Understanding Temporality of Reflection in Baby Tracking

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Abstract

Personal informatics literature has examined reflection in tracking, but there are gaps in our understanding of how self-initiated reflection that one engages in shortly after data collection has taken place occurs in everyday life and how technology can best support it. We use baby tracking as a case study to explore 'temporality,' the time over which reflection occurs relative to data collection, as caregivers track their baby's well-being over both short-term and long-term. We interviewed 20 parents in the U.S. who used baby-tracking technology. We find that parents ask different questions based on the time elapsed since data collection, such as checking alignment with medical guidance and prior patterns immediately after tracking or augmenting memory when reflecting hours later. We summarize these findings into a framework for short-term reflection in baby tracking that includes three windows: the immediate, in-between, and cumulative. We use these windows to identify helpful design patterns in baby-tracking technologies toward supporting temporally meaningful reflection and opportunities for further study in other self-tracking domains.

CCS Concepts

• **Human-centered computing → HCI theory, concepts and models**.

Keywords

personal informatics, reflection, tracking, temporality, baby tracking

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1 Introduction

The field of personal informatics (PI) intends to understand how people collect and reflect on personally relevant data toward self-understanding. PI systems are designed around key stages of self-tracking to support insights, goals, or behavior change. The reflection stage, where people examine their collected data to better understand their habits and act accordingly, is an integral step in gaining self-awareness and self-knowledge [40, 75]. To support reflection, PI literature has often focused on how technology can be designed to promote different reflective goals, such as reflection at different levels of depth [20] or domain-specific reflective needs, like predicting glucose levels for diabetes management [7, 104].

One core component of reflection is its *temporality*, that is, when reflection occurs relative to data collection. Perspectives in PI literature have highlighted that reflection can vary from occurring in the moment [40], shortly after [75], or over a long period of time [75]. However, when examining temporality, researchers have largely taken a long-term view of reflection, typically in support of behavior change [37, 84], or have focused on reflection-in-action [101] and short-term reflection prompted by explicit nudges, such as in some forms of Ecological Momentary Assessment [32]. This leaves unanswered questions about short-term reflection occurring shortly after data collection has concluded and which is self- rather than system-initiated, leading to gaps in our understanding of what questions people seek to answer with their data and how to better support them when they reflect in varying time frames.

Baby tracking, the use of technology to monitor and reflect on the daily routines of infants, offers a useful case study for understanding temporality as a whole, as both short- and long-term reflection are commonplace. The birth of a baby is accompanied by a host of tasks and immediate needs, such as feeding and changing diapers, that caregivers have to repeatedly perform, keep track of, and reflect on daily to ensure the well-being of their infant [2]. However, in addition to facing the sheer volume of tasks, caregivers' sleep declines both in terms of quality and total duration as they experience frequent sleep disruptions [48]. This, in turn, leads to higher levels of fatigue, thus making keeping track of such repetitive tasks difficult. Technological solutions, such as apps, are a crucial tool that some new parents and caregivers use to automate the record-keeping of their infants' daily routines [80]. For example, in a survey of 126 U.S.-based patients during their 6-week postpartum visit, 57% reported using an app to track infant feeding [30]. Many of the most downloaded baby-tracking mobile apps (e.g., Huckleberry [58], Baby Tracker [76], etc) offer additional features associated with a

baby's well-being, such as recording sleep, tummy time, and medication. Some apps require manual input, while others automatically collect data through wearable and IoT devices, such as infant wearables for tracking vitals or smart cribs for sleep tracking. Although past literature has identified different motivations for baby tracking (e.g., tracking the development of the baby [67, 68, 103], improving communication between caregivers [71, 103] and their medical providers [15, 108] and augmenting one's memory [28]), we have a limited understanding of how technology supports reflecting on collected data to achieve these goals. We therefore ask the following research question: **How is temporality tied to how parents reflect on their tracked data?**

To this end, we conducted in-depth interviews with 20 U.S.-based participants, all of whom were parents who had an infant in the past year and used some form of technology to track aspects of their infant's life (e.g., mobile apps or spreadsheets). Through qualitative analysis, we offer insights into *when* parents reflect on the tracked data, *why* they reflect in these different time frames, and *how* current baby-tracking technology supports reflection during them. These questions led to the core contribution of a framework posing that reflection occurs across different temporal windows that serve unique goals. Specifically, we propose that short-term reflection in baby tracking occurs in three windows relative to data collection: the *immediate*, *in-between*, and *cumulative* windows. In the immediate window, parents reflect during or immediately after data collection has concluded primarily to check alignment with medical guidelines and prior established patterns. In the in-between window, parents reflect on the last entries tracked and in between two tracking activities to augment their memory and plan ahead without the need for direct communication among different caregivers. In the cumulative window, parents reflect on tracked data within the past day to ensure their baby meets certain medically recommended totals and prepare for the remaining or following day. Long-term reflection is typically associated with identifying trends and patterns, seeking encouragement, and reminiscing, echoing findings from past literature in personal informatics [39, 106].

In developing this framework of temporality for baby tracking, we conclude by discussing design recommendations for improving short-term reflection in baby tracking and open questions about short-term tracking in other domains.

2 Background

The postpartum period is one of significant stress for new parents and caregivers. Caregivers can face significant sleep disruptions and fatigue, often due to their newborns' unpredictable schedules and the challenges of transitioning to their new roles [35, 48]. New parents or other caregivers have to take extensive care of their newborns, which manifests as a host of repetitive tasks that occur multiple times a day. Here, we review typical medical recommendations in the U.S., which is the cultural context of our study, but note that they might differ across countries and regions. In the first months, breastfed babies need to be fed 8–12 times in 24 hours [83], and formula-fed babies typically need to be fed every 3–4 hours [91]. An indicator of adequate hydration is that infants produce about six wet diapers and pass 3–4 stools in 24 hours by the end of the first week of their life [2]. Newborns typically lose some weight during the first week of their life [49], and some caregivers weigh their babies at home if they have concerns about weight gain or breastfeeding [31, 60]. Sleep is another dimension of the baby's daily routine that needs to be closely monitored. Infants' sleep ranges from 12–16 hours [97] distributed during daily naps and night sleep. To counteract the time spent sleeping on their backs, it is recommended that infants spend thirty minutes of 'tummy time' spread over a 24-hour period to optimize gross motor control development [57]. Finally, medication or vitamins are commonly administered at regular intervals. For example, breastfed babies are recommended to be given vitamin D drops daily [109], and pain relievers are often prescribed for fever and ear infections in older infants but need to be carefully spaced out throughout the day [56, 92].

Due to the large amount of information caregivers need to keep track of, baby tracking is often medically recommended. Some hospitals send new parents home with custom paper logs (e.g., [111]) to keep track of feedings and diapers for the first weeks of the newborn's life. Medical associations, such as the American Association of Pediatrics, recommend record-keeping to troubleshoot feeding difficulties [93]. At the same time, there is also a large commercial market for baby-tracking technologies that automate record-keeping processes. In 2022, a cross-sectional survey of 126 U.S.-based patients who were recruited during their 6-week postpartum visit reported that 57% used an app to track infant feeding [30]. Most of them also tracked diapers and sleep. In an earlier 2016 online survey of 357 Australian-based women who had given birth to at least one child in the past three years, 49% had used an app to track their children's growth, development, feeding, and sleep habits, among others [80]. Using tracking apps often makes it easier for the parents to rely on for the multitude of calculations, reminders, and tasks they must complete daily [64].

Currently, the Apple App Store and Android Google Play Store exhibit dozens of related apps, the most popular ones having hundreds of thousands, if not millions, of downloads. Multiple of these apps are featured on top charts for the Parenting category. Some examples are Huckleberry [58], Baby Tracker [76], What to Expect [41], and Nara Baby [87]. Many of these baby-tracking apps provide similar features and support tracking common categories such as nutrition, diapers, and sleep. Some include features to track 'tummy time,' 'story time,' 'bath time,' 'playtime,' etc. The apps often support shared accounts, cross-device syncing, reminders, and summary charts with daily, weekly, and monthly views. Additionally, some caregivers use monitoring devices such as the SNOO [54], a smart crib, and the Owlet Dream sock [95], a wearable device, that have accompanying tracking apps.

3 Related Work

Reflection is a deliberate cognitive process of retrospection that humans engage in regularly. The field of personal informatics (PI) has developed multiple theoretical models of reflection in tracking and has studied and led to the creation of different design features to better support reflection. In this work, we examine reflection in the context of baby tracking, specifically looking at short-term reflection over everyday activities that parents engage in when caring for their infants.

3.1 Theories of Reflection and their Application to Personal Informatics

Multiple disciplinary and epistemological perspectives have proposed theories about how people reflect on different aspects of their lives [8]. In some of the earliest modern philosophical examinations of thought, Dewey [27] defined reflection as a systematic, rigorous, and disciplined sequence of reflective thoughts that build off each other toward a meaning-making process. Cognitive and developmental psychology [70] have since continued understanding reflection as deliberate, non-automatic thinking that leads to new ideas and actions [89].

HCI posits that technology can help mediate reflection, leading to theoretical contributions and design recommendations to better understand and support reflection [14]. For example, Fleck and Fitzpatrick [46] established a framework that organized technology-supported reflection into different *levels* based on the depth of critical examination. Personal informatics (PI) literature [37, 75] also widely recognizes the value of reflection toward gaining deeper insights and potentially improving relevant aspects of one's self. In this context, reflection occurs in relation to collected data. For example, in their widely-used Stage-Based Model of personal informatics, Li, Dey, and Forlizzi [75] defined the reflection stage as "*viewing, exploring, or interacting with collected personal information and related insights or visualizations.*" Designing systems that support such reflection is of particular interest to PI literature. For example, Cho et al. [20] expanded on Fleck and Fitzpatrick's [46] model to describe design features for PI systems that can support each level of reflection, ranging from simple description to support revisitation of practices to transformative or critical reflection to support reassessment of one's position or stance. In our work, we use baby tracking to examine how design features of PI systems foster reflective practices. But rather than analyzing the depth of reflection, we focus on its 'temporality.'

The Stage-Based Model [75] labeled temporality as the time that has elapsed since data collection: users are described to reflect on their data in the 'short-term,' "*immediately after recording the information*" or in the 'long-term,' "*after several days or weeks involving extensive self-reflection.*" In contributing the Lived Informatics Model, Epstein et al. [40] elaborate on this understanding of temporality by suggesting that reflection may occur concurrently with collecting and integrating. Bentvelzen et al. [14] state that people use PI technology to reflect across a range of time intervals, "*from a single day to prioritising year-to-year analysis*". They further describe that people's goals and contexts influence how they reflect, sometimes desiring quick and actionable feedback and others desiring depth and exploration.

In describing reflective practices, PI literature often refers to Schön's [101] examination of when reflection occurs in relation to an action, which implies a temporal influence on how reflective practices occur. According to Schön, *reflection-in-action* is predicated on an encounter of a surprise disrupting a routine and leading to thinking about what one is doing while doing it to take a new action. Baumer [8] describes how this reflection often leads to the development of tacit knowledge, or the intuitive, experiential understanding embedded in practice, which Schön [101] refers to as 'knowing-in-action.' This tacit knowledge allows individuals to respond in unexpected situations by integrating reflection and action. On the other hand, *reflection-on-action* is retrospective critical thinking that one engages in after the action has concluded.

More broadly, HCI literature has examined temporality in relation to user experience. One such line of research considers temporality as the change in evaluative judgments on products over time [65]. Other work in HCI more closely aligns with the interpretation of temporality in PI by examining the timing of self-reports of user experience, particularly in the context of Ecological Momentary Assessment (EMA) [32]. Such work has highlighted different perspectives that arise in reports of experience made in the moment, after the fact, and in the future [33], leading to retrospective reflection. EMA, especially in the form of the experience sampling method, has led to new technology that explicitly nudges users to reflect on their recent experiences (e.g., [66]). Our work examines temporality in the context of PI in relation to when reflection occurs relative to data collection. It also assumes that such reflection is primarily driven by the individual on the data they collected rather than initiated by the system, which is a common assumption in the case of EMA systems.

When the PI literature has examined temporality, it has primarily examined self-directed reflection occurring in the long term, often involving data points collected over multiple weeks and months, if not years. Past literature has suggested that long-term reflection is tied to the identification of trends and patterns and is often connected to gaining better insights about oneself with the goal of behavioral change [1, 23, 98]. For example, in reviewing the PI literature, Epstein et al. surfaced that 44% of research papers examined how to support behavior change or self-improvement through tracking [37].

Nonetheless, short-term reflection is central to the use of PI systems. Temporal alignment with user reflective needs at the moment they arise is crucial for sustained engagement with PI tools. Bentvelzen et al. [14] showed how temporal mismatches, where tools prioritize long-term reflection while neglecting users' short-term reflective practices, often lead to lapsing and disengagement. Most work on self-directed short-term reflection has been closely aligned with Schön's [101] concept of reflection-in-action by highlighting the importance of sense-making at the time of interaction [44]. For example, in studying apps and devices for physical activity promotion, Gouveia et al. [51, 52] highlight that interactions were most commonly quick glances intended to answer questions about current data or to support planning for the immediate future. This leaves open the question of how people reflect after data collection has taken place but within a short time frame. Understanding this temporality of reflection can help guide the design of features intended to support different reflective goals by surfacing relevant information in the interactions and interfaces commonly used at a particular time point.

3.2 Designing for Reflection on Tracked Data

The research literature has provided rich guidance on how to design technology to support reflection in a variety of spaces [8, 9], including self-tracking among many domains (e.g., physical activity, nutrition, sleep, mental health) [37]. Personal informatics literature additionally regularly examines tracking and reflective practices in

a range of chronic health conditions such as multiple sclerosis [3], diabetes [7, 81], and migraines [100]. As such, a thorough review of our understanding of how tracking technology can support reflection is beyond the scope of this work. Cho et al. provide one such review, considering how strategies in personal informatics technology align with theory around levels of reflection and locus of agency [20]. We survey some of those design takeaways here, with a particular focus on how literature has considered designing to support reflection at different timespans.

The PI research literature has often examined how designs can promote depth of reflection over long-term data, similar to the community's theoretical understanding of reflective practices. For example, studies often contribute strategies for advancing the insights that people can receive, such as visualizations or other data summaries [12, 36, 38, 106] or interactive techniques for question-answering [69]. These works often center around the depth of long-term reflection, highlighting the difficulties in supporting reflection given the volume and complexities of data aggregated across weeks, months, or years. To address these concerns, other works seek to help researchers ensure their designs are promoting deep reflection. For example, Bentvelzen et al. contribute a survey instrument to measure whether people perceive a system as supporting insight, exploration, or comparison [13].

Toward supporting more short-term reflection, the PI literature has often drawn from techniques discussed in glanceable displays [16]. For example, lock screens or home screens on mobile and wearable devices can support awareness of tracked activities through visual summaries [22, 25, 52]. To support awareness of progress and immediate planning, people often use these displays to center daily totals over the course of the day. For example, watch faces frequently highlight the number of steps walked in a day, cumulative distance traveled, or calories burned so far [50, 63, 82]. People also seek out PI features to reflect on current measures, with displays prominently displaying metrics like blood pressure, heart rate, and glucose levels [63]. The PI literature has also explored both the features and impacts of short-term planning tools, often referred to as Time Management Planning (TMP). Defined by Parke et al. [96], TMP involves determining tasks for a particular day, prioritizing and scheduling them, and estimating the time required for each. Tools that support TMP have been shown to enhance users' awareness of their achievements, foster a greater sense of control over their time, and improve communication with others [72]. We turn our attention to this literature when considering ways to improve how baby-tracking apps currently support short-term reflection.

3.3 Baby Tracking in Human-Computer Interaction

Researchers in Human-Computer Interaction have proposed a number of novel technologies that support families in the upbringing of infants. Some have focused on support while at the hospital, especially for preterm infants [53], to transition from neonatal intensive care units to home care [55, 74]. Researchers have particularly focused on the logistics of feeding infants, for example, through the development of mobile apps to find vetted public spaces to breastfeed [4] and by crowdsourcing the design of breast pumps [29]. Other innovative approaches have aimed to increase the bond between infants and caregivers through the creation of sensors to monitor physical contact [113]. Within this broad literature, our work focuses on the lived experiences of users of baby-tracking technology, such as mobile apps and IoT wearable devices, which allow caregivers to monitor and reflect on different aspects of their infants' lives. Although technically, baby tracking goes beyond sole self-tracking, it is deeply intertwined with the caregiver. For example, mothers track breastfeeding and caregivers in general track for management, e.g., for knowing when to administer the next medication dosage. As Yamashita et al. [112] point out in tracking others in health contexts, tracking is not just about observing the tracked individual but also about the tracker's own role and actions toward the care recipient.

Literature on baby tracking has typically focused on supporting the high-level goal of ensuring a baby's well-being, which represents an abstract hedonic goal [88]. To support this goal, the literature has mostly centered around tracking tools that aim to support tracking growth and the early detection of developmental delays, such as asking questions to compare progress against clinical milestones [43, 59, 67, 103, 105]. These tools are often focused on tracking major milestones that develop over the baby's first months and years of life, such as rolling over, beginning to walk, or saying their first words. Collecting data and reflecting on it is, therefore, infrequent. For example, in thousands of parents using the babyTRACKS milestone tracker over multiple years, Ben-Sasson et al. report that parents entered 8.41 milestones on average [10, 11]. In using baby-tracking technology for monitoring daily activities, which is our focus, parents move from these more abstract and less-measured goals to concrete and quantitative goals, similar to other domains [88].

Caregivers also turn to baby tracking for other motivations. For example, to keep a variety of records, such as photos, either at the request of their pediatrician or to preserve memories [67, 68]. Parents also track to communicate with medical providers [15, 67, 108], coordinate care between partners [71], discuss and share tracking data with other family members [110], or reach consensus on differing observations during baby care [103]. New parents also seek out tracking and monitoring devices to alleviate feelings of anxiety and give them a higher sense of control [28, 79, 110]. Finally, prior work has identified that some caregivers use baby-tracking technology for memory augmentation, for example, by providing them with an alternate, more reliable means of remembering feedings and bowel movements [28].

Although past literature has identified different goals that motivate parents, little detail has been shared about how baby-tracking technology supports them in reflecting to achieve these goals. Our work finds similar motivations for baby tracking but centers them around the questions of *why* parents reflect on different time frames, *when* reflection occurs in relation to data collection, and *how* technology supports reflection in relation to these different time frames.

4 Methods

We recruited study participants throughout the United States. We began by recruiting via emails and word-of-mouth at local daycare centers near our home institutions. However, we were concerned

that these perspectives might be too uniform, such as sharing similar socioeconomic backgrounds with our research team, thus inadvertently introducing bias. To mitigate this, we expanded our recruitment to online communities that allowed us to advertise, such as Reddit, and through ResearchMatch.org. Administrators of online communities typically sought to protect the identities of their members, and we, therefore, purposefully limited the information we requested from participants, settling only on their and their infant's age and their self-identified gender.

Our calls for participation specified that we were interested in parents of infants (up to 12 months old) who have been tracking their daily routines (e.g., nutrition, sleep, diapers) using technological solutions such as apps or spreadsheets. We chose to include spreadsheets as custom tracking solutions are not uncommon among 'extreme users' [24], and our findings might extend to other users if their capabilities existed in ready-made technology. We restricted the age of tracked infants to up to 12 months as physiological changes that happen around that mark make tracking less useful. Once children enter the toddler years, they often transition to cow's milk. Their diets are more similar to that of their caregivers, and they mostly sleep through the night. Interested participants filled out a pre-screening Qualtrics questionnaire to provide basic demographic information about their age, gender, age of the child(ren), and tracking habits, which included whether they tracked with another caregiver, what categories they track(ed), and what apps or other forms of technology they used for tracking. Participants could opt to share representative screenshots of their baby-tracking technology. Qualifying participants were invited for a Zoom interview estimated to last up to an hour and were compensated 30 USD in Amazon gift cards. Our respective IRBs approved the recruitment and interview protocols.

4.1 Participants

We received 58 responses to our Qualtrics survey, which, after filtering for spam and ensuring that participants would meet our qualification criteria, resulted in the recruitment of 20 participants. Table 1 shows the demographic information of the participants, as well as the types of baby-tracking tools they used. Overall, we interviewed 18 parents who identified as female and two parents who identified as male. One of the female parents was in a same-sex relationship; all others were part of a heterosexual relationship. In all cases, both parents were involved in the upbringing of the child(ren). Fourteen participants were first-time parents, four participants were second-time parents, and two were fourth-time parents. At the time of the interview, parents' ages ranged from 27 to 41, with the average being 34.1 (average for females: 34.5). Their infants were as young as 1 month and as old as 12 months, with an average age of 6.35 months. One interviewee (P15) had twins. Six participants were recruited from our local communities and 14 from ResearchMatch.org and Reddit.

Many of our participants started tracking upon recommendation by their medical team (9/20), although they did not have any specific health concerns or because a peer who had a child recently recommended it as a good practice (9/20). Many parents tracked to more efficiently and effectively communicate with their medical care team (17/20) and other caregivers (11/20). Every participant mentioned tracking for better management of their daily routines. Other reasons to start tracking included to augment their memory (17/20), to feel a sense of control (16/20), for encouragement (9/20) and real-time monitoring (6/20), to gain a deeper understanding of their baby (12/20), to satisfy their curiosity (7/20), to experiment with different routines (11/20), and just in case the data were to be useful at some point (8/20). Many of these reported reasons have been identified in prior work, e.g., augmenting their memory [28], feeling a sense of control to alleviate anxiety [28, 110], and communicating with other caregivers [67, 110].

The most tracked categories (aspects of an infant's life being tracked) were nutrition (i.e., breastfeeding, bottle feeding, pumping, and/or solids) and diapers, which were tracked by all 20 participants. Seventeen participants tracked sleep. Growth (especially weight) and medicine (e.g., vitamin D, pain relievers) were each tracked by 10 participants. Additionally, four participants tracked baths, and three tracked 'tummy time.' The most popular tracking apps were Huckleberry [58] (used by nine participants) and Baby Tracker [76] (used by seven participants). Other apps included Solid Starts [102], What to Expect [41], Nara Baby [87], and Dairy-Bar [26]. Two participants used the app that accompanies the SNOO bassinet [54], and one participant used the app that comes with the Owlet Dream sock [95]. Five participants used spreadsheets as a customized solution for some tracking aspects. Not all tracking activities were done directly by parents: three participants sent their kids to a daycare that used a shareable tracking platform, such as BrightWheel [18], Transparent [107], and ProCare [99], and three received paper-based reports from their daycare.

4.2 Interview Procedures

We conducted semi-structured Zoom interviews, wherein the participants would describe and answer questions about their baby-tracking behaviors. The interviewers prepared questions based on the pre-screening questionnaire responses. Given new parents' limited personal time, we capped the interviews at one hour, including procedural matters such as introductions, receiving participant consent, and handling compensation. Excluding these procedural matters, the interviews lasted, on average, 45.08±10.73 minutes.

Our interviews consisted of three parts. First, we asked general questions, inquiring further about what participants tracked, whether they tracked collaboratively with another caregiver, and the importance of tracking different categories (e.g., nutrition, sleep, diapers, medication). In the second part, we asked about each tracking category and how needs evolved over the baby's lifetime. We used an interactive Figma board to visualize their responses and guide the discussion surrounding parents' tracking changes across various baby care categories. We noted specifics about their tracking and reflection behaviors about each category they tracked, discussing different moments in time ranging from the baby's birth to the current stage. For the closing questions, we asked participants about their anticipated timeline to stop tracking (if they planned to stop). We also asked them to detail the advantages and disadvantages of the technologies that they used, as well as any recommendations that they had to improve them. Our questions often organically led participants to pull their smartphones and

Table 1: Self-reported demographic information and baby-tracking technology used by the 20 parents we interviewed. The age of infants is noted in months. All participants were in a two-person relationship raising their infant(s) with the other parent.

ID	Age	Gender	Baby Age (months)	# Kid	Tracks with other Caregivers	Baby-Tracking Tools
P1	37	Female	8	1st	Husband, daycare	Huckleberry, SNOO, paper
P2	41	Female	7	2nd	Husband, daycare	Owlet Dream, Baby Tracker, paper
P3	37	Female	3	2nd	Husband	Baby Tracker, SNOO, spreadsheet
P4	36	Female	10	1st	Husband	Baby Tracker
P5	31	Female	5	1st	Husband	Huckleberry
P6	30	Female	1	1st	No	Huckleberry
P7	33	Female	12	1st	Husband, daycare	What to Expect, DairyBar, paper, Procare
P8	27	Male	7	1st	Wife, grandmother	Huckleberry
P9	34	Male	9	1st	Wife	Baby Tracker, spreadsheet
P10	36	Female	8	1st	Wife, daycare	Baby Tracker, Brightwheel
P11	35	Female	10	1st	Husband, daycare	Solid Starts, paper, Transparent
P12	41	Female	9	4th	Husband, grandmother	spreadsheet, paper
P13	36	Female	8	4th	No	Huckleberry, paper
P14	36	Female	7	1st	Husband	Baby Tracker
P15	35	Female	9	1st/2nd	No	Huckleberry
P16	34	Female	3	1st	Husband	Nara Baby
P17	27	Female	1	2nd	Partner	Baby Tracker
P18	31	Female	2	1st	Husband, Sister	Huckleberry, spreadsheet, paper
P19	33	Female	1	1st	Partner	Huckleberry, spreadsheet, paper
P20	32	Female	7	1st	Husband, daycare	Huckleberry, paper

look into their baby tracking apps to better understand their habits. Many participants showed us different aspects of the technology on camera to augment various discussion points.

4.3 Analysis

For our analysis, the audio of all the videos was analyzed using reflexive thematic analysis in six phases [17]. As a first step, the first three authors distributed the recordings and transcribed them. During this process, they familiarized themselves with the data by keeping notes in an individual log about each transcript and jotting down ideas about the portion of the dataset they transcribed. They then collectively discussed and shared these notes with the rest of the team. In the second phase, the three authors worked in joint sessions on each transcript, using an inductive orientation to generating codes and constructing themes. Through collaborative sessions with the entire research team, we iteratively revised and defined the final themes and codes before proceeding with writing. Our goal with this approach to analyzing our data was to "achieve richer interpretations of meaning" [19] through conversation among the authors that extends beyond a focus on coding reliability. During these meetings, we settled on temporality as a core focus. Through this lens, we applied five parent codes (*why track*, *types of reflection*, *collaboration in tracking*, *changes in tracking*, and *technology recommendations*) and 29 child codes to characterize participant's motivations and approaches to tracking across different time frames. After coding all transcripts, we collectively defined the different windows under which participants reflected and began writing up our findings. We additionally downloaded all the baby-tracking apps mentioned by our participants to review the design features that support short- and long-term reflection.

4.4 Positionality Statement

As researchers, we want to acknowledge our backgrounds and experiences with baby tracking. The last two authors both became new parents in the two years prior to running the study. They both used baby-tracking apps extensively, tracking multiple categories, such as breastfeeding, pumping, solids, diapers, and sleep, for more than one year. They both have used Huckleberry after independently researching the most popular apps. The last author has additionally used Baby Log. They both maintain social connections with new parents who have used and have anecdotally shared their experiences with these and other baby-tracking apps and IoT devices. The experience of both last authors with baby tracking brought awareness about the importance of short-term reflection and likely shaped how they interpreted how participants reflected on the data they collected. The first three authors are all students who do not have prior experience with baby tracking.

4.5 Limitations

Because we tried to minimize the information we requested from our participants (their and their infant's age and their self-identified gender), we do not have information about their ethnic and racial background, level of education, and socioeconomic background. Below, we contextualize the demographics of our participants within the landscape of the U.S. demographics and the limited parental support structures.

On average, our participants were older than typical first-time parents in the U.S. (27.4 years for mothers at first birth [94] vs 33.7 years for first-time mothers in our study). We suspect that tracking behavior might vary between older and younger parents, such as older parents being inclined to track more factors of their newborns due to higher rates of complications during the pregnancy process. Although we did not explicitly inquire about their socioeconomic status, we have indications that our participants came from a higher socioeconomic background and were less racially diverse. Seven interviewed parents brought up on their own that they had returned to work after a few months without indicating whether they were on paid or unpaid leave before that. For context, in 2023, only 28% of workers in the U.S. had access to paid family leave [90]. Mothers who utilize paid leave during their first pregnancy are more likely to be older, less likely to be a racial or ethnic minority, and more likely to be married at birth, have a higher education, and work full-time before the birth [62]. Six out of 20 participants further mentioned using a daycare center, where they received daily reports either on paper or through a dedicated app. This indicates a more formal childcare environment, which is often inaccessible to lower-income families [34].

Our participants were also inherently interested in baby tracking, finding the practice beneficial and keeping with it. Due to their diligence with tracking, we did not observe much lapsing, which prior work suggests can make it difficult to derive benefit from reflection [40]. Additionally, a handful of the parents used pen and paper for some of their tracking because of privacy concerns, and a few expressed concern about quantification. However, these concerns were not widespread, though prior work has stressed their risk [5, 73, 79, 110]. Additionally, prior research has highlighted concerns about baby-tracking technology hindering parents' intuition about their baby's needs and causing them to rely on technology rather than the baby's cues [47], but only one of our participants raised such concerns. Because our study represents parents who self-selected to use tracking technology, these perspectives were likely underrepresented in our work. However, such tensions are important to consider when designing with temporality in mind.

5 Results

Below, we describe when parents tended to reflect on data relative to when it was collected, surfacing the goals that motivated them to reflect at each of these different points in time.

5.1 Short-Term Reflection

Within a single day, parents tended to reflect on data about their children through three distinct mechanisms. Parents often reflected during data collection or immediately after the data collection was concluded to compare the recorded data against medical guidelines or typical patterns. Second, to avoid needing to remember details like when their child last ate, parents frequently reflected back on previous entries from the day. Finally, parents also reflected cumulatively across the day to compare against daily goals and prepare for the future.

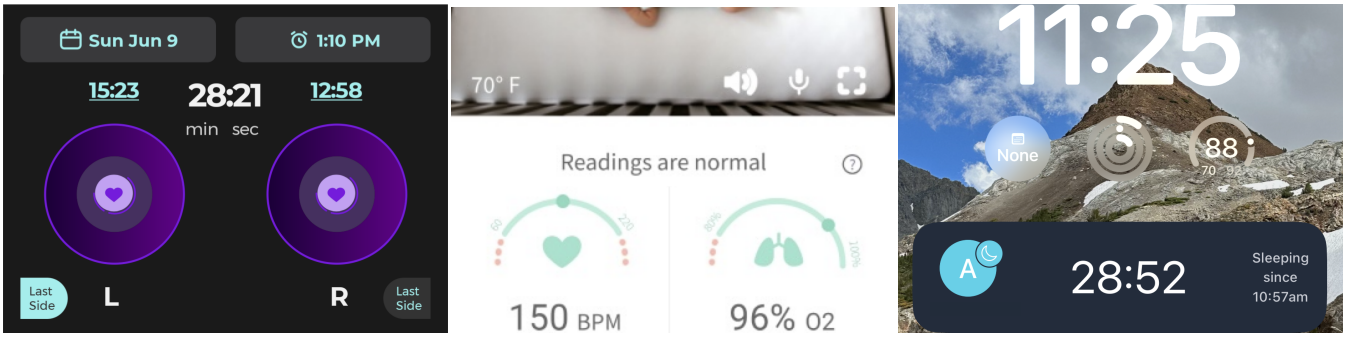
5.1.1 Reflecting during or immediately after data collection. We observed that participants reflected on their baby's well-being in real time while they were collecting data (either manually or automatically) or immediately after the data collection was completed. This observation is similar to how Li et al. [75] and subsequent adaptations (e.g., [40]) have understood short-term reflection, especially around reflection-in-action [101]. Parents tended to do this type of short-term reflection primarily to check the alignment of what was tracked with medical guidelines and prior patterns. Additionally, such real-time or immediate information made them more prepared for the near future. Figure 1 illustrates different ways that parents reflected during or immediately after data collection using baby-tracking technology.

Checking alignment with medical guidelines and prior patterns. One of the primary reasons parents reflected immediately was to confirm that what was tracked was in alignment with medical guidelines. For example, P6 used Huckleberry to monitor that her newborn did not exceed the recommendation of 3–5 minutes of 'tummy time'. P1 used Huckleberry to reflect on whether her baby ate enough: *"I do like to get a sense of how many minutes he eats because I know if he only eats five minutes, he probably didn't get enough."* Some parents reflected for peace of mind and control regarding the well-being of their child. P2 used the Owlet Dream sock to monitor her baby's vitals, specifically heart rate, for signs of illness: *"[I tracked] mostly for peace of mind in terms of me getting a better night's sleep, knowing that there's something that's sort of monitoring my child and [...] that I know will go off if there's any issues and wake me up."*

Parents also reflected to understand whether the collected data followed prior patterns they had implicitly observed in their babies. If the data was not typical or expected, parents could intervene while the baby's activity was still ongoing. For example, P19 would look into the currently-tracked breastfeeding duration on Huckleberry and compare it with her prior experience with her baby: *"Especially earlier in her life, she was a little bit of a sleepy eater. So what would happen is she would kind of stop after like 10 minutes. But if I know that she's capable of going for 20 minutes on one side, then I would try to use techniques to encourage her to continue eating."* P3, used the SNOO bassinet and its accompanying app *"to see how long she's been sleeping, especially if she starts to stir. And if I think she should be able to go a little bit longer, I will bump up the movement one level so that she gets back to sleep. My baseline is I want her to get at least five hours of sleep stretch; if we're under that, I'm more likely to bump it up [increase the SNOO's rocking motion] a little bit."*

Preparing for the near future. Immediate reflection also supported parents in preparing for the near future. For example, P14 noticed that after recording an unusually short nap on Baby Tracker, they could anticipate that the baby would be crankier: *"When he first wakes up, we also pay attention to whether it was a short or a longer nap. If he takes a short nap, then he might not be in the best mood. "* Noticing on Baby Tracker that breast milk was expressed or formula was prepared allowed P9 to prepare for when to feed his baby: *"The most important thing is shelf life of knowing when milk is expressed, how long it will keep safely for, or if you make formula, when it was made and how long it will keep for before it is recommended to dispose of it."*

Parents also reflected on recent data to schedule future actions, often setting up alarms and reminders. This often occurred in the context of medicine, which needs to be carefully spaced out based



(a) (b) (c)

Figure 1: Participants used baby-tracking technology to reflect on what was being tracked or was just tracked. For example, (a) they would look at the total duration of a breastfeeding session to confirm that it is within the medical recommendations and to plan the next time they would feed their infant (What To Expect App, scenario recreated by authors), (b) look at automated live readings of heart rate and oxygen levels to confirm that both values are normal and no action is required (Owlet App, promotional material [61]), and (c) consult glanceable ongoing sleep timer shown as lock-screen widgets to prepare for when their infant would wake up (Huckleberry App, scenario recreated by authors).

on medical guidance around how much time should elapse between doses. P10 tracked medication when her baby was sick to schedule an alarm for the next dose: *"We're tracking which medicine we gave, when we gave it, and how much so that we know when we can give it again if need be."* Similarly, P11 scheduled an alarm for the next feeding immediately after completing a feeding: *"I actually had an alarm that I just move, and every time I'd feed her, I'd move it to be three hours from when I was feeding her."*

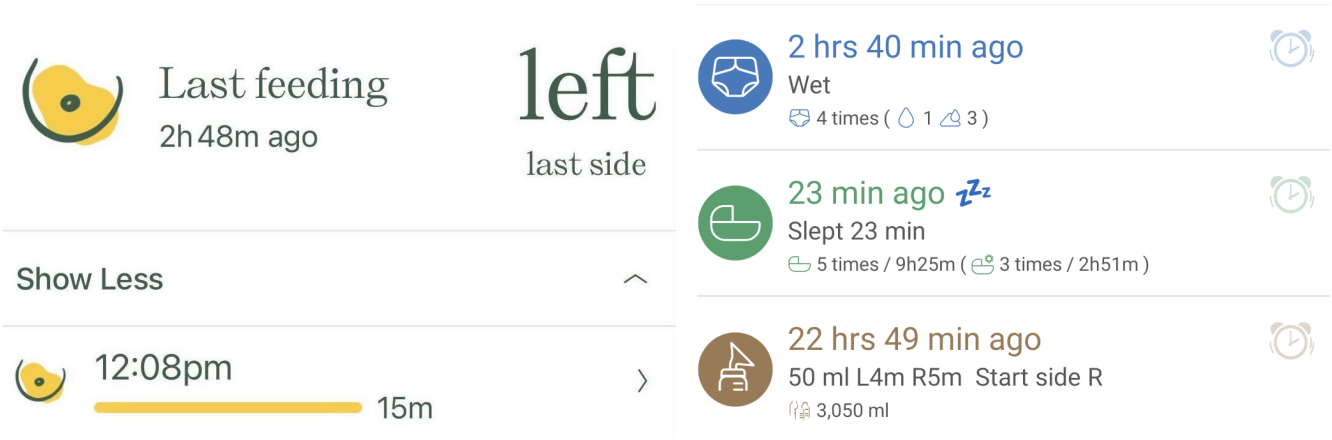
5.1.2 Reflecting on the last entry. Participants frequently reflected on the last entry or entries tracked to augment their memory, plan ahead, and bypass direct communication when multiple caregivers were involved. Here, entries were separated by a few hours for typically tracked categories, such as nutrition, naps, diapers, and medication. Participants typically tracked such categories multiple times a day and reflected on those entries at a similar frequency. Figure 2 shows two examples of how parents used baby-tracking technology to reflect on the last entry they tracked.

Augmenting memory and planning ahead. Participants often focused on the last entry as a means of augmenting their memories, which they often needed due to the exhaustion and difficulty of taking care of a newborn [6, 48]. P7 stated that tracking was especially helpful immediately following her baby's birth, as *"there's a lot to keep in your mind, and then you're exhausted, so you're not at your best mentally."* P19 emphasized the exhaustion of having a baby and the ease with which one might forget things: *"Because she's still young and we're still tired all the time, it's easy to forget things, so it's helpful to have [Huckleberry]. It's easier for me to remember to put it in an app than to remember the actual information."* For P15, who had twins, using Huckleberry to recall which baby fed on which side last was particularly important both to ensure that they both ate adequately but also to protect her supply because her children had different eating habits.

Parents often looked in their apps to remember what happened recently in the baby's life to determine what to do next. For example, P7 routinely considered recent activities on What to Expect: *"We kind of had a rundown of 'check the last time that she ate,' 'check the last time she had a diaper change,' and 'check the last time she slept and for how long.' You could see all of those three things in the app and know this one was done the longest ago, so I'll start there."* She continued to describe how monitoring when the baby had a last dirty diaper could help detect constipation. P20 would determine the next nap by looking at the last entry in Huckleberry. Similarly, reflection on previous entries confirmed whether the spacing of medication was adequate. To determine whether her child could receive more acetaminophen, P14 would check Baby Tracker: *"if it's been more than six hours and we notice he still has a fever or something, then we can give another dose."*

Tracking for memory augmentation was especially pertinent to breastfeeding parents, who used tracked data as a reminder to switch sides when feeding next. As P16 stated, *"It's helpful to also have a reminder of which side I started on last so I can make sure that I'm switching back and forth. Sometimes I'll access and reference the app [Huckleberry] to know which side to offer."* P19 also reflected on when the baby ate last to know whether she would need to feed again: *"If she wakes up at 4 am but I look at [Huckleberry] and see that she ate her bottle an hour ago, I know that she's probably not hungry. And so then I know I don't need to offer to feed her, I probably need to soothe her instead."*

Bypassing the need for direct communication among caregivers. When multiple people were involved in tracking and caring for the baby, such as parents taking turns or the baby being at daycare, participants often found this reflecting on prior entries advantageous. When taking over care duties, reflecting on the last entry allowed parents to understand what the baby did while they were in someone else's care and make plans. P10 noted that having a record of the baby's last feeding made it easier to prepare for the baby's needs without having to ask the other parent when taking shifts *"I didn't have to wake her up to ask 'when did you last feed the baby?' Or 'what time did she wake up?' It was in [Baby Tracker]."*



(a) (b)

Figure 2: Parents used baby tracking to reflect on what they last tracked. For example, (a) they looked at how long it has been since the last feeding and which side was the last one they breastfed on to determine when and which side to breastfeed next (Nara Baby App, scenario recreated by authors). Similarly, (b) they kept an eye on how long it has been since the last diaper change, nap, or pumping session to better anticipate or plan the next one (Baby Tracker App, shared with permission by P6).

P4 echoed that tracking on Baby Tracker allowed her to circumvent the need to explicitly communicate with her husband. When attending daycare, parents often receive a report for the day. In order to plan their baby's sleep schedule, P20 would focus on the last entry that daycare caregivers had written down, *"Our goal is to always have him asleep by eight. But if it's been a long time since his last nap or if he did not have a good day of naps at daycare, we try to make sure he's asleep no later than 7:30."*

5.1.3 Reflecting cumulatively. Parents also reflected cumulatively on their baby's activities over the course of a day to check whether they met daily medically recommended goals or to prepare for the remainder of the day or the next day. Figure 3 provides examples of different visualizations that parents would look at to reflect cumulatively.

Meeting daily requirements or goals. Parents tended to reflect on the past day to verify that daily goals and totals were met. Some examples of this included tallying up the number of diapers, hours of sleep, food volume, and frequency, often to meet medically recommended totals. As P3 stated: *"Every day I take a look at Baby Tracker and see how many times she's nursed because they recommend still at this point eight times a day minimum."* Similarly, P6, who had a one-month-old baby and uses Huckleberry, looked to meet the diaper goals given by their doctor: *"When I went to her first pediatrician visit, the doctor told me that she should have a wet diaper at least six times a day. So that's been my main goal, to keep an eye on how much she pees; if it's six times a day, I'm satisfied with it."*

Looking back on the past day provided parents with a sense of control, helping them confirm that their baby is healthy and meeting daily requirements. This was especially true for first-time parents, as P7 noted: *"As a first-time parent, it was just reassuring to be able to look back [on What to Expect] and say, yes, she did eat 32 ounces today."* P14 checked in on Baby Tracker totals not just to ensure that the baby is on track to meet daily requirements but also to better understand and predict her baby's behaviors: *"In the early afternoon, we check he's had like 20 ounces or 24 ounces total. We say, 'he's pretty much on track to how much he's normally eating per day.' By the end of the day, it's like, 'he normally eats around 34—35 ounces.' So we know he will likely sleep through the night."*

In meeting daily requirements, P2 mentioned that it would be helpful for apps to recommend guidelines that align with those given by medical providers: *"It would be helpful if these apps at least recommended the guidelines [...] Usually, kids of this age should be feeding X amount of days or diapers minimum should be six a day. It could be helpful if it was more incorporated because, as a parent, you just don't know."* P10 mentioned the potential benefits of having data-driven recommendations on what to do when they noticed that their child's cumulative food consumption within a day was low, especially for inexperienced parents: *"If an app told you or provided recommendations for what you should do if you are deviating from average, I might take more action."* However, P10 was also aware of the downsides of excessive tracking and recommendations, saying that it might be an *"overwhelming amount of anxiety."* P8 agreed that if tracking solutions required monitoring too much information, it leads to *"analysis paralysis."*

Preparing for the remaining day or day ahead. Additionally, parents looked at daily totals to manage decisions about the remaining activities of the day, such as how much to feed in the last meal or when to put the baby to sleep for a nap. For example, P10 adjusted his baby's sleep schedule based on the day's sleep totals thus far. He stated that daily, they tracked on Baby Tracker *"to have daily goals met [...] the goal is to sleep 20 hours a day. 'How close are we to that? Do we have to let the second nap be longer and let her sleep more than normal because the first nap was short? Do we expect that bedtime will come earlier today because she did not sleep a total amount today that is normal?'"*

For parents who pumped, such cumulative data could also be used to plan the night ahead. For example, P18 stated, *"Throughout*

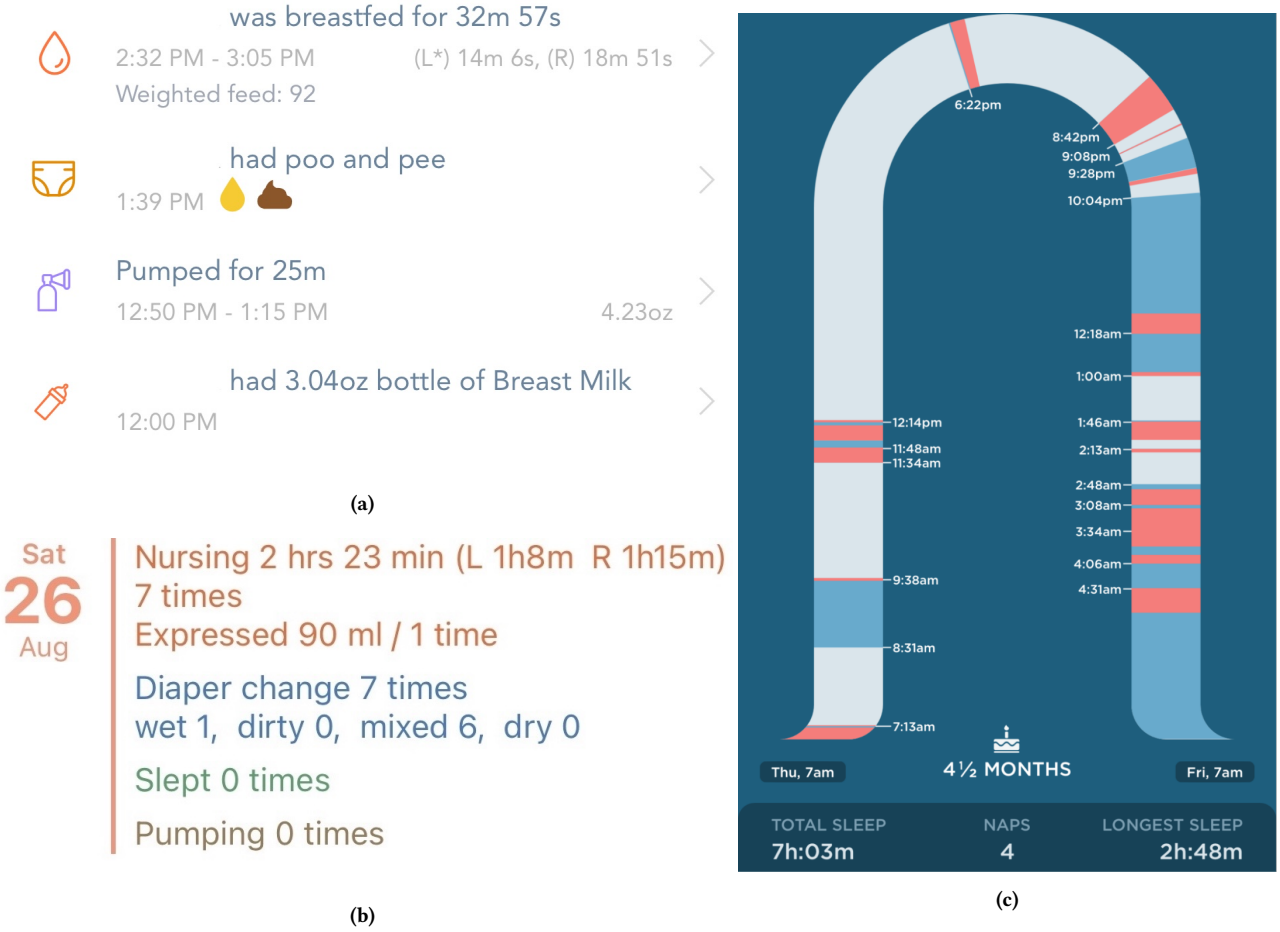


Figure 3: Parents examined cumulative views of what they tracked in their baby-tracking apps to better understand the day. These ranged from (a) list formats, where all individual logged events are listed, (b) summaries, which allow for a holistic view of what happened throughout the day, ensuring progress toward totals, or (c) visualizations that highlighted chronology alongside totals. (a: Huckleberry App, shared with permission by P19; b: Baby Tracker App, shared with permission by P2; c: SNOO App, shared with permission by P1).

the day, it [Huckleberry] would give you a total of how many times you've pumped for the day, and how many ounces you've pumped, and your total pumping time. I'd look at all of those metrics to see 'how many more times today I need to pump. And when can I start planning my nighttime pumping?' Because I want to try to time it so that I can have some longer stretches of sleep. So kind of looking at how I can structure the rest of my day based on what I've already done that day." P15 monitored feeding through the day so that she could prepare for the coming night, explaining that looking at the total amount of milk consumed allowed them to predict their baby's sleep. P18 utilized such information to recognize periods of intense 'cluster feeding': *"In the evening time, if she's really fussy and it seems like she wants to eat like every hour, if I look at like the total amount that she's gotten for that whole day and if it's below what her normal average is, then I'm like, okay, she's probably cluster feeding, and we do actually need to feed her every hour."*

Knowing cumulative information about the past day allowed parents not only to plan within a day but also to better anticipate the next day. For example, P20 looked at Huckleberry's daily summary of bottle data to prepare bottles for the upcoming day: *"I usually look at the daily summary to track and see, 'okay, we've got enough for our bottles tomorrow' or, 'we need to put him to bed a little sooner tonight because he only got 12 hours total of sleep yesterday.'"* Similarly, P8 mentioned using Huckleberry's summary of the current day to determine the goals for the next one: *"Daily trends for sure helped us get an idea of what it looked like today. This is what I'm going to aim for tomorrow."*

5.2 Long-Term Reflection

Parents reflected over days, weeks, or months of their child's data to establish what the norm for their child is, understand whether recent data follows past trends or brings a new stage for the baby and the caregivers, and seek emotional support.

Identifying trends and patterns. Similar to prior work in PI (e.g., [1, 23, 98]), parents used long-term reflection to identify trends and patterns, leading to deeper insights about their babies. For example, P9 would look at Baby Tracker for recent sleep trends to understand if his baby was experiencing a sleep regression: *"Knowing the total average of how many hours a day a child would sleep and then looking back it's like, she didn't sleep that much today, and then you see for multiple days in a row for seeing that trend it's like, perhaps we are having a regression right now. It's been two to three days consecutively where the total number of hours left is less than average."* Long-term reflection was also associated with management, as parents made decisions for the future based on established trends. For instance, P14 looked at Baby Tracker for diaper usage trends when planning for travel: *'Sometimes I like to check how many diapers he has used in a day or in the past few days [...] it was useful when we were traveling because it was like, okay, we have these many diapers. He's using an average of eight diapers per day. Is it enough for us to go there and back, or do we need to buy more before we come back?"*

When parents noticed deviations from previously established trends, they might make decisions on how to proceed. P16, by looking at Nara Baby for changing trends, would make changes to increase her milk supply: *"If I start to notice that it is dramatically declining, then that would tell me either I need to change how I'm pumping or change something else about what I'm doing, giving me feedback about what to do to protect my supply."* Sometimes, observed trends led parents to reach out to their medical providers, using long-term data in their communication. For example, P11 communicated concerns regarding their baby's feeding patterns: *"After noticing that it was only maximally eight ounces a day, we definitely checked in with our pediatrician."*

Seeking encouragement and reminiscing. Parents also reflected over the long term to seek encouragement and reminisce during challenging times. For instance, P5 mentioned that they found Huckleberry was valuable in verifying that sleep has been improving, *"I'll scroll back to kind of remind myself that it was worse or to see like, oh, actually, it was better. That's kind of like how we processed that it was a regression because we could see we were getting longer stretches, and now we're not. In the day-to-day, it can feel like it's just always bad."* P17 mentioned how tracking on Baby Tracker offered reassurance by allowing her to reflect on times she was able to successfully produce enough milk for her baby, even amid ongoing challenges with her breastfeeding supply: *"Breastfeeding has not been very successful with her. It was more being able to go back and look and say, 'Hey, you were able to get some done this day. You were able to do it sometimes here and there for her.' So it was more so a gratification type of thing."*

Parents also used long-term reflection for sentimental reasons like reminiscing. For example, P2 appreciated the Baby Tracker app's feature that allowed them to revisit moments from when their baby was two weeks old, a period that was difficult to recall clearly: *"you can go back and see what you were doing when she was two weeks old, which it's kind of a crazy period. It's hard to remember a lot of it, but it's kind of fun to go back. This is what we did, for like sentimental reasons a little bit."*

6 Discussion

The case of baby tracking provides a useful case study of the different goals that people have shortly after they have collected data. Parents frequently described reacting to their data to inform near-term actions, such as when to put their baby to sleep or whether their baby had eaten enough throughout the day. Our findings suggest that in baby tracking, *why* parents wanted to reflect on their data influenced *when* reflection occurs in relation to data collection, and *how* technology supported that reflection. We consolidate these insights into a framework of three distinct windows of short-term reflection and examine how design can better support each of them.

6.1 Introducing a Framework for Temporality of Reflection in Baby Tracking

Informed by the findings of our study on baby tracking, we now synthesize the vocabulary introduced in the Results into a theoretical framework of temporality of reflection in baby tracking, which encompasses both short- and long-term reflection.

In summary, our framework suggests that in baby tracking, short-term reflection on tracked data occurs in three distinct windows:

- The *Immediate Window*, where parents reflect on data during or immediately after tracking has concluded on what occurred.
- The *In-Between Window*, where parents reflect between two tracking activities on information gathered during the last entry.
- The *Cumulative Window*, where parents reflect cumulatively at the end of a time period where they set one or more tracking-related goals, often a day.

Long-term reflection on tracked data occurs when users reflect on many collected data points, typically focused on changes over time or progress toward larger goals. Figure 4 provides a visual representation of the proposed framework of temporality of reflection for baby tracking along with typical questions asked in baby tracking to facilitate them.

In our study, we observed that participants tended to undertake short-term reflection during the same day as data collection. Participants' goals for short-term reflection were often guided by medical recommendations that revolve around a 24-hour period, for example, the total number of diapers or breastfeeding sessions they should aim for within that time frame. In contrast, long-term reflection involved reflection on multiple data points and spanned longer periods of time, ranging from a few days to weeks. Long-term reflection typically focused on identifying and monitoring trends and patterns, seeking encouragement that aspects are improving, or reminiscing about past events. This longer time frame aligns with how prior literature has typically understood reflection around tracking to occur [40, 75, 84].

Drawing from our study observations, we now discuss *when* parents reflect on tracked data and *why* they reflect during these different windows.

6.1.1 Immediate window of short-term reflection. The immediate window refers to reflection that occurs during data collection or immediately after it has been completed. Past HCI work (e.g., [44]) follows Schön's [101] popular concept of reflection-in-action which

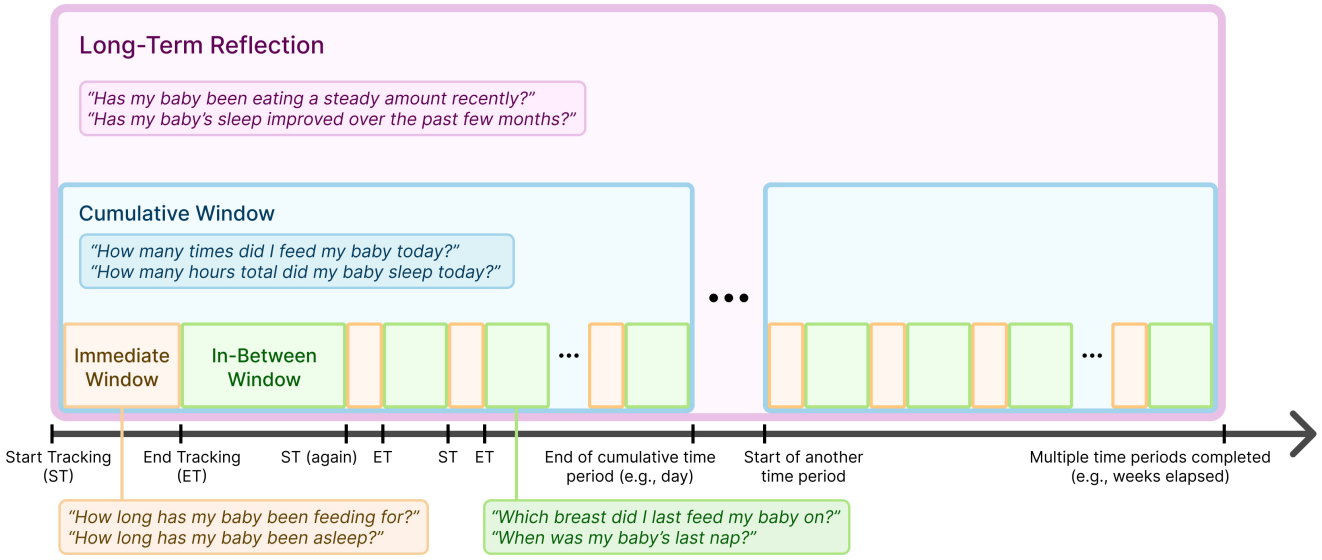


Figure 4: Our framework for temporality of reflection in baby tracking, including typical questions asked that motivate reflection in each window. Short-term reflection spans three types of windows. Reflection in the immediate window (orange boxes) occurs either during data collection or immediately after it. In the in-between window (green boxes), people reflect on the last entry, which can happen at any point between the last tracked event and the next data collection. In the cumulative window (blue boxes), reflection can happen on all or a subset of the data collected during that time frame. Long-term reflection (purple box) can happen on any longitudinal data collected over multiple time periods.

occurs while an activity is being undertaken. Reflection in the immediate window extends this timespan slightly to also incorporate reflection occurring after the data collected about the activity has concluded. In baby tracking, participants reflected as or after they tracked to check alignment with medical guidelines and prior patterns of their infant, such as to answer questions like '*How long has my baby been breastfeeding?*' or '*How long did my baby nap?*'. Such questions were particularly helpful in predicting and planning for the immediate future, such as looking at the duration of a nap that was just recorded to schedule the next nap. Participants mentioned combining such information with past trends, for example, to predict the baby's behavior if they found that it falls short of their usual sleep patterns.

Tracking, in general, can be fully manual, fully automated, or somewhere in between [21], and our observations of baby tracking suggest that goals for reflection in the immediate window are independent of how tracking has been initiated. For example, participants were able to reflect on how long the baby had been napping either by looking back at the timer they started or by checking the timer automatically started by their smart crib. Some fully automated tracking systems were often able to provide additional context to support reflection, such as enabling checking on the baby's vitals to provide some measure of sleep quality. But largely, our study suggests that reflection in the immediate window aims to provide an understanding of what occurred when tracking and preparing for upcoming events. Through this process, caregivers gradually build an intuitive understanding of their infants' patterns, cues, and recurring behaviors, which evolves into tacit knowledge [8]. This enhances their predictive capabilities over time, allowing them to better anticipate the infants' needs. For example, knowing how much the baby has slept so far allows them to predict when they are likely to wake up or whether they will be cranky because they just woke up after a short nap.

6.1.2 In-between window of short-term reflection. In the *in-between window*, reflection occurs between two instances of data collection, usually by reflecting on aspects of the last entry. This window is often utilized as a means of preparing oneself for the next tracking activity by reminding oneself of the previous one.

We observed two main reasons why participants reflected in the in-between window for baby tracking. First, in-between reflection was useful for identifying how much time has elapsed since the last entry, answering questions such as 'How long has it been since my baby ate/slept/had a diaper?'. This understanding enabled participants to plan ahead for their day, such as knowing that they still had a bit of time before the next feeding or nap. The intent with this essential to parents goal is to use technology as a memory aid, supporting the lowest level of reflection that enables revisiting data [20, 46]. Second, reflection in the in-between window also supported participants in making decisions about how to perform upcoming activities based on the last tracked data. For example, participants would seek to answer, 'Which breast did I feed on last?' so they started the next feeding on the opposite side. This process enabled parents to better manage their baby care activities while being more cognizant about their time and priorities. For example, by frequently checking when their baby last ate, they could decide

the optimal timing for subsequent tasks, such as the next feeding, following similar strategies to short-term time management planning around productivity goals [77].

6.1.3 Cumulative window of short-term reflection. In the *cumulative window*, people reflect across multiple data points collected during a part or the entirety of the short-term time interval. In our baby tracking study, participants mentioned reflecting on the data they tracked over the day in specific categories. For example, they looked at the total number of diapers changed throughout the day, the total number of breastfeeding sessions logged, or the amount of sleep time accumulated so far. Short-term reflection in the cumulative window is guided by questions corresponding to people's total-based goals and plans for the remaining time period. In baby tracking, participants asked questions like 'Did my baby eat enough today?' or 'How many wet diapers did my baby have today?' Knowing their baby's totals provided them with reassurance as it helped them determine if they were aligned with the medically recommended guidelines. If they had not met the daily guidelines, some participants mentioned working toward meeting them for the rest of the day or planning to meet them the day ahead. For example, some put the baby down for an extra nap if sleep totals were low, adjusted the amount they fed the baby during the last meal if current totals were below the target, or prepared the right amount of formula for the next day based on that day's consumption. Through this process, parents compare their infants' recorded totals against their knowledge of established benchmarks, recognizing any deviations. This process resembles retrospective reflection [33]. For example, by reviewing the total number of diapers recorded for the day, parents actively engage in comparative thinking, assessing whether their baby's feeding and hydration patterns align with recommended levels and identifying potential discrepancies.

6.1.4 Long-term reflection. Long-term reflection entails looking at changes over time or progress toward larger goals. In our study of baby tracking, participants sometimes looked at data collected in certain categories over multiple days or weeks, which is notably long in baby standards due to the rapid changes in an infant's life, but which can differ from other PI domains. For example, participants would ask questions like, 'Has my baby been sleeping enough this past month?' to gain deeper insights about their babies' habits past an individual day. Long-term reflection was useful for identifying whether they were going through an unusual period, e.g., a sleep regression or milk supply dip, and, if so, for establishing a plan for what to do as a result. Some participants also reflected on data in time frames from months to the entirety of their baby's life for sentimental reasons, such as reflecting on how much progress their baby had made toward adopting a regular sleep schedule. Overall, our study surfaces similar goals for long-term reflection to past discussions of the space, such as establishing trends and due to the emotional attachment with the first experiences in their baby's life [67, 68, 103].

6.2 Considering Temporality when Designing for Short-Term Reflection in Baby Tracking

With an understanding of when parents reflect and why, we now discuss how design can better support the different windows of reflection in baby tracking. By learning from research in other domains that looked at similar strategies for supporting short-term reflection, we discuss opportunities for improving baby-tracking technology.

6.2.1 Designing for the immediate window. To support reflection in the immediate window, current practices in our study suggest that technology should aim to prominently summarize the ongoing activity or the activity that was just concluded. Participants typically used live timers for categories where duration is important, like breastfeeding (Figure 1a) and sleep (Figure 1c). This practice supported them in reflecting on the duration of a tracked session while the activity is ongoing or has just been completed. When tracking as aided by passive sensing, immediate reflection can provide reassurance about information that is not as readily observable, such as vitals in the Owlet (Figure 1b).

Our study suggests that parents often checked in on tracked activities multiple times while they were occurring, such as seeing how long their baby had been napping. This need is often well-supported by glanceable displays, which prior studies have shown can support people in frequently monitoring other activities, like how much they walked throughout the day [25, 52, 85]. However, we observed only one example in our participants' baby-tracking apps, with Huckleberry's phone lock-screen widget supporting reflecting on in-progress naps or breastfeeding sessions (Figure 1c). Other baby-tracking apps could leverage this approach or extend it through smartwatch widgets or other passive displays. However, it is important to note that the characteristic accessibility of glanceable displays is both an advantage, in that users can always quickly glance at their data, but also a disadvantage, in that its ubiquitous presence may be distracting, overwhelming, and anxiety-inducing, concerns that have been raised in baby-tracking literature before (e.g., [110]).

Thinking beyond augmenting parents' existing practices, parents' needs suggest that baby-tracking technology could better support them in contextualizing the data that was just collected. For example, apps could indicate when a logged activity was out of the ordinary, such as informing parents that the recorded breastfeeding session was unusually short based on data collected in the past. A challenge in this space is that these sorts of alerts may be "obvious", particularly as parents begin to internalize their child's habits, as has been suggested in prior work in other domains [12, 38]. Nonetheless, this contextualization could help guide parents toward considering the implications of an unusual activity immediately after they track.

Apps supporting contextualization relative to a child's habits could further help parents establish future plans. For example, if a breastfeeding session is short, apps could help parents plan how to ensure their baby eats enough for the rest of the day. Existing features in popular baby-tracking apps, like Huckleberry and Nara Baby, provide some support toward this by allowing parents to set up future reminders, such as an alarm for when feeding should occur next or the next nap should be. However, baby-tracking apps

could better facilitate planning more holistically while taking into account specifics about the event that was just tracked, such as the time of the day that it was recorded and how this relates to prior patterns.

6.2.2 Designing for the in-between window. In the in-between window, parents often sought to better understand previously tracked activities to decide how to proceed. To support reflection in this short-term reflection window, we suggest that baby-tracking technologies prominently display summaries of previous activities. Baby-tracking apps typically support understanding of tracked activities effectively by summarizing them on their "home" screen. For example, as captured by Figures 2a and 2b, baby tracking apps often display how much time has passed since the last time the baby was fed, had a diaper change, or the last pumping session and information about the last recorded entry for each of these categories.

However, our study suggests that parents often wished that baby-tracking apps would better support them in deciding what activities to do, such as offering suggestions around what activities need to be completed next and when. The first-time parents we interviewed desired greater guidance on what activity should be prioritized at a given moment and often did not trust their intuition. For example, apps could observe and highlight that it has been a while since the baby last napped or ate, which might help the parent better understand their child's cues.

Supporting reflection in both the immediate and in-between windows requires that baby-tracking technology prominently summarizes activities, whether in progress or completed. However, further work is needed to understand how design should account for the difference in reflective goals in each window. For example, we expect that if an interface tries to support the in-between window by persistently displaying a summary of the past activity (e.g., on a lock screen or watch), it might prove distracting to parents who want to use the time in between naps or feeding sessions to spend quality time with their babies furthering concerns that have been raised previously about the excessive use of baby tracking [110] and hinted by our participants when describing possible 'analysis paralysis'. Conversely, these techniques could be more acceptable in the immediate window, where the activity being tracked (e.g., feeding, sleep) is more of the current focus. So, while both the immediate and in-between windows have similar needs around what data to surface, they can differ in how technology should support the interaction.

6.2.3 Designing for the cumulative window. Similar to the in-between window, our study suggests that baby-tracking apps are typically effective at providing a summary of activities completed throughout the day, typically through lists (e.g., Figure 3a), summaries (e.g., Figure 3b) or chronological views (e.g., Figure 3c). However, parents often pointed to a desire for more data-driven or medically recommended guidance, helping them decide what to do when they are not meeting cumulative daily goals. Participants frequently brought up making a mental comparison between what the apps showed and what their medical team had recommended as a target. Baby-tracking technology could provide guidance on what steps to take if their child was not meeting medically recommended feeding goals for the day. Apps could similarly provide support around how to proceed if the cumulative data were out of the ordinary, such as noting that the milk supply has been decreasing and accompanying this with a plan for bringing it back to higher levels. In such cases, apps could also provide recommendations based on data collected across different categories. For example, if the total number of 'dirty' diapers recorded for the day was unusually low, the apps could combine this information with what was recorded about the solid foods that the baby consumed, indicating potential culprits for constipation.

However, tension exists between providing users with useful recommendations and overwhelming them with excessive data or, even worse, dangerous medical advice. Researchers have suggested that excessively relying on apps and data can lead to parents' lack of trust in their own abilities to care for their infant and reduced need to utilize their intuition and lived experiences [78, 110]. Parents would need to filter and adapt the advice they receive based on the characteristics and preferences of their children and their own values, something that has been observed in message-based dissemination systems [42]. Moreover, medical recommendations in the space describe the habits of "average" children, while parents quickly discover that their infants' needs and growth do not always perfectly align with such recommendations. Additionally, many children have well-understood reasons for being outside of these recommendations, such as preterm babies who have different nutritional needs than full-term babies. When tracking apps fail to account for such factors, including the inherent diversity of experiences, they both serve as a frequent reminder that the experience is not "normal" and have the potential to offer unrealistic guidance [45]. Further, guidance can verge on dangerous territory as parents can become too reliant on the technology recommendations instead of turning to their medical team, especially in periods when their baby should receive medical care, for example, because they are ill.

Finally, many baby-tracking apps struggle to support reflection in the cumulative window because they do not allow customization of the interval length users find useful to reflect on cumulatively. We observed that one app, Huckleberry, provides some support toward that by allowing users to set when a new day begins based on their usual morning wake-up time (e.g., it starts at 5 am and ends at 9 pm.) However, even this feature is not widespread, and other apps, like 'What to Expect,' have a default interval of 24 hours that always starts at 12 am. A more flexible approach could instead rely on when the baby wakes up rather than a set time. This approach can also help adapt to changes in the baby's routines as they grow, potentially enabling more consistent comparison within a baby. Supporting the customization of the cumulative window will allow parents to better manage the tracking period according to their (or their child's) daily needs and routines.

6.3 Considerations Beyond Baby Tracking

While we primarily focused on temporality of reflection, we observed a range of collaborative practices around baby tracking, which would warrant further investigation. For example, parents and other caregivers used short-term tracking for handoff purposes, such as informing another about what the baby did when in their care. Further work could contribute to a better understanding of

what extent tracking features assisted with this sort of communication, and how to design technology to improve communication. For example, in other domains, it has been suggested that manual tracking can support communication between caregivers [112]. But particularly given the complex interpersonal ecosystem in baby tracking (e.g., parents, daycare, other caregivers), it would be valuable to better understand and improve any breakdowns in short-term tracking support [86].

Beyond baby-tracking, there is ample opportunity to explore short-term reflection in other PI domains and develop a more holistic understanding of people's reflective needs. When characterizing the three windows of short-term reflection in baby tracking, we observed parallels to other common tracking practices. For example, similar to the immediate window of baby tracking, users of apps for management of type 1 diabetes reflect on their blood glucose levels immediately after manually logging them to make decisions about whether to take insulin or consume sugar [7, 81]. We found that cumulative reflection goals in baby tracking appeared similar to classic goals in daily physical activity monitoring, such as preparing for the remainder of the day or coming up with a plan for future days.

To support this understanding, further work could review common goals across domains, as well as typical design strategies used by tracking apps to support them. These observations could surface under-explored opportunities in particular domains. For example, we found glanceable displays to be an underutilized strategy to promote short-term reflection in baby tracking. The short-term reflective needs in some domains may result in some windows being more prevalent than others or may require refining some of the definitions we have established in baby tracking. For example, in step tracking, reflection in the immediate window may be less relevant, while the cumulative window is more important, as people may be more concerned with how much they walked in total versus specifically after an event.

One area that we see having parallels with the temporality of reflection and practices observed in baby tracking is that of managing chronic health conditions. People with chronic conditions, e.g., multiple sclerosis [3], typically seek out tracking to gain control over their experience, which is similar to how many participants described their motivations for baby tracking. Chronic conditions typically require significant daily maintenance and planning to manage, making technology for short-term reflection particularly valuable. Both baby tracking and chronic conditions typically start with a state of unknown at the beginning, with significant initial tracking efforts around following the day-to-day needs. Additionally, prior work has surfaced similar reflective needs immediately following an activity related to chronic care management. Management of type 1 diabetes is accompanied by multiple blood glucose tests a day, and past studies have indicated that users of diabetes smartphone apps reflect on their blood glucose levels immediately after manually logging them to make decisions about whether to take insulin or consume sugar [7, 81]. Prior literature also describes use cases that parallel reflection in the in-between window. In such cases, one might ask, 'When did I last take my medication?' to determine when to take the next one, similar to questions asked by parents about what they tracked last. In managing diabetes, for instance, tracking the time of the last insulin dose is crucial to ensure that the next one is administered at the correct time [81].

That said, we recognize that chronic conditions as a whole have characteristics that may not align with the temporal aspects of reflection of baby tracking, and individual chronic conditions may have additional specific needs. Chronic condition management may have a greater period of self-experimentation to establish an effective care plan, while short-term baby tracking needs tend to be fairly well-understood (e.g., medical recommendations around diet, diapers, etc., in the first months of life of the baby). However, we anticipate that baby-tracking needs evolve more rapidly than chronic care needs as babies change and develop, and therefore, short-term reflective goals may continue to evolve. Additionally, prior work in chronic conditions like migraines [100] has highlighted how the impact of the condition may impact when a person chooses to track (e.g., wait to journal until after the migraine has passed), which may impact the potential for short-term reflection. Further work could compare and contrast needs in these spaces, drawing insights from how technology in each domain supports short-term reflection.

7 Conclusion

Through studying people's experiences with baby tracking, we highlight how people's varied reflective goals lead to reflection at different points in time relative to data collection. In addition to reflecting during data collection and holistically over weeks, months, or years of data, parents often reflect to address short-term needs immediately, in-between data collection, and cumulatively across the day to plan, communicate, and check alignment with medical recommendations. Baby-tracking technology should aim to better support these short-term reflective goals across the different temporality windows, such as by comparing a tracked event to data-driven trends about that baby or against medical recommendations. Further work would benefit from examining the application of these reflective windows to other tracking domains, especially chronic conditions with similar daily maintenance needs.

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