM Designing Interactive Systems Conference. July 6-10, 2020, Eindhoven, The Netherlands*. ACM Inc., New York, NY, USA, 245–250. https://doi.org/10.1145/3393914.3395856

[8] Daniel A. Epstein, An Ping, James Fogarty, and Sean A. Munson. 2015. A lived informatics model of personal informatics. In *UbiComp 2015 - Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing. September 7-11, 2015, Osaka, Japan*. ACM Inc., 731–742. https://doi.org/10.1145/2750858.2804250

[9] Daniel A Epstein, Lucas M Silva, Jong HO Lee, Craig Hilby, Elizabeth V Eikey, Clara Caldeira, Mayara Costa Figueiredo, Xi Lu, Lucretia Williams, Jong Ho Lee, Qingyang Li, Simran Ahuja, Qiuer Chen, Payam Dowlatyari, Sazeda Sultana, and Yunan Chen. 2020. Mapping and Taking Stock of the Personal Informatics Literature. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 4, 4, Article 126 (2020), 38. https://doi.org/10.1145/3432231

[10] Thomas Fritz, Elaine M Huang, Gail C Murphy, and Thomas Zimmermann. 2014. Persuasive Technology in the Real World: A Study of Long-Term Use of Activity Sensing Devices for Fitness. In *CHI' 14. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. April 26 - May 01 2014, Toronto, ON, Canada*. ACM Inc., New York, NY, USA, 487–496. https://doi.org/10.1145/2556288.2557383

[11] William W Gaver, Jacob Beaver, and Steve Benford. 2003. Ambiguity as a Resource for Design. In *CHI '03: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. April 5–10, 2003, Ft. Lauderdale, Florida, USA*. ACM Inc., New York, NY, USA, 233–240.

[12] Noura Howell, Laura Devendorf, Tomás Alfonso Vega Gálvez, Rundong Tian, and Kimiko Ryokai. 2018. Tensions of data-driven reflection: A case study of real-time emotional biosensing. In *CHI '18. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. April 21–26, 2018, Montréal, QC, Canada*, Vol. 2018-April. ACM Inc., New York, NY, USA, 1–13. https://doi.org/10.1145/3173574.3174005

[13] Noura Howell, Laura Devendorf, Rundong Tian, Tomás Vega Galvez, 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 *DIS '16: Proceedings of the 2016 ACM Conference on Designing Interactive Systems. June 04-08, 2016, Brisbane, QLD, Australia*. ACM Inc., New York, NY, USA, 865–870. https://doi.org/10.1145/2901790.2901850

[14] Kasper Karlgren, Barry Brown, and Donald Mcmillan. 2022. From Self-Tracking to Sleep-Hacking: Online Collaboration on Changing Sleep. *Proceedings of the ACM on Human-Computer Interaction* CSCW2, Article 517, 6 (11 2022), 1–26. https://doi.org/10.1145/3555630

[15] Megan Knittel, Faye Kollig, Abrielle Mason, and Rick Wash. 2021. Anyone else have this experience?": Sharing the Emotional Labor of Tracking Data About Me. *Proceedings of the ACM on Human-Computer Interaction* 5, CSCW1, Article 79 (4 2021), 79. https://doi.org/10.1145/3449153

[16] Amanda Lazar, Christian Koehler, Theresa Jean Tanenbaum, and David H Nguyen. 2015. Why We Use and Abandon Smart Devices. In *UbiComp '15. Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing. September 7-11, 2015, Osaka, Japan*. ACM Inc., New York, NY, USA, 635–646. https://doi.org/10.1145/2750858.2804288

[17] Ian Li, Anind Dey, and Jodi Forlizzi. 2010. A Stage-Based Model of Personal Informatics Systems. In *CHI'10: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. April 10–15, 2010, Atlanta, Georgia, USA*. ACM Inc., 557–566.

[18] Fannie Liu, Laura Dabbish, and Geoff Kaufman. 2017. Can biosignals be expressive? How visualizations affect impression formation from shared brain activity. *Proceedings of the ACM on Human-Computer Interaction* 1, CSCW, Article 71 (11 2017), 21. https://doi.org/10.1145/3134706

[19] Fannie Liu, Mario Esparza, Maria Pavlovskaia, Geoff Kaufman, Laura Dabbish, and Andrés Monroy-Hernández. 2019. Animo: Sharing Biosignals on a Smartwatch for Lightweight Social Connection. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 3, 1 (3 2019), 1–19. https://doi.org/10.1145/3314405

[20] Stine Lomborg and Kirsten Frandsen. 2016. Self-tracking as communication. *Information, Communication & Society* 19, 7 (8 2016), 1015–1027. https://doi.org/10.1080/1369118X.2015.1067710

[21] Xi Lu, Yunan Chen, and Daniel A Epstein. 2021. A Model of Socially Sustained Self-Tracking for Food and Diet. *PACM on Human Computer Interaction* 5, CSCW2, Article 451 (10 2021), 1–32. https://doi.org/10.1145/3479595

[22] Kathryn McElroy. 2017. *Prototyping for Designers*. O'Reilly, Sebastopol, California, USA.

[23] Nick Merrill and Coye Cheshire. 2017. Trust Your Heart: Assessing Cooperation and Trust with Biosignals in Computer-Mediated Interactions. In *CSCW '17. Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing. February 25–March 1, 2017, Portland, OR, USA*. ACM Inc., New York, NY, USA, 2–11. https://doi.org/10.1145/2998181.2998286

[24] Laura R. Pina, Sang-Wha Sien, Clarissa Song, Teresa M. Ward, James Fogarty, Sean A. Munson, and Julie A. Kientz. 2020. DreamCatcher: Exploring How Parents and School-Age Children Can Track and Review Sleep Information Together. *Proceedings of the ACM on Human-Computer Interaction* 4, CSCW1, Article 70 (5 2020), 25. https://doi.org/10.1145/3392882

[25] Amon Rapp. 2018. Gamification for Self-Tracking: From World of Warcraft to the Design of Personal Informatics Systems. In *CHI '18. Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems. April 21–26, 2018, Montreal, QC, Canada*. ACM Inc., New York, NY, USA, 1–15. https://doi.org/10.1145/3173574.3173654

[26] Amon Rapp. 2023. Wearable technologies as extensions: a postphenomenological framework and its design implications. *Human-Computer Interaction* 38, 2 (2023), 79–117. https://doi.org/10.1080/07370024.2021.1927039

[27] Amon Rapp and Federica Cena. 2016. Personal informatics for everyday life: How users without prior self-tracking experience engage with personal data. *International Journal of Human-Computer Studies* 94 (2016), 1–17. https://doi.org/10.1016/j.ijhcs.2016.05.006

[28] Amon Rapp, Alessandro Marcengo, Luca Buriano, Giancarlo Ruffo, Mirko Lai, and Federica Cena. 2018. Designing a personal informatics system for users without experience in self-tracking: a case study. *Behaviour & Information Technology* 37, 4 (4 2018), 335–366. https://doi.org/10.1080/0144929X.2018.1436592

[29] Amon Rapp and Lia Tirabeni. 2020. Self-tracking while doing sport: Comfort, motivation, attention and lifestyle of athletes using personal informatics tools. *International Journal of Human-Computer Studies* 140 (8 2020), 13. https://doi.org/10.1016/j.ijhcs.2020.102434

[30] Amon Rapp and Maurizio Tirassa. 2017. Know Thyself: A Theory of the Self for Personal Informatics. *Human-Computer Interaction* 32, 5/6 (2017), 335–380. https://doi.org/10.1080/07370024.2017.1285704

[31] Xipei Ren, Bin Yu, Yuan Lu, and Aarnout Brombacher. 2018. Exploring Cooperative Fitness Tracking to Encourage Physical Activity among Office Workers. PACM on Human-Computer Interaction. *Proceedings of the ACM on Human-Computer Interaction* 2, CSCW. Article 146 (10 2018), 20. https://doi.org/10.1145/3274415

[32] Daniela K Rosner, Saba Kawas, Wenqi Li, Nicole Tilly, and Yi-Chen Sung. 2016. Out of Time, Out of Place: Reflections on Design Workshops as a Research Method. In *CSCW'16. Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing. February 27 - March 02, 2016, San Francisco, CA, USA*. ACM Inc., New York, NY, USA, 1131–1141. https://doi.org/10.1145/2818048.2820021

[33] Pedro Sanches, Kristina Höök, Corina Sas, and Anna Ståhl. 2019. Ambiguity as a resource to inform proto-practices: The case of skin conductance. *ACM Transactions on Computer-Human Interaction* 26, 4, Article 21 (7 2019), 32. https://doi.org/10.1145/3318143

[34] Dennis Schleicher, Peter Jones, and Oksana Kachur. 2010. Bodystorming as embodied designing. *Interactions* 17, 6 (11 2010), 47–51. https://doi.org/10.1145/1865245.1865256

[35] Phoebe Sengers and Bill Gaver. 2006. Staying Open to Interpretation: Engaging Multiple Meanings in Design and Evaluation. In *DIS '06. Proceedings of the 6th conference on Designing Interactive systems. June 26–28, 2006, University Park, Pennsylvania, USA*. ACM Inc., New York, NY, USA, 99–108.

[36] Tamar Sharon. 2017. Self-Tracking for Health and the Quantified Self: Re-Articulating Autonomy, Solidarity, and Authenticity in an Age of Personalized Healthcare. *Philosophy and Technology* 30, 1 (3 2017), 93–121. https://doi.org/10.1007/s13347-016-0215-5

[37] John Toner. 2018. Exploring the dark-side of fitness trackers: Normalization, objectification and the anaesthetisation of human experience. *Performance Enhancement & Health* 6, 2 (8 2018), 75–81. https://doi.org/10.1016/J.PEH.2018.06.001

[38] Elisabeth Van Dijk, Femke Beute, Joyce H.D.M. Westerink, and Wijnand A. IJsselsteijn. 2015. Unintended effects of self-tracking. In *CHI'15. Workshop on 'Beyond Personal Informatics: Designing for Experiences of Data'. April 18-23, 2015, Seoul, South-Korea*. Seoul, South Korea. https://www.researchgate.net/publication/274008273

[39] Dennis Wang, Marawin Chheang, Siyun Ji, Ryan Mohta, and Daniel A. Epstein. 2022. SnapPI: Understanding Everyday Use of Personal Informatics Data Stickers on Ephemeral Social Media. *Proceedings of the ACM on Human-Computer Interaction* 6, CSCW2, Article 539 (11 2022), 27. https://doi.org/10.1145/3555652