Data Every Day: Designing and Living with Personal Situated Visualizations

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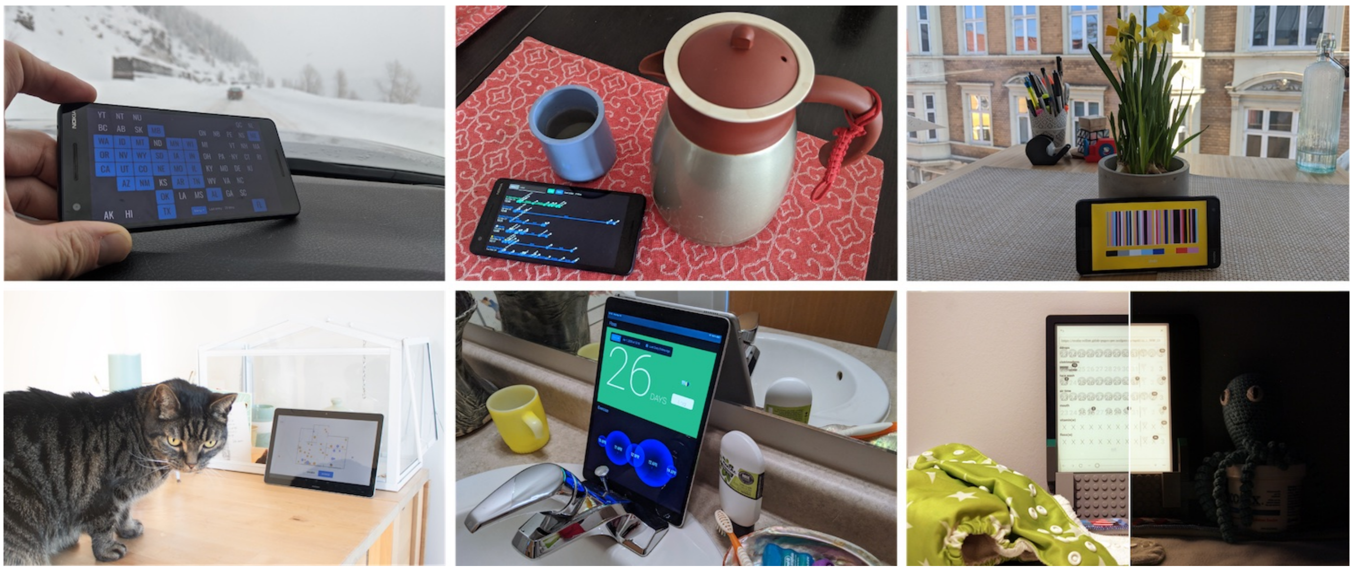

Figure 1: Six of our situated trackers shown in situ. Clockwise from upper left—*license plate tracker* ,(11) *tea brewing tracker* (24), *clothing color tracker* (14), *diaper dashboard* (21), *nightly tracker dashboard* (19), and *cat tracker* (30).

ABSTRACT

We explore the design and utility of situated manual self-tracking visualizations on dedicated displays that integrate data tracking into existing practices and physical environments. Situating self-tracking tools in relevant locations is a promising approach to enable reflection on and awareness of data without needing to rely on sensorized tracking or personal devices. In both a long-term autobiographical design process and a co-design study with six participants, we rapidly prototyped and deployed 30 situated self-tracking applications over a ten month period. Grounded in the experience of designing and living with these trackers, we contribute findings on logging and data entry, the use of situated displays, and the visual design and customization of trackers. Our results demonstrate the potential of customizable dedicated self-tracking visualizations that are situated in relevant physical spaces, and suggest future research opportunities and new potential applications for situated visualizations.

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CCS CONCEPTS

• **Human-centered computing → Information visualization**.

KEYWORDS

self-tracking, situated visualization, personal data

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1 INTRODUCTION

Throughout their history, visualization tools have predominantly aimed to communicate ideas and solve problems in professional settings. Even today, visualization and analytics systems target mainly traditional desktop and office use cases. Over the past decade, however, a growing array of personal informatics [58] and personal visualization [44] tools have started to enable data collection and exploration at more personal scales. Work on immersive analytics [88] and ubiquitous analytics [30] has also begun to push visualization techniques into settings beyond the desktop [80].

Yet personal visualization and analysis tools have tended to focus on specific application domains like fitness [35, 38, 97] and sleep tracking [13, 79] which rely on automated sensor-driven data collection. Even more general personal data collection and visualization tools like Kim et al.'s OmniTrack [55] still mainly take the form of desktop and mobile applications that are often isolated from the tasks and phenomena they analyze and visualize. However, new technologies like immersive mixed reality, digital textiles, and ubiquitous low-power displays offer the potential to integrate visualization and tracking tools more deeply and pervasively into the fabric of everyday life. By situating dedicated visualizations in existing environments [93], these systems can make it possible to record and visualize data in-situ and to embed trackers into people's existing practices to support a multitude of everyday tasks.

In this paper, we examine the potential of dedicated visualizations, situated in relevant physical spaces, which support lightweight manual input, and are tailored to support unique and personal tracking. Specifically, we describe the experience of designing, deploying, and living with 30 different situated visualizations over the course of ten months in total, via an autobiographical design process (five months), a co-design study with 6 participants (three months), and a period of extended use of a subset of the designs by a smaller set of the authors and participants (five months). Our trackers combine data input and visualizations on the same dedicated always-on displays and span a variety of application areas including tracking morning snooze habits, communal plant watering in an office, clothing colors, work breaks, fermentation projects, and exercise routines.

We make the following contributions:

- We present 30 different situated self-tracking visualizations that we designed, deployed, and lived with over the course of more than ten months as part of our autobiographical design and co-design studies. This set of tracker designs illustrates the diversity of potential use cases for personalized situated trackers and highlights design parameters and features that can inform the design of new customizable tracking tools.
- Based on our experiences, we contribute reflections and implications for the design of situated trackers including takeaways related to logging and data entry, visual design, customization of situated trackers, and adaptation to specific environments, spaces, and activities.
- We derive a set of reusable template designs that can serve a variety of tracking tasks including image-based trackers, streak trackers, and timeline trackers.

Our findings also confirm observations on tracker design made in prior studies, grounding these findings in a wide range of designs and a rich longitudinal slice of lived experience drawn from over ten months of designing and using situated self-tracking data visualizations. Our experiences and observations highlight the potential for customizable self-tracking visualizations that easily integrate into people's everyday lives and allow people to track phenomena specific to their personal interests through an ecosystem of tracking tools.

2 RELATED WORK

We first review related research on personal informatics, casual visualization, and situated visualization and tracking.

2.1 Personal Informatics

Personal informatics is a research area concerned with developing systems that help people collect personal information to improve self-knowledge. Research in personal informatics has been explored in a large number of domains including health conditions [2, 65, 96], women's health [32, 40, 95], food [16, 60], mental health and well-being [6, 52, 67], sleep [13, 79], activity tracking [38, 59, 97], and productivity [54].

The area of personal informatics has seen a number of developments that refined and extended its conceptual foundations. Li et al. [58] coined the term personal informatics and defined a stage-based model for personal informatics systems consisting of five stages: preparation, collection, integration, reflection, and action. What is particularly relevant for our work is the recommendation to allow rapid iteration between the stages and the suggestion to focus on multiple facets. Rooksby et al. [82] criticized Li et al.'s stage-based model for being technology-centric, and only allowing reflection and action to happen once technology is in place. Instead, they suggest the term "lived informatics" to characterize personal informatics that takes place over a range of lived activities. Rooksby et al. emphasize a number of points that are relevant to our work: considering social tracking over personal tracking, the need to take interweaved trackers in a broader information ecology into account, and that data is meaningful in the context in which it is produced and may lose that meaning if removed from that context. Epstein et al. [33] introduce a stage-based lived informatics model, and argue that behaviour change is not the only goal of tracking; tracking can also happen for pure curiosity or record-keeping purposes.

A number of studies have found that manual tracking created more awareness and engagement and gives people full control over their data [14, 15, 59]. However, manual tracking can be tedious and may cause data-gathering fatigue [61]. Choe et al. [14] argue for semi-automated approaches that combine the benefits of manual and automated tracking. Examples of such tools include OmniTrack [55], which allows people to semi-automatically gather personal data, Reporter [46], a mobile app that provides timed questionnaires for data gathering, and Dreamcatcher [74] a situated semi-automated tracking project for families to track sleep data. DataSelfie [53] is another questionnaire-based tool for data collection that supports mapping personal data to custom visualizations and Trackly [3] allows customizable self-tracking of multiple sclerosis self-management through a pictorial-based approach. In our design process, we decided to focus on a manual tracking approach which allowed us to simplify the prototyping, installation and customization process, and easily support privacy with local data storage. It also enabled us and our participants to track personal and subjective data that cannot easily be captured by sensors.

2.2 Personal and Casual Visualization

There have been several research initiatives within the information visualization community that examine how to facilitate visualizing data for non-experts. Pousman et al. [78] proposed the notion of "casual information visualization" to characterize visualizations intended for non-expert users and non-work applications. Casual information visualization typically includes personally-relevant rather than work-motivated data and supports insights that are not necessarily analytical. A related research topic is personal visualization and personal visual analytics. Huang et al. [44] provide a taxonomy of design dimensions for personal visualization and analytics systems, and characterize a variety of existing personal tools based on their context, data, and insights.

At the same time, design paradigms like Huron et al.'s "constructive visualization" [45] have emphasized providing simple physical or digital building blocks that empower novices to create novel data visualizations, often with an emphasis on personal data. Thudt et al.'s exploration of personal physicalizations in domestic settings [89], in particular, highlights how self-tracking using simple data physicalizations can support self-reflection and insight. Other relevant examples include Cairn [34], a physicalization for situated data collection in FabLabs, Physikit [42], a system that supports the creation of physical ambient visualizations of environmental data in the home, and Karyda et al.'s [49] work on data objects for reflective self-tracking. Our work expands on this area by offering a focused exploration of the design and use of situated visualizations for self-tracking through an autobiographical and co-design study.

2.3 Situated Visualization and Tracking

Recent visualization research has begun to envision applications beyond the desktop [47, 80], which can support visualization and visual analytics everywhere [30, 63]. This includes a growing emphasis on situated visualization [92, 93], which focuses on visualizing data in proximity to physical referents, such as people, places, or objects, that the data is related to. The key premise of situated visualization is to support interaction with and reflection on data in settings beyond those traditionally supported by visualization systems, leveraging the benefit of having the data available in-situ. Research on situated visualization includes several application areas such as public and urban visualization [17, 18, 56, 87], tools for urban planners [92], wearable visualization [64], and supporting reflection in domestic settings [85]. Researchers have also explored different ideation, sketching and prototyping approaches for designing situated visualizations [9, 19, 29, 90].

Research on ambient and pervasive displays [22, 70] has focused on displaying content on contextually situated displays like InfoCanvas [86] or the Hermes office displays [12]. A variety of emerging interaction technologies and technology platforms also have the potential to facilitate situated visualization, including solutions that rely on mixed or virtual reality [63, 92]. Another promising approach is the use of small wireless information displays that can be placed in a wide variety of locations. For example, work on situated glyphs has examined small displays that provide contextual task-related visualizations to workers in a healthcare facility [50, 90]. Small e-paper displays have also been used as a platform for public polling displays to gather and show data relevant to urban communities [17, 19, 20]. Several projects have explored the use of small displays to provide in-situ information, without specifically focusing on data visualization. For instance, Grosse-Puppendahl et al. [36] created situated energy-neutral e-paper displays in a sticky note form factor. Meanwhile, CloudDrops [71] integrate contextual information on stamp-sized displays into personal and work environments and PostBits [72] use small displays to show blocks of information in a home setting. Building on this prior research, our work focuses on small situated displays that integrate into the environment and surface data visualizations that focus on self-tracking. In particular, we contribute a deeper exploration of situated tracking tools that expands upon systems like Heed [73], which investigated in-situ self-reporting but not the use of situated visualization and I/O Bits [91], which examined short-term situated self-tracking via e-paper displays.

In recent years, it has also become easier to embed small displays in textiles as battery-free e-paper displays [28] or LED displays [64]. A notable example is Project Jacquard [77], which explores the integration of electronics in textiles to support interactivity and low-resolution displays through thermochromic pigments [27]. Going forward, these technologies will likely make it much easier to enable situated visualization and self-tracking in everyday clothing, furniture, vehicles, and domestic spaces. The mobile device displays we use allow us to explore a future in which such small displays are further miniaturized, inexpensive, energy-efficient, and easy to deploy at large scales. They also allow us to gain insights into the opportunities and potential challenges of living with ubiquitous data visualizations.

3 DESIGN PROCESS AND APPROACH

We conceived this project as a way of exploring the potential for deeply personalized and situated visualization tools to support a diverse range of everyday tasks and reflections. Specifically, we hoped to envision new and wide-ranging applications for personal informatics enabled by emerging technologies like ubiquitous displays that make it possible to situate information throughout everyday domestic and work environments.

Before embarking on our autobiographical design process, the three authors (Nathalie, Jo, and Wesley) decided on a shared technical infrastructure and target platform. Our overall objective was to support rapid design and creation and allow us to explore a wide variety of trackers that were dedicated, situated, and easy to customize. We motivated our process via four design goals:

- DG1 *Trackers should be dedicated and persistent.* We chose to focus on designs that display a single persistent visualization and support glanceable and peripheral use. Using trackers with dedicated always-on displays allowed us to streamline the data entry process compared to logging in an application on a personal mobile device. Interactions that might require additional time in traditional mobile apps like Reporter [46] (including time to unlock the device and load the app) can often be reduced to just one or two touches on dedicated trackers.
- DG2 *Trackers should be relevantly situated.* To examine the impact of situating designs close to relevant physical referents, we

chose to focus on designs that could be placed close to a location, object, task, activity, or phenomenon.

DG3 *Trackers should support lightweight manual input.* ather than relying on sensors or automated tracking, we designed all of our trackers to support simple manual inputs. This decision made it possible to capture a diverse range of lived experiences that might otherwise be difficult to instrument and also reduced the overhead and complexity often associated with (semi-)automated tracking.

DG4 *Trackers should be easy to adapt, iterate, and personalize.* To be able to experiment with a broad range of potential applications, we focused on simple, reusable, and customizable tracker designs. Our objective was to be able to prototype new trackers, repurpose existing ones, or iterate on previous designs in only a few hours.

Based on these design goals, we chose to prototype our trackers and visualizations with web technologies and display them using off-the-shelf mobile phones, tablets, and e-readers [1]. This allowed us to rapidly prototype visualizations using a diverse set of development tools and deploy them wirelessly to devices in multiple locations. We implemented many of our visualizations (14) using Vega-Lite [84] and Bootstrap, and used D3.js [8] (2) or plain HTML, CSS and JavaScript (14) for the rest. All trackers share a common codebase and utilize the same underlying data structure to record the author, version, cycle, name, and timestamp for each tracking event. We extended this basic data structure with additional attributes to suit the unique data captured by each of our individual trackers. We served these web apps directly to devices from a remote GitLab repository but stored all data locally on the devices using the browser's local storage. We displayed trackers using the device's web browser in full screen mode and the display set to be always on. We managed battery life either by constantly connecting the device to a power supply or by charging them at night.

3.1 Design Process

We created our tracking applications over the course of ten months in an autobiographical design process and a co-design study with six participants (see Figure 2). For the first two and a half months, we employed a structured and iterative autobiographical design process. For approximately the next three months, we continued our autobiographical design while integrating six additional people into our design process using a co-design approach. For the last five months, we and some of our participants continued to use and more gradually evolve a subset of our designs. The last phase consisted of long-term use of a set of the trackers.

3.1.1 Autobiographical Design: Creating Our Own Trackers. In the first part, the three authors designed and prototyped trackers for themselves following an autobiographical design process [23, 69] and used each of the trackers themselves and together with colleagues and family members. Autobiographical design [69, 94] is a first-person research method in HCI that is characterized by extensive self-usage of systems built by researchers themselves. Autobiographical research and autoethnographic methods are particularly suited to gain deep insights into long-term usage of technology in personal and intimate spaces [23], including systems for self-tracking [26, 41, 94] and domestic use cases [24, 25, 39]. Autobiographical design blurs the lines between research and private life [23] and generally produces generative results rather than broadly generalizable ones. To ensure academic rigour, we followed the five tenets of autobiographical design [23, 68]. In particular, our design process originated out of (1) "genuine needs" – one of the authors had a strong interest in and extensive prior experience with self-tracking and building tools for self-tracking, the other two authors were interested in exploring the experience of living with situated self-tracking visualizations. The systems we developed were (2) "real systems"– they were functional and interactive so that they could be integrated into our real-life experiences. We employed (3) "fast tinkering" – we designed and built the prototypes with continuous refinement and iterative design in mind. We followed a structured approach to ensure (4) "record keeping and data collection" – documenting the design process for each tracker, along with weekly logs, pictures, iterations, and reflections in a shared cloud storage folder. Finally, while we abandoned some of the trackers to explore new designs, we followed this design process for ten months to ensure (5) "long-term usage" that would lead to a holistic understanding of the impact of the trackers and the design variations. Our approach was also inspired by recent initiatives in the information visualization community which emphasize the value of structured reflective practices in visualization design studies [66] and researcher participation in target domains through "design by immersion" [37].

We rapidly prototyped trackers in weekly design cycles and used a diary study [11] approach to reflect on our designs and the process of creating and using them. Two authors (Nathalie and Wesley) created and used tracking applications over the course of ten months and the third (Jo) joined for the last eight months. During the first five months, we created our trackers in design cycles, each with structured planning, prototyping, use, and reflection phases. Each design cycle lasted approximately one week, although their exact length varied depending on availability and time constraints of the authors. In some cases, we chose to stop using the trackers at the end of the design cycle and pursue new designs. However, we also continued to use and reflect on many of the trackers long after the end of their initial cycles.

Authors. All three authors are human-computer interaction and visualization researchers with technical expertise.

Nathalie Bressa (A1) is a Postdoc working in the area of HCI and information visualization (and a PhD student at the time of the study). Nathalie had some prior experience with tracking exercise related data with commercial tools and was interested in exploring situated and manual self-tracking to be able to track data with customized tools that offer more personalized tracking opportunities than the applications previously used.

Jo Vermeulen (A2) is a research scientist in an industry HCI and visualization research team (and at the time of starting this project, an assistant professor of computer science). Jo has previously explored tracking personal data such as fitness and health data or time tracking, both using commercial tools and devices

[1] https://github.com/nathaliebressa/situated-personal-visualizations

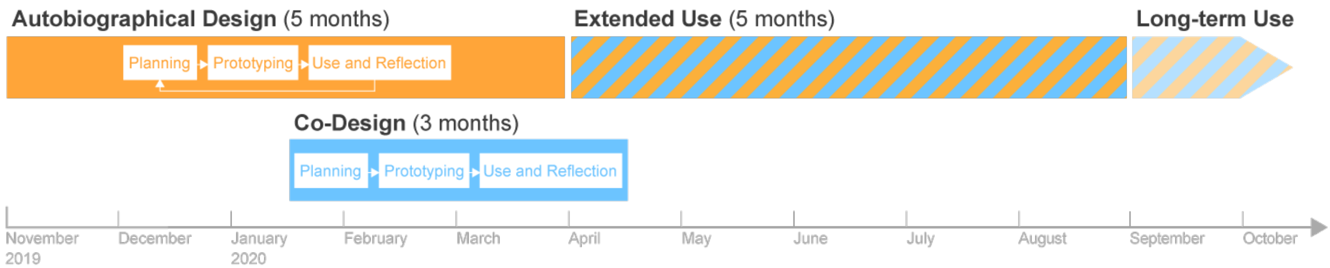


Figure 2: Timeline of our design process. We started with autobiographical design (duration: 5 months), and after two and a half months, we began integrating additional people into our design process with a co-design phase (duration: 3 months). Afterwards, there was a period of extended use of a select set of visualizations, both by ourselves and by our participants (duration: 5 months), followed by long-term use of a selection of trackers.

(Fitbit, Apple Watch, Toggl Track) as well as with custom spreadsheets and charts. For this project, Jo was particularly interested in gaining insights on how to best design and situate these trackers and visualizations.

Wesley Willett (A3) is an associate professor of computer science with a longstanding personal and research interest in personal informatics systems and practices. Over the last 15 years, Wesley has tracked exercise, sleep, emotional state, and a variety of other kinds of personal information using a combination of commercial and DIY tracking tools — including both digital and physical situated trackers.

Planning. We started each new planning phase with a group meeting where we discussed our experiences from the past cycle and our plans for the next one. We discussed initial concepts for any new trackers, typically focusing on how our next round of trackers could explore new kinds of data or address issues observed in the previous rounds. Our objective was for each tracker to target a unique and active area of personal interest for the author who created it and to reflect their desire to understand specific phenomena related to their everyday spaces and practices.

Prototyping. After planning our next designs and updates, we implemented the trackers using our common code base and shared repository. Each tracker took between 30 minutes to one day of work to complete, with most requiring only a few hours. Where possible, we reused code from previous iterations to speed up prototyping.

Use and Reflection. Once each prototype was operational, we started using the new tracker and continued using updated trackers from the previous cycle. While using the trackers, we reflected on our experiences regarding tracking, visual design of trackers, and the prototyping process and recorded these reflections with shared diary documents in a cloud storage service. For each tracker, we started with a high-level description of the tracker, then authored regular diary entries to capture our ongoing observations. We did not set strict update intervals between diary entries and relied on updating diaries when we made notable observations. We also took screenshots and photos of the trackers that we incorporated into our reflections. At the end of each cycle we redesigned, adapted, or retired unsuccessful designs and incorporated our observations into the next iteration.

3.1.2 *Co-Design: Creating Trackers with Participants.*

After two and a half months of self-experimentation, we integrated additional people into our design process to examine a wider variety of designs and experiences. We used a co-design approach [7, 83] in which end-users actively participate in the design process in a collaborative process to develop solutions that meet their needs. We retained the same three-phase design cycle and data collection practices as in our autobiographical design. In each phase of the design cycle, we collaborated with the participants to create trackers that allowed them to record and reflect on phenomena and practices that interested them. We also added an additional brainstorming session in the beginning and a debriefing interview at the end of the process. Our study was approved by the University of Calgary's Conjoint Faculties Research Ethics Board.

Participants. We recruited 6 participants (P1–P6; 5 female; 1 male, aged 26-35) who designed either one or two situated trackers each. The participants were from our extended work and social network and all had prior research experience in human-computer interaction or information visualization. We intended for the co-design participants to complement our autobiographical design process, rather than for these participants to be representative for the general population. Table 1 outlines participants' background, motivations, and prior tracking experience.

Planning. We started the planning phase with a brainstorming and sketching session where we discussed the participant's initial ideas and sketched a possible design for the tracker. Participants chose what they wanted to track themselves using the trackers from our autobiographical design cycles as sources of inspiration.

Prototyping. Based on participants' designs, we implemented trackers using our framework. We had an additional meeting with each participant during the development to show them the prototype and adapt the design if needed.

Use and Reflection. Once participants took ownership of their tracker, they deployed it in a location of their choice. As in our autobiographical design, we asked participants to write reflections in diary entries and take photos of the trackers in situ. Instead of the the 1-week cycles we used in the autobiographical study, co-design participants could continue to use the trackers for longer periods of time. At the end of the process, we organized a final meeting with each participant in which we conducted a short semi-structured debriefing interview (see supplemental material). We also provided

	Age	Occupation	Trackers	Motivation and Experience
P1	26	MSc Student & Software Developer	*thesis progress tracker* (22), *productivity tracker* (27)	P1 wanted to track their thesis progress and ultimately designed two trackers. The first focused on chapter-by-chapter progress and the second tracked productive work hours. P1 had prior experience with both self-built and commercial manual and automated tracking tools.
P2	35	Professor	*fermentation tracker* (23), *tea brewing tracker* (24)	P2 wanted to track fermentation projects and their tea brewing process. P2 had prior experience with tracking health, food, and productivity-related data using automated and manual commercial tracking tools.
P3	29	MSc Student	*door shock tracker v2* (25), *morning routine tracker* (28)	P3 was interested in refining the *door shock tracker* (3) that Nathalie had designed for their shared office space. P3 also wanted to track and gain insight into time spent on their morning routine. P3 had prior experience tracking health, sleep, and food-related data using both paper-based and commercial tracking tools.
P4	26	MSc Student	*plant tracker* (26)	P4 was interested in developing a plant watering tracker for their shared office space after discussions of how to keep track of plant watering responsibilities. P4 had some prior experience with tracking exercise.
P5	27	PhD Student	*tea preference tracker* (29)	P5 wanted to track their tea consumption to gain a better overview of which teas they like and which they enjoy less. P5 had no prior experience with self-tracking except for briefly trying a commercial focus tracking tool.
P6	30	PhD Student	*cat tracker* (30)	P6 wanted to track their cat's habits and where it frequently stays in the apartment, both when asleep and awake. P6 had no prior experience with self-tracking.

Table 1: Details about age, occupation, motivation, and experience of the co-design participants.

participants with their data and the code for the trackers so that they would be able to continue to use the tracker if they liked to.

4 SITUATED TRACKER DESIGNS

During our design process, we created a total of 30 designs (see Figure 3, Table 2, and supplemental material). These included 21 trackers from the autobiographical design stage (numbered with white bubbles (1) ... (19)) and 9 from the co-design stage (numbered with grey bubbles (22) ... (30)). Over the course of ten months, we recorded a total of 2,941 data points across all designs, with the total number per tracker ranging from 6 to 442 (additional data points from long-term use are marked in the table). The most-used tracker recorded data points on 209 different days, while the least-used included only a single day. For consistency, we report only days in which the tracker recorded new data. However, this under-counts some trackers like the *productivity tracker* (27), which P1 used for over three months and which served as a regular source of reflection, despite relatively few interactions.

Most (21) of our trackers were for personal use while 9 of the trackers were used by multiple people. The number of people using the group trackers varied from around 10–15 people in an office for the *door shock tracker* (3), *door shock tracker v2* (25), and *plant tracker* (26), four people for the (11) and two people for the *cookie tracker* (5), *fluid intake tracker* (17), *bathroom dashboard* (20), *diaper dashboard* (21), and *tea brewing tracker* (24).

The data we and the participants tracked spanned a variety of different application areas. Six of the trackers dealt with tracking food intake and cooking related data which included the *interval tracker* (4), *cookie tracker* (5), *fluid intake tracker* (17), *fermentation tracker* (23), *tea brewing tracker* (24), and *tea preference tracker* (29). Four trackers were concerned with tracking work related habits and productivity, including the *work break tracker* (2), *interruption tracker* (8), *thesis progress tracker* (22), and *productivity tracker* (27). Three of the trackers were used to track exercise routines including the *streak tracker* (9), *timeline bubble tracker* (12), and *cycling streak tracker* (15). Two focused on family health and hygiene (*bathroom dashboard* (20), *diaper dashboard* (21)). Other application areas included tracking static shocks in an office (*door shock tracker* (3) and *door shock tracker v2* (25)), logging routines and tasks in the morning (*morning task tracker* (13), *morning routine tracker* (28)), and monitoring snooze patterns (*snooze tracker* (1), *snooze tracker v2* (6)).

Because we focused on lightweight manual input (**DG3**), most of the trackers required a very small number of touches to enter data. Many (such as the *door shock tracker* (3) or the *clothing color tracker* (14)) include just a single button for logging events. Others, including the *conversation tracker* (7), *expectation tracker* (10), and *fluid intake tracker* (17), required an additional selection before pressing the log button. The (11), *plant tracker* (26), and *tea preference tracker* (29) meanwhile, supported touch input directly on the visualizations themselves. The *fermentation tracker* (23) and *tea brewing tracker* (24) offered more customizable data entry with the option to enter text as a label for each data entry with quick access to previously used labels by tapping existing data points.

4.1 Visualizations

Our tracker designs used a variety of visual representations.

Bar charts. We created six bar chart visualizations including the *snooze tracker* (1) and *cookie tracker* (5) and stacked bar charts like the *work break tracker* (2) and *door shock tracker* (3). These charts showed counts by weekday ((1), (3), (2)) or counts per person ((5), (17)) with stacked bars showing additional data attributes (like shocked/not shocked by a door for the *door shock tracker*).

Timeline and calendar visualizations. Six of our designs visualized logged events sequentially in timelines or calendar grids. These included the *timeline bubble tracker* (12) which showed a single data point per day, the *morning routine tracker* (28) which showed parallel timelines for a seven-day period, and the *fermentation tracker* (23) and *tea brewing tracker* (24) which displayed multiple aligned timelines. Meanwhile, the *bathroom dashboard* (20) and *diaper dashboard* (21) each used parallel timelines for tracking multiple different items including medications and diaper changes.

Image-based visualizations. We created three image-based visualizations, in which users could draw data points at 2D coordinates on top of an underlying diagram or photo. The *plant*

Figure 3: All 30 visualizations created and used in our design explorations. First row—*snooze tracker* (1), *work break tracker* (2), *door shock tracker* (3), *interval tracker* (4), *cookie tracker* (5). Second row—*snooze tracker v2* (6), *conversation tracker* (7), *interruption tracker* (8), *streak tracker* (9), *expectation tracker* (10). Third row—(11), *timeline bubble tracker* (12), *morning task tracker* (13), *clothing color tracker* (14). Fourth row—*cycling streak tracker* (15), *rain streak tracker* (16), *fluid intake tracker* (17), *customizable streak tracker* (18), *nightly tracker dashboard* (19). Fifth row— *bathroom dashboard* (20), *diaper dashboard* (21), *thesis progress tracker* (22), *fermentation tracker* (23), *tea brewing tracker* (24), *door shock tracker v2* (25). Sixth row—*plant tracker* (26), *productivity tracker* (27), *morning routine tracker* (28), *tea preference tracker* (29), *cat tracker* (30). For details on each tracker, see Table 2. Further information on the trackers including goals, design, and use is available in supplemental material.

tracker (26) and *cat tracker* (30) each use a floor plan to allow users to indicate points in space (indicating where in the office a plant had been watered or where in the apartment the participant's cat had been). The *tea preference tracker* (29) , meanwhile, incorporates a photograph of a shelf with teas, allowing P5 to directly add ratings on top of individual tins.

Dot plots. We built three trackers (the *conversation tracker* (7), *morning task tracker* (13), and *door shock tracker v2* (25)) which used dot plots to display smaller numbers of discrete data points. The *door shock tracker v2*, for instance, shows the last two days of data and represents each static shock with an orange circle and each non-shock with a blue circle.

Heatmaps. We created two trackers (the *expectation tracker* (10) and *snooze tracker v2* (6)) that display data with saturation-varying color scales. The *snooze tracker v2* uses a calendar heatmap to show snooze counts for each day, while the *expectation tracker* displays expectation and reality ratings of each day in two parallel rows.

Number-based designs. Four of our visualizations do not include charts or other abstract representations of data, and instead display only numbers. The *productivity tracker* (27) displays a count of the productive hours P1 spent working on their thesis. The four *streak trackers* ((9), (18), (15), (16)), meanwhile, use large numerals to show the number of consecutive days an event has been recorded.

		Name	Data	Location	Creator	Adapted from	Stationary	Mobile	Personal	Social	# Users	Data points	Unique days used
Autobiographical Design	(1)	snooze tracker	Alarm snoozes per morning	Bedroom	A1		■		■		1	99	12
	(2)	work break tracker	Breaks skipped/taken	Office desk	A3	(1)	■		■		1	12	4
	(3)	door shock tracker	Times shocked/not by door	Next to office door	A1	(1)	■			■	10–15	257	19
	(4)	interval tracker	Intervals between eating	Phone in pocket	A3			■	■		1	6	2
	(5)	cookie tracker	Cookies eaten	Next to cookie jar	A3	(4)	■			■	2	130	6
	(6)	snooze tracker v2	Alarm snoozes per morning	Bedroom	A1		■		■		1	105	25
	(7)	conversation tracker	Conversations by person & topic	Office desk & bag	A1		■	■	■		1	63	7
	(8)	interruption tracker	Interruptions during work	Office desk	A3	(4)	■		■		1	6	3
	(9)	streak tracker	Consecutive days of exercise	Countertop	A3		■		■		1	8	7
	(10)	expectation tracker	Daily expectations vs. reality	Phone in bag	A1	(6)		■	■		1	32	16
	(11)	license plate tracker	License plates spotted	Car console	A3		■			■	4	67	12
	(12)	timeline bubble tracker	Amount of exercise per day	Office desk	A3		■		■		1	35	20
	(13)	morning task tracker	Tasks done/skipped each morning	Bedroom	A1		■		■		1	13	5
	(14)	clothing color tracker	Color of clothes worn	Next to closet	A1		■		■		1	209 * (+153)	209 * (+153)
	(15)	cycling streak tracker	Consecutive days of cycling	Front door	A2	(9)	■		■		1	15	15
	(16)	rain streak tracker	Consecutive days of rain	Next to window	A2	(9)	■		■		1	21	21
	(17)	fluid intake tracker	Types of drinks per person	Above coffee maker	A2		■			■	2	442	31
	(18)	customizable streak tracker	Consecutive days of [flossing]	Personal tablet	A3	(9)	■		■		1	57	51
	(19)	nightly tracker dashboard	Dashboard with both (12) & (18)	Personal tablet	A3		■		■		1	–	–
	(20)	bathroom dashboard	Daily exercise, floss, vitamins, etc.	Bathroom counter	A3	(19)	■			■	2	299	73
	(21)	diaper dashboard	Diaper ointment, vitamins, etc.	Diaper station	A3	(20)	■			■	2	146 * (+832)	23 * (+162)
Co-Design	(22)	thesis progress tracker	Thesis progress by chapter	Desk & bag	P1		■	■	■		1	12	1
	(23)	fermentation tracker	Water kefir fermentation process	Next to kefir jar	P2		■		■		1	13	7
	(24)	tea brewing tracker	Tea brewing process	Next to tea pot	P2	(23)		■		■	2	95	10
	(25)	door shock tracker v2	Times shocked/not by door	Next to office door	P3		■			■	10–15	397	32
	(26)	plant tracker	Plants watered in an office	Next to sink	P4		■			■	10–15	129	35
	(27)	productivity tracker	Hours of productive work	On apartment wall	P1		■		■		1	28	8
	(28)	morning routine tracker	Time between morning tasks	On bed	P3	(23)	■		■		1	98	15
	(29)	tea preference tracker	Tea consumption preferences	Next to tea shelf	P5	(26)	■		■		1	44 * (+63)	22 * (+37)
	(30)	cat tracker	Cat movement in apartment	Desk in apartment	P6	(26)	■		■		1	103	11

Table 2: Details of all 30 trackers we created. Trackers marked with an asterisk (∗) saw long-term use after the end of the 10-month study (additional days and data points indicated in parentheses). Numbers of users for (3), (25), and (26) are estimates. More comprehensive descriptions of each tracker and tracking goals can be found in the supplemental material.

Emojis and icons. Finally, six of our trackers use emojis and icons in their visualizations and input elements. The *morning task tracker* (13) and *tea brewing tracker* (24), for instance, use emojis as individual data points to mark events on a timeline. Other trackers include emojis and icons in a descriptive way to label buttons and text on the tracker ((15), (16), (17), (29)). Emojis and icons were particularly useful for specifying data attributes and labeling interface elements without cluttering the visualization with text labels.

4.2 Tracker Placement and Physical Referents

We designed each tracker with the intention of placing it in a relevant location where it could support regular tracking and provide visual feedback for tasks and decisions associated with that location (Figure 4). However, as Willett et al. highlight [93], situating visualizations next to a relevant physical referent can be complicated, especially when multiple different referents exist for a visualization.

Situating near objects. Some of our trackers related directly to a specific physical object (*tea brewing tracker* (24)→teapot, *fermentation tracker* (23)→water kefir jar). In these cases, placing the trackers either on or immediately adjacent to the object ensured that they were visible and manipulable when performing related tasks. P2, who designed the *tea brewing tracker* (24), remarked that it could be useful to visually link trackers with their physical referents, for instance by marking both with the same color to make their connection clearer.

Situating in spaces. Others, like the *work break tracker* (2) and *license plate tracker* (11) were difficult to situate immediately next to a relevant physical object. However, they could be easily left in accessible locations (like an office wall or car dashboard, respectively) in which relevant events or observations were likely to take place.

Situating to support tasks. In other cases, we chose to situate trackers in locations that were far from their specific referents and instead placed them in locations relevant to the broader task or activity. For example, P4's *plant tracker* (26) took the form of a single display located near an office sink, rather than displays located at each of the individual plants around the office. Similarly, Wesley chose to display the *nightly tracker dashboard* (19) at a single central location in the house that supported easy nightly reflection but was not physically collocated with the activities (like exercise and flossing) that it tracked. P1, who created the *productivity tracker* (27), placed it centrally in a highly visible spot in their apartment where it would be visible during the day as they worked from home. The *rain streak tracker* (16) was situated near a large window in the kitchen to facilitate tracking when noticing that it was raining. In other

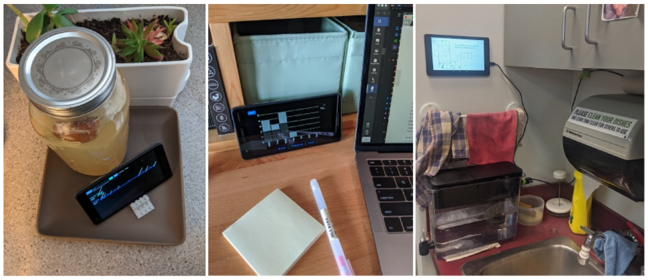


Figure 4: Left—*fermentation tracker* (23) situated next to water kefir jar. Middle—*work break tracker* (2) situated in an office space. Right—*plant tracker* (26) situated near an office sink.

cases, the connection between the tracker and referent was more abstract. For instance, Nathalie intended to use the *conversation tracker* (7) to track daily conversations in a variety of settings. This entailed either physically carrying the device throughout the day or keeping it in locations that could be frequently accessed.

5 FINDINGS

We distilled our findings based on the material we collected during our autobiographical and co-design studies. These included diary entries from authors and participants, researchers' notes, photographs and screenshots of trackers, and notes from interviews with our participants. We used an ongoing and iterative reflective process in which all authors discussed and compared their experiences and observations with the trackers in weekly design cycle meetings during the autobiographical design phase. All authors iteratively identified and refined themes after the first phase of the design process by taking notes in their personal documents which we then later aggregated in a shared document. Each author first reflected on experiences individually in the diary entries, then read the other authors' diary entries to extract additional themes. We then synthesized and refined our observations through group discussions involving all authors. We identified themes based on the individual themes suggested by each author in their personal journals, which we then compared and discussed to find common themes and observations. Generating the themes was an iterative, introspective process where we aimed to create a shared understanding of our experiences of living with our trackers while also critically examining and reflecting on our roles as researchers in the process.

For the co-design phase, participants were directed to keep diary entries documenting their experiences. Based on the diary entries from individual co-design participants, Nathalie prepared targeted questions and a set of general questions for the semi-structured debriefing interviews for all participants (see supplemental material). Nathalie interviewed all participants and took notes. All authors analyzed the diary entries and notes from participants' interviews by reading participants' diary entries individually, discussing them, and then conceptualizing themes. Subsequently, all authors matched themes from the autobiographical design process with the themes from the co-design process by combining and grouping similar themes to distill the final set. Based on these experiences, we highlight observations, challenges, and opportunities related to prototyping situated visualizations—with particular emphasis on data entry, the impact of situated and persistent displays, visual design, and customization.

5.1 Logging and Data Entry

Projects like SleepTight [13], DataSelfie [53], and Reporter [46] have previously shown the merits of manually tracking data. Our observations further confirm the value of manual data entry, which made it possible to create a rich and flexible range of tracking experiences. In addition, we found that features like back-filling, error-correction, and visual feedback emerged as important additions in nearly all of our applications, and are likely to be essential for streamlining data entry in future situated trackers.

5.1.1 *Manual Data Entry.*

***Takeaway**: Lightweight manual input facilitates new and emergent situated self-tracking practices.*

Our designs skewed towards personal informatics domains in which the phenomena of interest are either largely subjective or are directly connected to real-world actions or observations. By relying on simple manual inputs and situated displays, our prototypes allowed us to log and examine a variety of phenomena that would have been difficult to track in an automated or semi-automated way. This decision to eschew automated tracking in favor of manual approaches also highlighted several other advantages of relying on low-effort human inputs. From a design perspective, most of our trackers took just a few hours to design, implement, and deploy—in stark contrast to some of our own prior tracking projects which relied on sensors and automation. This rapid prototyping process enabled us to explore many possible designs. More generally, our experience suggests that lightweight manual trackers can also make it easier for end-users to tailor and repurpose trackers for new domains, since there is no need to adjust sensors, calibrate thresholds, or change automation routines.

However, automated or semi-automated approaches may still hold promise for future situated self-tracking tools [14]. Some of our trackers like the *snooze tracker* (1) and *streak tracker* (9) could readily be automated by instrumenting existing devices like an alarm clock or exercise app or by connecting them to existing personal data streams. Situated displays could facilitate development of (semi-)automated tracking systems, making it simpler to see and correct tracking results in real-time. Similarly, situated displays could be advantageous for many kinds of existing personal informatics data, like diet logs or screen time trackers, allowing them to surface data in more relevant locations.

5.1.2 *Back-Filling Missed Entries.*

***Takeaway**: Back-filling functionality for logging missed data is essential for almost all manual trackers.*

We generally recorded events when they happened and relied on timestamps from the data entries to drive the visualizations. This helped streamline logging, but posed problems for visualizations where data entry could easily be skipped or forgotten. For instance, when using the *morning task tracker* (13), Nathalie forgot to enter

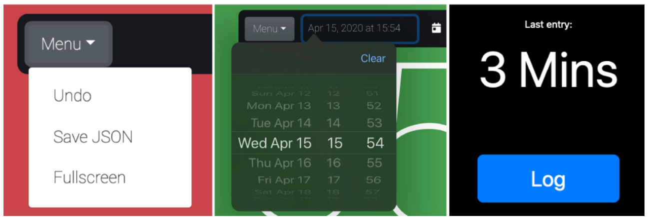


Figure 5: Left—Menu with undo functionality we integrated in all of our trackers. Middle—Rewinding time to back-fill data in the *customizable streak tracker* (18). Right—Elapsed time counter used in the *interval tracker* (4) and many other subsequent designs.

data for two days which led to missing data points in the visualization: "For the first couple of days, logging worked out quite well. But I quickly ran into issues when I forgot to input data which led to holes in the visualization." [Nathalie]. These kinds of omissions were especially problematic for visualizations like the *streak tracker* (9) where missing a single data entry could break the entire visualization: "Once I had failed to enter runs, the visualization got out out of sync and basically became useless. Even though I had a multi-day streak, the visualization couldn't show it." [Wesley]. To address this, the *customizable streak tracker* (18) introduced a back-filling interface (Figure 5-middle) that allowed "rewinding" of the visualization to enter data points for times in the past. We later incorporated this functionality into several other trackers ((15), (16), (17)). Similarly, the late-stage *diaper dashboard* (21) incorporated streaks into a timeline that showed several weeks of data and made back-filling daily values easy.

5.1.3 Correcting Errors.

***Takeaway**: Basic error correction functionality is critical for most manual trackers.*

All of the trackers included a simple undo functionality (Figure 5-left) to correct immediate mistakes. We found that this was sufficient most of the time because the relative simplicity of most of the trackers made errors easy to detect at entry time. However, we observed that for the some of the more complex trackers, including the image-based visualizations ((26), (29), (30)) and the *license plate tracker* (11), accidental presses often went unnoticed and became difficult to correct later: "Accidental presses were a bit of a problem. These were easy to fix using undo…but only if you noticed them." [Wesley]. More fine-grained error correction for editing individual data points afterwards could be a valuable addition to trackers that require data entry of multiple attributes or manual text entry like the *fermentation tracker* (23). In fact, when designing the trackers, the authors often used implementations and strategies specific to trackers to make corrections like downloading and reloading data or creating temporary custom UI elements to delete specific data objects. Wesley's timeline-based visualizations ((12), (20), (21)) similarly circumvented this problem by allowing users to touch and update the values of individual days at any point.

5.1.4 Visual Feedback.

***Takeaway**: Visually-salient feedback at logging time makes it easier to detect errors and can encourage future tracking.*

We found that providing clear visual feedback whenever a data point was added also helped viewers detect errors, especially for more visually complex designs. For instance, in Nathalie's *door shock tracker* (3), seeing small changes in the bar charts became increasingly challenging as people added more and more data. This often made it difficult to determine whether an input had registered and discouraged subsequent logging. The *door shock tracker v2* (25) addressed this issue by showing a smaller slice of data (only two days) and by replacing the stacked bar charts with individual dots, making new entries more visually apparent. Likewise, early versions of the *fluid intake tracker* (17) showed seven days worth of data, but for subsequent versions Jo chose to visualize only a single day—reducing visual clutter and providing clearer visual feedback. Starting with the *interval tracker* (4), we also included a small elapsed-time counter (Figure 5-right) in many of our designs to highlight the amount of time that had passed since the last entry. These counters often served as reminders to record data or take action based on it, and also offered visual feedback that helped verify when presses had been recorded and detect accidental touches: "Showing the last entry was a really useful addition [to *cookie tracker* (5)], both for tracking our use and for debugging accidental presses. It also encouraged competition and observation." [Wesley].

5.2 Situated and Persistent Displays

Dedicated displays that were always on and situated in relevant locations facilitated regular tracking habits and often served as a reminder to reflect or take action based on the data.

5.2.1 Trackers as Reminders.

***Takeaway**: Situated trackers serve as physical reminders to encourage tracking and facilitate routines.*

We found that situating the trackers at relevant locations helped encourage regular logging. For instance, placing the *cookie tracker* (5) next to a cookie jar and the *door shock tracker* (3) on the wall next to an office door spatially tied those trackers to the relevant activities and actively encouraged logging. Similarly, the *cycling streak tracker* (15) positioned near Jo's front door acted as a reminder and nudge to take the time to go for a bike ride. The experience of seeing the display turn green after returning from a bike ride and entering the data was seen as something to look forward to and could sometimes be a goal in itself.

P1's *productivity tracker* (27) also highlighted the value of situating their tracker in a central location in their apartment, where it served as a "physical reminder" to work on their thesis. This contrasted strongly with their earlier *thesis progress tracker* (22) which was not situated and remained forgotten in their bag on many occasions: "I pretty much just carried it around, I might have had it out on the desk sometimes as I was writing but at some point I gave up on that and just left it in my backpack." [P1]. This aligns with findings from Choe et al.'s SleepTight [13] where visually prominent widgets on mobile phones served as reminders to track data when using that device. Our results suggest that situated displays in physical environments can similarly serve as reminders that encourage participants to track data.

5.2.2 Trackers in Social Settings.

***Takeaway**: The visual design of social trackers requires sensitivity to data privacy and social context.*

We designed several of our visualizations, including the *cookie tracker* (5) and the *fluid intake tracker* (17), to directly encode information about the person tracking data to explicitly support use by two people. For example, the *fluid intake tracker* included a selection widget for indicating which member of the couple each new entry corresponded to. While Jo designed the tracker so that each person could log their own fluid intake, in practice the pair often added data on behalf of one another (such as when making coffee for two). We observed a similar behaviour with the *tea brewing tracker* (24), where the couple using that tracker added identifying information, marking whose teacup had been filled and when. In all of these cases, we noticed that tracking together as a pair provided social reinforcement. Encounters of social traces (traces of tracking by the other user) [75] served as encouragement to track data regularly.

On the other hand, we observed that ambiguous visual encodings were often desirable for individual trackers that were displayed in shared spaces. For example, P1 noted that they displayed the *productivity tracker* (27) in their public living space, but that even their domestic partner did not know what data the tracker was showing: "He has looked at it, I have never explained what anything means." [P1]. Wesley's initial *timeline bubble tracker* (12) and *streak tracker* (9) also spent most of their time in public living areas, but lacked any explicit label that might reveal what data they were showing. In these cases, people felt this lack of explicit labels or encodings struck a satisfying balance between visibility and privacy. This aligns with prior work on menstrual [32] and fitness [21] tracking tools, which have highlighted the importance of discrete design for sensitive data.

However, displays like the *door shock trackers* ((3),(25)), which targeted more public spaces and larger numbers of people, incorporated more explicit labeling. We added captions and instructions to each—prefixing both *door shock* trackers with a direct question ("Did this door shock you?"). Similarly, the *plant tracker* (26) featured a short imperative sentence ("Touch the floor plan to indicate where you watered a plant"). We also primed these displays by adding some initial data, making it easier for passersby to understand the visualizations and encouraging participation.

All three of these more public visualizations saw extensive use by other people in the communal spaces, accumulating hundreds of data points from people other than the authors and co-design participants. These displays highlight the potential for shared tracking to facilitate discussion within those broader groups. The initial *door shock tracker* (3) lead to numerous conversations between people around the issue of static shocks in the office and how to mitigate them: "People have been coming up with theories why certain people get shocked while others aren't." [Nathalie]. People in the office started multiple initiatives based around the tracker, including collecting suggestions for mitigating shocks on a nearby whiteboard, putting a wrapper around the door handle, and creating a sign with instructions on how to not get shocked. This ongoing discussion also led P3 to design and deploy the follow-up tracker ((25)).

Similarly, the *plant tracker* (26) acted as a communal reminder to water the plants in the office, helping P4 (who designed the tracker) and others in the office distribute the load of watering plants and build an awareness of watering practices: "I would generally pass by it once or twice a day [and think] 'oh yeah, this [plant watering] is a thing I can consider." [P4]. Roughly two weeks (18 days) after we deployed the tracker, the office space closed as a result of the COVID-19 pandemic. At this point, the plant tracker became an even more explicit asynchronous coordination mechanism for the few people who continued to access the space. As administrators allowed only a dwindling number of people to enter the office, the tracker allowed them to coordinate and ensure that plants were still watered, while also providing a strong sense of shared activity. After the office closed, the tracker remained in ongoing use for several months. Our observations highlight the sociality of tracking—especially co-present tracking among families, friends and co-workers—in the context of lived informatics [82] and the importance of designing for shared tracking experiences.

5.2.3 Where Situated Persistent Displays Pose Challenges.

***Takeaway**: Persistent displays likely create more opportunities for reflection and encourage more frequent logging, but may have less impact where existing mobile devices are already part of a routine.*

Based on our design goals, we developed each visualization with the expectation of displaying it on a dedicated device with an always-on screen. As highlighted by the examples above, we found that these always-visible visualizations often provided useful reminders to track and reflect. Yet over time we found that several specific visualizations ultimately proved just as useful on our personal phones or tablets as on the dedicated displays. This was especially evident in situations like the *nightly tracker dashboard* (19)—where personal mobile devices were already part of an existing routine (such as plugging in a tablet or phone before going to bed) which aligned well with the tracking behavior (in this case recording flossing and daily exercise). Similarly, Wesley continued to actively use the *license plate tracker* (11) on their personal phone even after repurposing its dedicated display for use with a later visualization. Here, the act of seeing an out-of-state plate (rather than looking at the visualization) was the primary trigger for using the tracker. Moreover, the author's personal device was almost always accessible both in the car as well as when walking, which created more opportunities to track. As a result, we found that this visualization actually saw more use on a personal device than on the dedicated one. Bressa et al. [9] similarly point out that placing visualizations close to physical referents might not always be the most desirable solution since some visualizations are more useful in highly visible and accessible places. When the tracker could not be directly situated with a task or activity, we also saw examples of "pre-logging" where both authors and participants reported entering data prior to completing a task. These pre-logged entries often served as a commitment device [10]. For example, P3 placed the *morning routine tracker* (28) next to their bed. However, multiple tasks that were part of their morning routine, like making breakfast, took place in other parts of the apartment. Here, P3 emphasized how logging created a sense of accountability and encouragement to complete the task: "You logged the data, you made the commitment."[P3].

In a few cases, like with the *conversation tracker* (7), tracking data was not connected to a routine or action that included a personal device and the tracking itself was difficult to situate anywhere but on the author themselves. Here, tracking data regularly proved to be more challenging, with Nathalie often forgetting to track conversations and having to back-fill data from memory: "I was on a trip over the weekend which made tracking a lot more difficult. I made some notes during the day and then input the data afterwards which was quite tedious." [Nathalie]. This particular application (and others like it) may lend themselves more readily to more subtle wearable tracking tools such as electronic textile displays. Finally, some tracking phenomena simply didn't call for persistent displays. During a long sequence of dry days, Jo decided to reconfigure the *rain streak tracker* (16) to have the display turn off automatically—rather than continually displaying the same information with no data to log.

5.2.4 Abandonment of Trackers.

***Takeaway**: Accommodating for abandonment in the design process is an important part of a tracker's life cycle.*

A combination of personal investment, how well tracking activities could be situated in spaces, how well our trackers integrated into existing routines, and whether tracking habits could be maintained influenced each tracker's abandonment and long-term use. Trackers that could not be well-situated into spaces and routines (including the *conversation tracker* (7) and *thesis progress tracker* (22)) saw limited use and were ultimately abandoned. In the case of the *thesis progress tracker* (22), P1 then developed an updated version ((27)) which better fulfilled their tracking goals. In particular, P1 noted that the chapter-by-chapter progress in the first version was too coarse-grained and led to pressure: "It was there, making me feel guilty." [P1]. Tracking productive work hours using the *productivity tracker* (27), meanwhile, fit more naturally into their writing routine, since "The bar was lower for hitting a button." [P1].

We also designed several trackers specifically for use during finite periods of time, rather than to support indefinite use. For example P1's *productivity tracker* (27) was intended for use during the duration of their thesis writing, while Wesley's *cookie tracker* (5) and *license plate tracker* (11) were built for a specific family holiday visit and road trip. In other cases, trackers were used and abandoned multiple times. P5 tracked data with the *tea preference tracker* (29) on-and-off over a multi-month period depending on their current tea habits: "Usage was mostly connected to whether or not I was drinking tea." [P5]. For other trackers, personal investment decreased over time as participants and authors gained insights into the tracked phenomena. For the snooze trackers((1), (6)), Nathalie felt that after around a month of tracking snooze habits, tracking more data would not lead to additional insights—which Epstein et al. [31] have also identified as a common reason for abandonment of tracking tools.

Ultimately, while some of our trackers remained in use more than a year after their creation, abandonment was an essential part of our design process and allowed us to more quickly converge on trackers that supported both short-term and long-term tracking goals. Considering abandonment as an explicit part of each tracker's life cycle also suggests opportunities for new personal informatics tools that specifically target short-term and evolving use.

Figure 6: Left— The dark-themed *snooze tracker v2* (6). Middle— The brightly-colored *productivity tracker* (27). Right—Customized titles on the *nightly tracker dashboard* (19).

5.3 Visual Design and Customization

The visual design of situated trackers impacts their saliency and usability across settings as well as their potential for adaptation and reuse.

5.3.1 Tailoring Visualizations to Everyday Settings.

***Takeaway**: The visual design of trackers can require considerable adaptation to integrate into the aesthetic, lighting, and environmental constraints of specific spaces.*

The evolution of our prototypes highlighted the importance of adapting visualizations to the environment in which they are situated. We created many of our designs for use in domestic settings like bedrooms and living areas where backlit displays proved overly bright and distracting, especially at night [51]. In response, we adjusted the majority of our designs to use dark color schemes that allowed them to integrate more naturally into these environments (Figure 6-left): "The dark theme integrated better into my bedroom environment than the light theme since it is less bright, especially during the night." [Nathalie].

However, we found that light color schemes worked well for those visualizations—like the *door shock trackers* ((3),(25)) and *plant tracker* (26)—that we created for highly illuminated office environments. In these cases, the bright displays helped attract attention to displays that were situated in uncommon locations near doors and in an office's communal kitchen. Meanwhile, the trackers we deployed on e-paper displays with adjustable backlights ((20),(21)) provided the best of both worlds, allowing us to tune the visibility of the display in both day and night. For the *diaper dashboard* (21), this even made it possible to use the display itself as a subtle night-light during nighttime diaper changes (Figure 1). These experiences suggest that low-power e-paper displays [28, 36] with adjustable illumination could be a good platform for future situated trackers, requiring less power than LCD or LED displays and adapting more easily to low-light conditions.

Across our designs, we also explored the use of color as a mechanism for drawing attention and differentiating visualizations. We created several visualizations—such as the *streak trackers* ((9),(15),(18)) and *productivity tracker* (27)—that used bright full-color backgrounds to draw attention and serve as reminders to track or perform the task that was being tracked. Wesley also found color especially useful as a mechanism for differentiating visualizations from one another and creating associations between the displays and their referents. A number of visualizations—such as the *work break tracker* (2) and *door shock tracker* (3)—shared very similar implementations.

Here, using different color schemes and labels allowed us to create visualizations that felt conceptually distinct and better suited to their unique tracking tasks.

In other cases, we used colors solely for aesthetic reasons. The orange color for the *productivity tracker* (27) was a "cheerful, fun, pop of color" in P1's apartment (Figure 6-middle). Similarly, Nathalie changed the background color of the *clothing color tracker* (14) from black to yellow when moving to a new apartment, so that the tracker would match the space's interior and the yellow flowers on their table: "I'm back home [...] and decided to change the color scheme of my tracker to fit the rest of the yellow theme in my apartment." [Nathalie]. For P5, designing the *tea preference tracker* (29) required careful consideration of both the design and colors choices, since the tracker would be visible in their apartment for a longer period of time. P5 noted that "If this was/is [sic] gonna be a long-term thing, I'd prefer it to function as a decoration as well."[P5]. This aligns with Rodgers and Bartram's observations of domestic energy feedback visualizations [81] and highlights the potential value of creating aesthetic coherence between visualizations and the surrounding environment.

5.3.2 Data Attributes and Aggregation.

***Takeaway**: Focusing on few data attributes and a suitable time frame to visualize simplifies tracker design and data entry.*

We found it useful to focus on the most relevant data attributes we wanted to track to avoid introducing a lot of variables. As a result, most of our trackers required just one or two button presses or simple touch input to enter data. Meanwhile, examples like the *conversation tracker* (7), which involved tracking multiple attributes at the same time led to longer and more tedious data entry. In response, we designed later examples like the *tea brewing tracker* (24) and *fermentation tracker* (23) (both of which allowed free-text entry for attributes) to make it possible to quickly reuse previously-entered text, thereby reducing overhead. Especially when designing trackers together with participants, finding the most relevant aspects of data to track was essential. For our own trackers, we found that focusing on one or two data attributes to track was enough to gain meaningful insights into what we were tracking in most cases.

Another consideration when designing a tracker was the amount of data to show in a visualization and how to aggregate that data. For many of our visualizations, we decided to display a week's worth of data, as in the *snooze tracker* (1), *work break tracker* (2), *morning task tracker* (13), *conversation tracker* (7), and *door shock tracker* (3). Other visualizations (like the like the *snooze tracker v2* (6) and *expectation tracker* (10)) displayed one month of data, while a few (including the *fluid intake tracker* (17) or *door shock tracker v2* (25)) focused only on the current day. For our visualizations, we found that showing only a fraction of the data was sufficient most of the time. Deciding on how much data to show was dependent on each tracker's application, specifically what the intent behind tracking was and which insights the person tracking the data wanted to obtain. For monitoring fluid intake ((17)), showing only the current day was sufficient to ensure that one was drinking enough, while tracking productivity (*productivity tracker* (27)) was intended to incentivize productive work and create a feeling of accomplishment when seeing all the tracked data.

5.3.3 Customization and Reuse.

***Takeaway**: Recurring similarities across designs suggest that a small number of tracker templates might be able to support a wide variety of tracking applications.*

Our set of trackers included a wide range of different designs, some of which were uniquely tailored to more specific tasks or domains while others were more general in their visual appearance. Our most generic designs could be repurposed without any interface modifications. Designs like the *timeline bubble tracker* (12) and *streak tracker* (9) emphasize time intervals and counts without domain-specific details and could be reused to track a wide variety of phenomena (as evidenced by the *cycling streak tracker* (15) and *rain streak tracker* (16)). The *customizable streak tracker* (18) and the three tracker dashboards ((19), (20), (21)) embrace this reusability more explicitly, allowing end-users to dynamically change the visualizations' labels and formatting so that the trackers can be repurposed without changing any code (Figure 6-right). Many of our other designs were only lightly tailored to specific applications and could be reused by re-labeling input and output elements. Visualization designs like the *snooze tracker* (1), and *cookie tracker* (5) can be adapted just by changing the axis labels or button text.

Ultimately, our experience suggests that a small vocabulary of templates can support a diverse set of tracking practices (see Table 3). The trackers which we reused that could most easily be templated included image-based, streak, and timeline trackers. The streak trackers ((9), (15), (16), (18)) track consecutive time intervals to show streaks and gulfs. They worked well for tracking recurring phenomena such as consecutive days of rain for the *rain streak tracker* (16) or to build and track daily habits such as exercise (*streak tracker* (9)) and cycling (*cycling streak tracker* (15)).

Our timeline-based trackers ((23), (24), (28)) show event sequences and the elapsed time in between them. The *fermentation tracker* (23) and *tea brewing tracker* (24) use exactly the same underlying code, but were easy to re-use for different kinds of tracking because of their support for custom annotations. These trackers worked well for comparing multiple event sequences and investigating patterns across timelines. For instance, the *morning task tracker* (13) helped P3 identify patterns in their morning routine and clarify misconceptions about their time use: "The visualization indicates that my previous perception that I might subconsciously procrastinate by sipping coffee [...] is actually wrong." [P3].

Our image-based trackers that use photos or maps to mark points in a space ((26), (29), (30)) were tailored to very specific tasks and locations. Yet these can also be easily adapted to other applications simply by replacing the underlying image. These were well-suited to track spatial data that is related to the layout of a room or other physical objects and to aggregate data in one central view. The *plant tracker* (26), for instance, provided an overview of all the plants in one location instead of at each individual plant to coordinate plant watering and the *cat tracker* (30) was located at a central point in P6's apartment which helped P6 get an overview of their cat's habits: "I get a better picture of it and I am more aware of it now I am tracking it." [P6].

Many of our other designs, like our bar chart visualizations, could also be easily templated. Adding lightweight end-user support for customizing time intervals, colors, button labels, and other simple

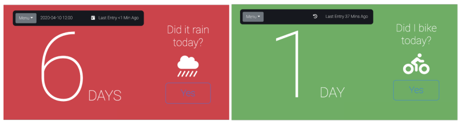
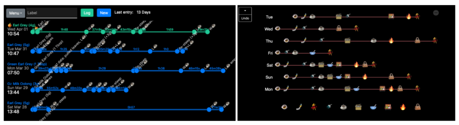
Type	Image	Applications	Tracking goals	Tracker examples
Image-based		Tracking data by adding points in a 2D coordinate space on top of an image.	Getting an overview of spatial data by using, for instance, floor plans or photos.	*plant tracker* 26 *tea preference tracker* 29 *cat tracker* 30
Streak		Tracking events in consecutive time intervals (days, hours, etc.) to show streaks and gulfs.	Tracking regular phenomena or habits such as exercise.	*streak tracker* 9 *cycling streak tracker* 15 *rain streak tracker* 16 *customizable streak tracker* 18
Timeline		Visualizing the sequence of data entries and the elapsed time between them.	Comparing event sequences and investigate patterns such as routines.	*fermentation tracker* 23 *tea brewing tracker* 24 *morning routine tracker* 28

Table 3: Tracker templates from across our set of tracker designs.

visual elements could greatly extend the versatility of a small set of designs, similar to how a small set of reconfigurable physical visualization cubes supported a variety of different use cases in Houben et al.'s Physikit [42].

6 DISCUSSION

Our explorations revealed strengths and weaknesses associated with prototyping personal situated visualizations on existing mobile devices, while also highlighting the value of simple, expressive, and adaptable designs and the potential of new hardware platforms and data sources. Because of the autobiographical nature of our personal experiments and the relatively young, technically-skilled, and motivated nature of all of our participants, we do not attempt to draw generalizable conclusions about tracking behavior or specific tracking use cases. However, our experiences living with and iteratively designing lightweight situated trackers highlight a variety of takeaways and opportunities that can inform the design of future systems. Given the diverse and motivated audiences for personal informatics and physical tracking documented in prior work [1, 4, 15], we also expect that simple individualized situated trackers have the potential for considerable uptake beyond the small population we considered in our study.

6.1 Prototyping Situated Visualizations with Smartphones

Using smartphones and tablets as our primary prototyping platform provided a number of advantages, allowing us to quickly design, develop, and deploy new visualizations using web technologies. However, the power requirements of these devices made them harder to use in some locations. Because devices needed to be plugged in at least once every 1-2 days, we tended towards use cases where the phones could remain connected to an electrical outlet or could be routinely recharged. These power issues, along with the relatively high cost of even entry-level smartphones also made it more challenging to prototype complex tracking applications that might span larger numbers of screens. However, concerns about the durability of these devices kept us from examining more extreme use cases in locations like kitchens and outdoor spaces where humidity and temperature might damage the hardware. However, our experiences in using e-readers for several later trackers suggest that inexpensive and self-powered e-paper displays [36] along with new low-power touch-sensing and wireless hardware can help address many of these issues in future production systems.

6.2 Simplicity, Adaptability, and Expressivity

When we were creating situated trackers for ourselves and with participants, simplicity was key to defining what data to track and how to design visualizations and data entry. When designing visualizations for smartphone and tablet-sized displays that were integrated into different personal and public spaces, we found it especially important for designs to be simple, lightweight, and visually clear to provide glanceable information and enable situated reflection. Designing for simplicity required a careful balance of capturing and visualizing enough data to gain useful insights, while not complicating data entry or visually cluttering the interface of the trackers.

To achieve this, we found it most useful to create trackers that captured only a few data attributes, allowing us to simplify data entry and minimize tracking overhead that could discourage regular tracking habits. Over the course of our designs, we also began to incorporate basic error correction functions like undoing entries, backfilling missed entries, and providing visual feedback on data entry tracking into almost all of our designs. The complexity of the visualization designs varied considerably and was highly dependent on the participant and their use case. However, we often found that showing a fraction of the data—either as counts or as simple charts—was sufficient to provide quick and glanceable access to the information. Bressa et al [9] have similarly observed that simple displays of information are useful for small situated displays and non-analytical tasks.

Simple designs also allowed us to easily adapt, repurpose, and reuse previously created trackers (see 5.3.3) without investing time in prototyping new designs from scratch. The simplicity and reusability of our designs allowed us to perform more active and iterative prototyping which incorporated considerable real-world use. Our trackers were closely intertwined with people's personal habits, practices, and the settings in which the trackers were deployed. Here the lightweight nature of our designs made them much easier to tweak and adapt to accommodate different routines and environments. These short cycles also made it easy to explore alternative ways of situating trackers and allowed us to quickly adapt, iterate, or abandon designs that did not prove useful or interesting. Adaptive, flexible, and expressive visualization design approaches like these are especially relevant in the context of self-tracking, where prior work has identified numerous reasons why people tend to abandon their tracking practices [31, 57]. More broadly, relying on simple, adaptable, and easily-deployable designs helped us engage in a more active and evolving process of "lived informatics" [82] rather than fixating on specific visualization designs or tracking hardware. This highlights the importance of considering adaptation, customization, and abandonment as part of the natural lifecycle of these tools and designing trackers explicitly to accommodate them.

As such, our trackers and design process highlight the potential for future research into authoring tools that enable expressive and rapid creation of trackers. Examples like our image-based trackers (26,29,30) hold particular promise and could likely be adapted to replace a number of our other designs. Related tools like DataSelfie [53] and research on self-tracking with paper bullet journals [1, 4] also emphasize the potential of expressive and customizeable self-tracking and may serve as a promising source of inspiration for new situated visualization design platforms. Based on our experience, one promising opportunity for future personal informatics systems might involve the creation of broader ecosystems for sharing and customizing simple yet diverse tracker designs. Such systems might follow an "app store" model similar to those already used for downloading and customizing faces and complications on many smartwatches. In such an ecosystem, designers and developers could create and publish new tracker templates using more specialized development tools (including the kinds of web technologies we used). End-users could then draw on this diverse collection of trackers—customizing, relabeling, and tuning them on their devices to tailor the templates to their own unique tracking situations. Such an approach recognizes that the space of possible tracker designs is vast, while at the same time acknowledging that many individual designs can support a variety of different kinds of tracking with only minor customization. We expect that this kind of broader ecosystem of simple, adaptable, and expressive tracking tools could ultimately support a much wider range of mobile and situated self-tracking than current systems do.

6.3 New Platforms and Data Sources

We expect displays with form factors similar to those we used in this study to become increasingly inexpensive and widespread. Full-color flexible e-paper displays, in particular, seem likely to provide improvements in energy efficiency while also enabling more seamless integration of visualizations into a wide range of environments. Technologies like digital wallpaper and textiles also present compelling (albeit considerably more distant) opportunities for integrating data in domestic spaces. Advances in lightweight mixed reality, meanwhile, may soon permit purely digital situated visualizations that can inhabit an even wider range of environments and could be quickly disabled to reduce distraction.

However, as noted in 5.2.3, a number of our trackers focused on logging activities or phenomena that were not tied to a particular routine, space, or setting. Situating these trackers via a persistent display in a particular physical location did not make sense, since tracking often happened on-the-go, forcing participants to back-fill data. In these situations, wearable tracking tools for data entry on existing devices such as smartwatches or through subtle interaction [76] via e-textiles (such as Pinstripe [48]) may be a compelling direction for further research. Simple wearable data displays [77] integrated into clothing could also support these tasks—although visualizing personal data on publicly visible garments presents a variety of potential design challenges. Alternative input technologies like speech and gesture recognition could also complement the manual self-tracking tools we explored. For example, many of the types of data entry we explored with our trackers could be conveniently entered with short commands through a voice assistant ("Log that I had a cup of green tea" or "I snoozed three times this morning") or via gestures directed towards the display.

More broadly, our findings and insights may also inform the design of situated persistent displays for other kinds of less-personal data. For example, situated displays could be well suited to integrate outside data of interest into spaces that are part of personal routines or habits. For instance, spatially-relevant data from community data sources (such as air quality [43], noise [62], or pollen counts in the area) could be displayed in a location that is relevant to one's morning routine, such as near the breakfast table in the kitchen. Situated displays could also allow people to easily view less-personal sensor data (such as per-room air quality or humidity measurements) in the locations where it is most relevant. Future research focusing on these kinds of applications could build upon insights from our design process as well as from other in-situ data displays such as CloudDrops [71], PostBits [72], and Physikit [42].

7 CONCLUSION: DATA IN EVERYDAY LIFE

Our examples illustrate just a few of the myriad ways in which situated visualizations can already be used to quantify and visualize phenomena, activities, and observations that span daily life. Yet as inexpensive and immersive display technologies become ever more pervasive, introducing visualizations into these kinds of everyday environments will become even easier. The presence of increasingly ubiquitous information displays will undoubtedly create more opportunities for visualizations to support communication, serve as external memory, increase productivity, and help us better understand our environments and ourselves. Despite numerous point examples of personal, social, and domestic visualization tools designed for everyday settings, the visualization community has yet to deeply consider the implications of truly ubiquitous data displays. Increasing numbers of personal and situated visualizations bring with them the potential for distraction and information overload, and raise questions about the degree to which data should command our attention and drive our everyday decision-making. While our trackers showcase some possible applications for increasingly ubiquitous visualization, they also highlight the importance of giving individuals control over what they track as well as how and where they visualize it. Moreover, our experience emphasizes the need for situated visualization platforms and design methodologies that carefully consider the physical, social, and cognitive environments in which data will be surfaced. Given the growing risk of visual and cognitive saturation, future tracking tools will likely need to place even greater emphasis on minimalism—creating “silent” visualizations that can recede into the background [5] and helping individuals opt out or modify their practices when those tools become a burden or a distraction. Ultimately, we must help ensure that these everyday visualizations augment our understanding of the world and complement our own observation skills, rather than short-circuiting them.

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REFERENCES

[1] Parastoo Abtahi, Victoria Ding, Anna C. Yang, Tommy Bruzzese, Alyssa B. Romanos, Elizabeth L. Murnane, Sean Follmer, and James A. Landay. 2020. Understanding Physical Practices and the Role of Technology in Manual Self-Tracking. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 4, 4, Article 115 (Dec. 2020), 24 pages. https://doi.org/10.1145/3432236

[2] Phil Adams, Elizabeth L. Murnane, Michael Elfenbein, Elaine Wethington, and Geri Gay. 2017. Supporting the Self-Management of Chronic Pain Conditions with Tailored Momentary Self-Assessments. In *Proc. of CHI '17*. ACM, 1065–1077. https://doi.org/10.1145/3025453.3025832

[3] Amid Ayobi, Paul Marshall, Anna L. Cox, and Yunan Chen. 2017. Quantifying the Body and Caring for the Mind: Self-Tracking in Multiple Sclerosis. In *Proc. of CHI '17*. ACM, 6889–6901. https://doi.org/10.1145/3025453.3025869

[4] Amid Ayobi, Tobias Sonne, Paul Marshall, and Anna L. Cox. 2018. Flexible and Mindful Self-Tracking: Design Implications from Paper Bullet Journals. In *Proc. of CHI '18*. ACM, Article 28, 14 pages. https://doi.org/10.1145/3173574.3173602

[5] Dominikus Baur. 2017. Silent Augmented Reality. *Hacker Noon* (18 Aug 2017). https://hackernoon.com/silent-augmented-reality-f0f7614cab32 https://hackernoon.com/silent-augmented-reality-f0f7614cab32.

[6] Frank Bentley and Konrad Tollmar. 2013. The Power of Mobile Notifications to Increase Wellbeing Logging Behavior. In *Proc. of CHI '13*. ACM, 1095–1098. https://doi.org/10.1145/2470654.2466140

[7] Susanne Bødker, Kaj Grønbæk, and Morten Kyng. 1993. Cooperative design: Techniques and experiences from the Scandinavian scene. In *Participatory design. Principles and practices*, Doug Schuler and Aki Namioka (Eds.). Lawrence Erlbaum Associates, 157–176.

[8] Michael Bostock, Vadim Ogievetsky, and Jeffrey Heer. 2011. D3: Data-Driven Documents. *IEEE Trans. Visualization & Comp. Graphics (Proc. InfoVis)* (2011). http://vis.stanford.edu/papers/d3

[9] Nathalie Bressa, Kendra Wannamaker, Henrik Korsgaard, Wesley Willett, and Jo Vermeulen. 2019. Sketching and Ideation Activities for Situated Visualization Design. In *Proc. of DIS '19*. ACM, 173–185. https://doi.org/10.1145/3322276.3322326

[10] Gharad Bryan, Dean Karlan, and Scott Nelson. 2010. Commitment devices. *Annu. Rev. Econ.* 2, 1 (2010), 671–698.

[11] Scott Carter and Jennifer Mankoff. 2005. When Participants Do the Capturing: The Role of Media in Diary Studies. In *Proc. of CHI '05*. ACM, 899–908. https://doi.org/10.1145/1054972.1055098

[12] Keith Cheverst, Alan Dix, Daniel Fitton, Mark Rouncefield, and Connor Graham. 2007. Exploring Awareness Related Messaging through Two Situated-Display-Based Systems. *Human–Computer Interaction* 22, 1-2 (May 2007), 173–220. https://doi.org/10.1080/07370020701307955

[13] Eun Kyoung Choe, Bongshin Lee, Matthew Kay, Wanda Pratt, and Julie A. Kientz. 2015. SleepTight: Low-Burden, Self-Monitoring Technology for Capturing and Reflecting on Sleep Behaviors. In *Proc. of Ubicomp '15*. ACM, 121–132. https://doi.org/10.1145/2750858.2804266

[14] Eun Kyoung Choe, Bongshin Lee, Haining Zhu, Nathalie Henry Riche, and Dominikus Baur. 2017. Understanding Self-Reflection: How People Reflect on Personal Data through Visual Data Exploration. In *Proc. of PervasiveHealth '17*. ACM, 173–182. https://doi.org/10.1145/3154862.3154881

[15] 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 *Proc. of CHI '14*. ACM, 1143–1152. https://doi.org/10.1145/2556288.2557372

[16] Chia-Fang Chung, Elena Agapie, Jessica Schroeder, Sonali Mishra, James Fogarty, and Sean A. Munson. 2017. When Personal Tracking Becomes Social: Examining the Use of Instagram for Healthy Eating. In *Proc. of CHI '17*. ACM, 1674–1687. https://doi.org/10.1145/3025453.3025747

[17] Sandy Claes, Jorgos Coenen, and Andrew Vande Moere. 2018. Conveying a Civic Issue Through Data via Spatially Distributed Public Visualization and Polling Displays. In *Proc. of NordiCHI '18*. ACM, 597–608. https://doi.org/10.1145/3240167.3240206

[18] Sandy Claes and Andrew Vande Moere. 2013. Street Infographics: Raising Awareness of Local Issues Through a Situated Urban Visualization. In *Proc. of PerDis '13*. ACM, 133–138. https://doi.org/10.1145/2491568.2491597

[19] Jorgos Coenen, Maarten Houben, and Andrew Vande Moere. 2019. Citizen Dialogue Kit: Public Polling and Data Visualization Displays for Bottom-Up Citizen Participation. In *Proc. of DIS '19 Companion*. ACM, 9–12. https://doi.org/10.1145/3301019.3325160

[20] Jorgos Coenen, Eslam Nofal, and Andrew Vande Moere. 2019. How the Arrangement of Content and Location Impact the Use of Multiple Distributed Public Displays. In *Proc. of DIS '19*. ACM, 1415–1426. https://doi.org/10.1145/3322276.3322294

[21] Sunny Consolvo, Katherine Everitt, Ian Smith, and James A. Landay. 2006. Design Requirements for Technologies That Encourage Physical Activity. In *Proc. of CHI 06'*. ACM, 457–466. https://doi.org/10.1145/1124772.1124840

[22] Nigel Davies, Sarah Clinch, and Florian Alt. 2014. Pervasive Displays: Understanding the Future of Digital Signage. *Synthesis Lectures on Mobile and Pervasive Computing* 8, 1 (2014), 1–128. https://doi.org/10.2200/S00558ED1V01Y201312MPC011

[23] Audrey Desjardins and Aubree Ball. 2018. Revealing Tensions in Autobiographical Design in HCI. In *Proc. of DIS '18*. ACM, 753–764. https://doi.org/10.1145/3196709.3196781

[24] Audrey Desjardins and Ron Wakkary. 2016. Living In A Prototype: A Reconfigured Space. In *Proc. of CHI '16*. ACM, 5274–5285. https://doi.org/10.1145/2858036.2858261

[25] Audrey Desjardins, Ron Wakkary, and William Odom. 2015. Investigating Genres and Perspectives in HCI Research on the Home. In *Proc. CHI '15*. ACM, 3073–3082. https://doi.org/10.1145/2702123.2702540

[26] Laura Devendorf, Kristina Andersen, and Aisling Kelliher. 2020. The Fundamental Uncertainties of Mothering: Finding Ways to Honor Endurance, Struggle, and Contradiction. *ACM Trans. Comput.-Hum. Interact.* 27, 4, Article 26 (September 2020), 24 pages. https://doi.org/10.1145/3397177

[27] Laura Devendorf, Joanne Lo, Noura Howell, Jung Lin Lee, 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 *Proc. of CHI '16*. ACM, 6028–6039. https://doi.org/10.1145/2858036.2858192

[28] Christine Dierk, Molly Jane Pearce Nicholas, and Eric Paulos. 2018. AlterWear: Battery-Free Wearable Displays for Opportunistic Interactions. In *Proc. of CHI '18*. ACM, Article 220, 11 pages. https://doi.org/10.1145/3173574.3173794

[29] Alix Ducros, Clemens N. Klokmose, and Aurélien Tabard. 2019. Situated Sketching and Enactment for Pervasive Displays. In *Proc. of ISS '19*. ACM, New York, NY, USA, 217–228. https://doi.org/10.1145/3343055.3359702

[30] Niklas Elmqvist and Pourang Irani. 2013. Ubiquitous Analytics: Interacting with Big Data Anywhere, Anytime. *Computer* 46, 04 (apr 2013), 86–89. https://doi.org/10.1109/MC.2013.147

[31] Daniel A. Epstein, Monica Caraway, Chuck Johnston, An Ping, James Fogarty, and Sean A. Munson. 2016. Beyond Abandonment to Next Steps: Understanding and Designing for Life after Personal Informatics Tool Use. In *Proc. of CHI '16*. ACM, 1109–1113. https://doi.org/10.1145/2858036.2858045

[32] Daniel A. Epstein, Nicole B. Lee, Jennifer H. Kang, Elena Agapie, Jessica Schroeder, Laura R. Pina, James Fogarty, Julie A. Kientz, and Sean Munson. 2017. Examining Menstrual Tracking to Inform the Design of Personal Informatics Tools. In *Proc. of CHI '17*. ACM, 6876–6888. https://doi.org/10.1145/3025453.3025635

[33] Daniel A. Epstein, An Ping, James Fogarty, and Sean A. Munson. 2015. A Lived Informatics Model of Personal Informatics. In *Proc. of Ubicomp '15*. ACM, 731–742. https://doi.org/10.1145/2750858.2804250

[34] Pauline Gourlet and Thierry Dassé. 2017. Cairn: A Tangible Apparatus for Situated Data Collection, Visualization and Analysis. In *Proc. of DIS '17*. ACM, 247–258. https://doi.org/10.1145/3064663.3064794

[35] Rúben Gouveia, Evangelos Karapanos, and Marc Hassenzahl. 2015. How Do We Engage with Activity Trackers? A Longitudinal Study of Habito. In *Proc. of Ubicomp '15*. ACM, 1305–1316. https://doi.org/10.1145/2750858.2804290

[36] Tobias Grosse-Puppendahl, Steve Hodges, Nicholas Chen, John Helmes, Stuart Taylor, James Scott, Josh Fromm, and David Sweeney. 2016. Exploring the Design Space for Energy-Harvesting Situated Displays. In *Proc. of UIST '16*. ACM, 41–48.

https://doi.org/10.1145/2984511.2984513

[37] Kyle Wm. Hall, Adam J. Bradley, Uta Hinrichs, Samuel Huron, Jo Wood, Chris Collins, and Sheelagh Carpendale. 2020. Design by Immersion: A Transdisciplinary Approach to Problem-Driven Visualizations. *IEEE Transactions on Visualization and Computer Graphics* 26, 1 (2020), 109–118.

[38] Daniel Harrison, Paul Marshall, Nadia Bianchi-Berthouze, and Jon Bird. 2015. Activity Tracking: Barriers, Workarounds and Customisation. In *Proc. of Ubicomp '15*. ACM, 617–621. https://doi.org/10.1145/2750858.2805832

[39] Yasamin Heshmat, Carman Neustaedter, and Brendan DeBrincat. 2017. The Autobiographical Design and Long Term Usage of an Always-On Video Recording System for the Home. In *Proc. of DIS '17*. ACM, 675–687. https://doi.org/10.1145/3064663.3064759

[40] Sarah Homewood, Harvey Bewley, and Laurens Boer. 2019. Ovum: Designing for Fertility Tracking as a Shared and Domestic Experience. In *Proc. of DIS '19*. ACM, 553–565. https://doi.org/10.1145/3322276.3323692

[41] Sarah Homewood, Amanda Karlsson, and Anna Vallgårda. 2020. Removal as a Method: A Fourth Wave HCI Approach to Understanding the Experience of Self-Tracking. In *Proc. of DIS '20*. ACM, 1779–1791. https://doi.org/10.1145/3357236.3395425

[42] Steven Houben, Connie Golsteijn, Sarah Gallacher, Rose Johnson, Saskia Bakker, Nicolai Marquardt, Licia Capra, and Yvonne Rogers. 2016. Physikit: Data Engagement Through Physical Ambient Visualizations in the Home. In *Proc. of CHI '16*. ACM, 1608–1619. https://doi.org/10.1145/2858036.2858059

[43] Yen-Chia Hsu, Paul Dille, Jennifer Cross, Beatrice Dias, Randy Sargent, and Illah Nourbakhsh. 2017. Community-Empowered Air Quality Monitoring System. In *Proc. of CHI '17*. ACM, 1607––1619. https://doi.org/10.1145/3025453.3025853

[44] Dandan Huang, Melanie Tory, Bon Adriel Aseniero, Lyn Bartram, Scott Bateman, Sheelagh Carpendale, Anthony Tang, and Robert Woodbury. 2015. Personal Visualization and Personal Visual Analytics. *IEEE Transactions on Visualization and Computer Graphics* 21, 3 (March 2015), 420–433. https://doi.org/10.1109/TVCG.2014.2359887

[45] Samuel Huron, Sheelagh Carpendale, Alice Thudt, Anthony Tang, and Michael Mauerer. 2014. Constructive Visualization. In *Proc. of DIS '14*. ACM, 433–442. https://doi.org/10.1145/2598510.2598566

[46] ReporterApp Inc. 2020. Reporter App. Web. Retrieved January 31, 2020 from http://reporter-app.com/.

[47] Yvonne Jansen and Pierre Dragicevic. 2013. An Interaction Model for Visualizations Beyond The Desktop. *IEEE Transactions on Visualization and Computer Graphics* 19, 12 (Dec 2013), 2396–2405. https://doi.org/10.1109/TVCG.2013.134

[48] Thorsten Karrer, Moritz Wittenhagen, Leonhard Lichtschlag, Florian Heller, and Jan Borchers. 2011. Pinstripe: Eyes-Free Continuous Input on Interactive Clothing. In *Proc. of CHI '11*. ACM, 1313–1322. https://doi.org/10.1145/1978942.1979137

[49] Maria Karyda, Merja Ryöppy, Jacob Buur, and Andrés Lucero. 2020. Imagining Data-Objects for Reflective Self-Tracking. In *Proc. of CHI '20*. ACM, 12 pages. https://doi.org/10.1145/3313831.3376844

[50] Fahim Kawsar, Jo Vermeulen, Kevin Smith, Kris Luyten, and Gerd Kortuem. 2011. Exploring the Design Space for Situated Glyphs to Support Dynamic Work Environments. In *Proc. of Pervasive '11*. Springer Berlin Heidelberg, 70–78. https://doi.org/10.1007/978-3-642-21726-5_5

[51] Matthew Kay, Eun Kyoung Choe, Jesse Shepherd, Benjamin Greenstein, Nathaniel Watson, Sunny Consolvo, and Julie A. Kientz. 2012. Lullaby: A Capture & Access System for Understanding the Sleep Environment. In *Proc. of Ubicomp '12*. ACM, 226–234. https://doi.org/10.1145/2370216.2370253

[52] Christina Kelley, Bongshin Lee, and Lauren Wilcox. 2017. Self-Tracking for Mental Wellness: Understanding Expert Perspectives and Student Experiences. In *Proc. of CHI '17*. ACM, 629–641. https://doi.org/10.1145/3025453.3025750

[53] Nam Wook Kim, Hyejin Im, Nathalie Henry Riche, Alicia Wang, Krzysztof Gajos, and Hanspeter Pfister. 2019. DataSelfie: Empowering People to Design Personalized Visuals to Represent Their Data. In *Proc. of CHI '19*. ACM, Article 79, 12 pages. https://doi.org/10.1145/3290605.3300309

[54] Young-Ho Kim, Jae Ho Jeon, Eun Kyoung Choe, Bongshin Lee, KwonHyun Kim, and Jinwook Seo. 2016. TimeAware: Leveraging Framing Effects to Enhance Personal Productivity. In *Proc. of CHI '16*. ACM, 272–283. https://doi.org/10.1145/2858036.2858428

[55] Young-Ho Kim, Jae Ho Jeon, Bongshin Lee, Eun Kyoung Choe, and Jinwook Seo. 2017. OmniTrack: A Flexible Self-Tracking Approach Leveraging Semi-Automated Tracking. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 1, 3, Article 67 (Sept. 2017), 28 pages. https://doi.org/10.1145/3130930

[56] Lisa Koeman, Vaiva Kalnikaité, and Yvonne Rogers. 2015. "Everyone Is Talking about It!": A Distributed Approach to Urban Voting Technology and Visualisations. In *Proc. CHI '15*. ACM, 3127–3136. https://doi.org/10.1145/2702123.2702263

[57] Amanda Lazar, Christian Koehler, Joshua Tanenbaum, and David H. Nguyen. 2015. Why We Use and Abandon Smart Devices. In *Proc. of Ubicomp '15*. ACM, 635–646. https://doi.org/10.1145/2750858.2804288

[58] Ian Li, Anind Dey, and Jodi Forlizzi. 2010. A Stage-Based Model of Personal Informatics Systems. In *Proc. of CHI '10*. ACM, 557–566. https://doi.org/10.1145/1753326.1753409

[59] Ian Li, Anind K. Dey, and Jodi Forlizzi. 2012. Using Context to Reveal Factors That Affect Physical Activity. *ACM Trans. Comput.-Hum. Interact.* 19, 1, Article 7 (May 2012), 21 pages. https://doi.org/10.1145/2147783.2147790

[60] Yuhan Luo, Peiyi Liu, and Eun Kyoung Choe. 2019. Co-Designing Food Trackers with Dietitians: Identifying Design Opportunities for Food Tracker Customization. In *Proc. of CHI '19*. ACM, Article 592, 13 pages. https://doi.org/10.1145/3290605.3300822

[61] Giorgia Lupi and Stefanie Posavec. 2016. *Dear Data*. Chronicle Books.

[62] Nicolas Maisonneuve, Matthias Stevens, Maria E. Niessen, and Luc Steels. 2009. NoiseTube: Measuring and Mapping Noise Pollution with Mobile Phones. In *Information Technologies in Environmental Engineering*. Springer Berlin Heidelberg, 215–228. https://doi.org/10.1007/978-3-540-88351-7_16

[63] Kim Marriott, Falk Schreiber, Tim Dwyer, Karsten Klein, Nathalie Henry Riche, Takayuki Itoh, Wolfgang Stuerzlinger, and Bruce H. Thomas. 2018. *Immersive Analytics*. Vol. 11190. Springer.

[64] Matthew Mauriello, Michael Gubbels, and Jon E. Froehlich. 2014. Social Fabric Fitness: The Design and Evaluation of Wearable E-Textile Displays to Support Group Running. In *Proc. of CHI '14*. ACM, 2833–2842. https://doi.org/10.1145/2556288.2557299

[65] Mollie McKillop, Lena Mamykina, and Noémie Elhadad. 2018. Designing in the Dark: Eliciting Self-Tracking Dimensions for Understanding Enigmatic Disease. In *Proc. of CHI '18*. ACM, Article 565, 15 pages. https://doi.org/10.1145/3173574.3174139

[66] Miriah Meyer and Jason Dykes. 2020. Criteria for Rigor in Visualization Design Study. *IEEE Transactions on Visualization and Computer Graphics* 26, 1 (2020), 87–97.

[67] Elizabeth L. Murnane, Tara G. Walker, Beck Tench, Stephen Voida, and Jaime Snyder. 2018. Personal Informatics in Interpersonal Contexts: Towards the Design of Technology That Supports the Social Ecologies of Long-Term Mental Health Management. *Proc. ACM Hum.-Comput. Interact.* 2, CSCW, Article 127 (nov 2018), 27 pages. https://doi.org/10.1145/3274396

[68] Carman Neustaedter, Tejinder K. Judge, and Phoebe Sengers. 2014. Autobiographical design in the home. In *Studying and Designing Technology for Domestic Life: Lessons from Home*. Vol. 135. Morgan Kaufmann Waltham, MA.

[69] Carman Neustaedter and Phoebe Sengers. 2012. Autobiographical Design in HCI Research: Designing and Learning through Use-It-Yourself. In *Proc. of DIS '12*. ACM, 514–523. https://doi.org/10.1145/2317956.2318034

[70] Kenton O'Hara, Mark Perry, Elizabeth Churchill, and Daniel Russell. 2003. *Public and situated displays: Social and interactional aspects of shared display technologies*. Vol. 2. Springer Science & Business Media.

[71] Simon Olberding, Jürgen Steimle, Suranga Nanayakkara, and Pattie Maes. 2015. CloudDrops: Stamp-Sized Pervasive Displays for Situated Awareness of Web-Based Information. In *Proc. of PerDis '15*. ACM, 47–53. https://doi.org/10.1145/2757710.2757718

[72] Juan Pablo, Piyum Fernando, Priyashri Sridhar, Anusha Withana, Suranga Nanayakkara, Jurgen Steimle, and Pattie Maes. 2016. PostBits: Using Contextual Locations for Embedding Cloud Information in the Home. *Personal Ubiquitous Comput.* 20, 6 (Nov. 2016), 1001–1014. https://doi.org/10.1007/s00779-016-0967-z

[73] Gaurav Paruthi, Shriti Raj, Seungjoo Baek, Chuyao Wang, Chuan-che Huang, Yung-Ju Chang, and Mark W. Newman. 2018. Heed: Exploring the Design of Situated Self-Reporting Devices. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 2, 3, Article 132 (Sept. 2018), 21 pages. https://doi.org/10.1145/3264942

[74] Laura 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. *Proc. ACM Hum.-Comput. Interact.* 4, CSCW1, Article 070 (May 2020), 25 pages. https://doi.org/10.1145/3392882

[75] Bernd Ploderer, Wolfgang Reitberger, Harri Oinas-Kukkonen, and Julia Gemert-Pijnen. 2014. Social Interaction and Reflection for Behaviour Change. *Personal Ubiquitous Comput.* 18, 7 (Oct. 2014), 1667–1676. https://doi.org/10.1007/s00779-014-0779-y

[76] Henning Pohl, Andreea Muresan, and Kasper Hornbæk. 2019. Charting Subtle Interaction in the HCI Literature. In *Proc. of CHI '19*. ACM, Article 418, 15 pages. https://doi.org/10.1145/3290605.3300648

[77] Ivan Poupyrev, Nan-Wei Gong, Shiho Fukuhara, Mustafa Emre Karagozler, Carsten Schwesig, and Karen E. Robinson. 2016. Project Jacquard: Interactive Digital Textiles at Scale. In *Proc. of CHI '16*. ACM, 4216–4227. https://doi.org/10.1145/2858036.2858176

[78] Zachary Pousman, John Stasko, and Michael Mateas. 2007. Casual Information Visualization: Depictions of Data in Everyday Life. *IEEE Transactions on Visualization and Computer Graphics* 13, 6 (Nov. 2007), 1145–1152. https://doi.org/10.1109/TVCG.2007.70541

[79] Ruth Ravichandran, Sang-Wha Sien, Shwetak N. Patel, Julie A. Kientz, and Laura R. Pina. 2017. Making Sense of Sleep Sensors: How Sleep Sensing Technologies Support and Undermine Sleep Health. In *Proc. of CHI '17*. ACM, 6864–6875. https://doi.org/10.1145/3025453.3025557

[80] Jonathan C Roberts, Panagiotis D Ritsos, Sriram Karthik Badam, Dominique Brodbeck, Jessie Kennedy, and Niklas Elmqvist. 2014. Visualization beyond the

Desktop–the Next Big Thing. *IEEE Computer Graphics and Applications* 34, 6 (Nov 2014), 26–34. https://doi.org/10.1109/MCG.2014.82

[81] Johnny Rodgers and Lyn Bartram. 2011. Exploring Ambient and Artistic Visualization for Residential Energy Use Feedback. *IEEE Transactions on Visualization and Computer Graphics* 17, 12 (Dec 2011), 2489–2497. https://doi.org/10.1109/TVCG.2011.196

[82] John Rooksby, Mattias Rost, Alistair Morrison, and Matthew Chalmers. 2014. Personal Tracking as Lived Informatics. In *Proc. of CHI '14*. ACM, 1163–1172. https://doi.org/10.1145/2556288.2557039

[83] Elizabeth B.-N. Sanders and Pieter Jan Stappers. 2008. Co-creation and the new landscapes of design. *CoDesign* 4, 1 (2008), 5–18. https://doi.org/10.1080/15710880701875068

[84] Arvind Satyanarayan, Domink Moritz, Kanit Wongsuphasawat, and Jeffrey Heer. 2017. Vega-Lite: A Grammar of Interactive Graphics. *IEEE Transactions on Visualization and Computer Graphics* 23, 1 (Jan 2017), 341–350. https://doi.org/10.1109/TVCG.2016.2599030

[85] Samarth Singhal, Carman Neustaedter, William Odom, Lyn Bartram, and Yasamin Heshmat. 2018. Time-Turner: Designing for Reflection and Remembrance of Moments in the Home. In *Proc. of CHI '18*. ACM, 1–14. https://doi.org/10.1145/3173574.3173753

[86] John Stasko, Todd Miller, Zachary Pousman, Christopher Plaue, and Osman Ullah. 2004. Personalized Peripheral Information Awareness Through Information Art. In *Proc. of UbiComp '04*. Springer Berlin Heidelberg, 18–35.

[87] Alex S. Taylor, Siân Lindley, Tim Regan, David Sweeney, Vasillis Vlachokyriakos, Lillie Grainger, and Jessica Lingel. 2015. Data-in-Place: Thinking through the Relations Between Data and Community. In *Proc. of CHI '15*. ACM, 2863–2872. https://doi.org/10.1145/2702123.2702558

[88] Bruce H. Thomas, Gregory F. Welch, Pierre Dragicevic, Niklas Elmqvist, Pourang Irani, Yvonne Jansen, Dieter Schmalstieg, Aurélien Tabard, Neven A. M. ElSayed, Ross T. Smith, and Wesley Willett. 2018. Situated Analytics. In *Immersive Analytics*. Springer International Publishing, 185–220. https://doi.org/10.1007/978-3-030-01388-2_7

[89] Alice Thudt, Uta Hinrichs, Samuel Huron, and Sheelagh Carpendale. 2018. Self-Reflection and Personal Physicalization Construction. In *Proc. of CHI '18*. ACM, Article 154, 13 pages. https://doi.org/10.1145/3173574.3173728

[90] Jo Vermeulen, Fahim Kawsar, Adalberto L. Simeone, Gerd Kortuem, Kris Luyten, and Karin Coninx. 2012. Informing the Design of Situated Glyphs for a Care Facility. In *Proc. of IEEE VL/HCC '12*. 89–96. https://doi.org/10.1109/VLHCC.2012.6344490

[91] Kendra A. Wannamaker, Sandeep Zechariah George Kollannur, Marian Dörk, and Wesley Willett. 2021. I/O Bits: User-Driven, Situated, and Dedicated Self-Tracking. In *Proc. of DIS '21*. ACM, 523–537. https://doi.org/10.1145/3461778.3462138

[92] Sean White and Steven Feiner. 2009. SiteLens: Situated Visualization Techniques for Urban Site Visits. In *Proc. of CHI '09*. ACM, 1117–1120. https://doi.org/10.1145/1518701.1518871

[93] Wesley Willett, Yvonne Jansen, and Pierre Dragicevic. 2017. Embedded Data Representations. *IEEE Transactions on Visualization and Computer Graphics* 23, 1 (Jan. 2017), 461–470. https://doi.org/10.1109/TVCG.2016.2598608

[94] Kaiton Williams. 2015. An Anxious Alliance. In *Proceedings of The Fifth Decennial Aarhus Conference on Critical Alternatives (CA '15)*. Aarhus University Press, 121–131. https://doi.org/10.7146/aahcc.v1i1.21146

[95] Nadia Campo Woytuk, Marie Louise Juul Sondergaard, Marianela Ciolfi Felice, and Madeline Balaam. 2020. Touching and Being in Touch with the Menstruating Body. In *Proc. of CHI '20*. ACM. https://doi.org/10.1145/3313831.3376471

[96] Naomi Yamashita, Hideaki Kuzuoka, Keiji Hirata, Takashi Kudo, Eiji Aramaki, and Kazuki Hattori. 2017. Changing Moods: How Manual Tracking by Family Caregivers Improves Caring and Family Communication. In *Proc. of CHI '17*. ACM, 158–169. https://doi.org/10.1145/3025453.3025843

[97] Rayoung Yang, Eunice Shin, Mark W. Newman, and Mark S. Ackerman. 2015. When Fitness Trackers Don't "Fit": End-User Difficulties in the Assessment of Personal Tracking Device Accuracy. In *Proc. of Ubicomp '15*. ACM, 623–634. https://doi.org/10.1145/2750858.2804269