Title

Towards Multi-Device Ecosystems for Personal and Family Health Tracking

Author

Silva, Lucas M.

Publication Date

2024

UNIVERSITY OF CALIFORNIA,
IRVINE

Towards Multi-Device Ecosystems for Personal and Family Health Tracking

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Informatics

by

Lucas M. Silva

Dissertation Committee:
Assistant Professor Daniel A. Epstein, Co-Chair
Robert A. and Barbara L. Kleist Professor Gillian R. Hayes, Co-Chair
Associate Professor Yunan Chen
Professor of Clinical Psychiatry Kimberley Lakes

2024

DEDICATION

To Priscila, my wife, who took on this journey alongside me and made this work possible. Your care and partnership has motivated and supported me in every single part of my efforts. This dissertation is much your as it is mine.
To my children, Elisa, Natan, and Lia, who have taught me with practice more than any of my favorite theories. You are my inspiration and my love.
To ADHD families and others that navigate neurodivergency in their everyday lives. My hope is that my dissertation helps shape technologies to be useful in your journeys.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

I am deeply grateful for the support, guidance, and encouragement I have received throughout my Ph.D. journey and my previous academic training. Above all, I thank God, who has undoubtedly been my guide.

I am privileged to have two of the most amazing advisors, Daniel and Gillian. Their guidance in projects and in developing my skills have truly been life changing, enabling me to shape my career around my passions. I am forever grateful for their support in so many dimensions of my life and that of my family. This dissertation is but a glimpse of how they have impacted my worldview and the progress of my work.

Having two advisors has also allowed me to be part of two amazing labs. My friends in the PIE and STAR labs have directly contributed to my work, including Jazette, Lucretia, Elizabeth, Emani, Arpita, Aehong, Armando, Vitica, and Sohyeon from STAR; and Xi, Eunkyung Jo, Dennis, Matthew, and Whitney from PIE lab. They have been my critics, reviewers, and sometimes advisors as well.

A special thanks goes to Nick and Elizabeth (Lizz, again). It was not easy and certainly taking this journey alongside theirs soothed out a lot of the hurdles. I am extremely grateful for their help and friendship, from facing deadlines to facing mountain lions. It has been wonderful to see their work progress and the fruit of their efforts.

I am also fortunate to have had incredible people support me in my projects and towards each program milestone. Franceli Cibrian, Yunan Chen, Kimberley Lakes, and Sabrina Schuck have helped me think more critically and across disciplines. Many of my research questions, study designs, and analyses were shaped by our conversations. And also thank you to Evropi Stefanidi, who has helped me think more about how to empower children with ADHD.

I would also like to thank Cleidson, Mayara, and Clara, who were instrumental in my career shift and helped my transition to UCI. Thank you to Clarisse, Yuqi, and David, for being great mentees and contributing significantly to my studies. My work would also not be possible without the willingness and effort of my study participants, who among busy and often stressful life moments still made time to be involved in my projects.

I would like to thank my parents, Norval and Lau, that although with limited resources instilled in me an appreciation for education and knowledge, sacrificing so I could have more opportunities. I also appreciate my sisters, Ana and Sara, for their love and patience with their older brother. Finally, I am thankful to Priscila, Elisa, Natan, and (most recently) Lia - my wonderful wife and children. They have inspired and supported me, often piloting studies. This work has been the result of Priscila's efforts as much as mine, and it is my greatest privilege to have that partnership.

Finally, this work was done with the support of the NSF (award IIS-2237389), the AHRQ (award 5R21HS028871-02), the CERES network, UCI's Public Impact Fellowship, Fred M. Tonge Endowed Graduate Award, and Rob Kling Memorial Endowed Fellowship.

VITA

Lucas M. Silva

EDUCATION

Doctor of Philosophy in Informatics **2024**
University of California, Irvine *Irvine, California*

Masters of Science in Computer Science **2015**
Universidade Federal do Pará *Belém, Brazil*

Bachelor of Science in Computer Science **2013**
Universidade Federal do Pará *Belém, Brazil*

RESEARCH EXPERIENCE

Graduate Research **2019–2024**
University of California, Irvine *Irvine, California*

Consumer Insights Intern **2022**
Netflix *Los Gatos, California*

User Experience Research Intern **2021**
Google *Remote, California*

TEACHING EXPERIENCE

Teaching Assistant - User Interface Software **2019–2021**
University of California - Irvine *Irvine, California*

Teaching Assistant - Information Retrieval **2020**
University of California - Irvine *Irvine, California*

REFEREED JOURNAL PUBLICATIONS

[1] **Lucas M. Silva**, , Elizabeth A. Ankrah, Yuqi Huai, and Daniel A. Epstein. 2023. Exploring Opportunities for Multimodality and Multiple Devices in Food Journaling. Proc. ACM Hum.-Comput. Interact. 7, MHCI, Article 209 (September 2023), 27 pages.

[2] Elizabeth A. Ankrah, Franceli L. Cibrian, **Lucas M. Silva**, Arya Tavakoulnia, Jesus A. Beltran, Sabrina E.b. Schuck, Kimberley D. Lakes, and Gillian R. Hayes. 2023. Me, My Health, and My Watch: How Children with ADHD Understand Smartwatch Health Data. ACM Trans. Comput.-Hum. Interact. 30, 4, Article 59 (August 2023), 25 pages.

[3] Ahmet Baki Kocaballi, Emre Sezgin, Leigh Clark, John M Carroll, Yungui Huang, Jina Huh-Yoo, Junhan Kim, Rafal Kocielnik, Yi-Chieh Lee, Lena Mamykina, Elliot G Mitchell, Robert J Moore, Prasanth Murali, Elizabeth D Mynatt, Sun Young Park, Alessandro Pasta, Deborah Richards, **Lucas M. Silva**, Diva Smriti, Brendan Spillane, Zhan Zhang, Tamara Zubatiy. Design and Evaluation Challenges of Conversational Agents in Health Care and Well-being: Selective Review Study. Journal of medical Internet research 24, 11 (2022), e38525.

[4] **Lucas M. Silva**, Franceli L. Cibrian, Daniel A. Epstein, Arpita Bhattacharya, Elizabeth A. Ankrah, Elissa Monteiro, Jesus A. Beltran, Sabrina E. Schuck, Kimberley D. Lakes, and Gillian R. Hayes. 2022. Adapting Multidevice Deployments During a Pandemic: Lessons Learned From Two Studies. IEEE Pervasive Computing 21, 1 (jan 2022), 48–56.

[5] Daniel A. Epstein, Clara Caldeira, Mayara Costa Figueiredo, **Lucas M. Silva**, Xi Lu, Lucretia Williams, Jong Ho Lee, Qingyang Li, Simran Ahuja, Qiuer Chen, Craig Hilby, Sazeda Sultana, Payam Dowlat Yari, Elizabeth V. Eikey, and Yunan Chen. 2020. Mapping and Taking Stock of the Personal Informatics Literature. Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT 2020) 4, 4 (2020).

REFEREED CONFERENCE PUBLICATIONS

[1] **Lucas M. Silva**, Franceli L. Cibrian, Clarisse Bonang, Arpita Bhattacharya, Aehong Min, Elissa M. Monteiro, Jesus A. Beltran, Sabrina E. B. Schuck, Kimberley D. Lakes, Gillian R. Hayes, and Daniel A. Epstein. 2024. Co-Designing Situated Displays for Family Co-Regulation with ADHD Children. In Proceedings of the CHI Conference on Human Factors in Computing Systems (CHI '24).

[2] **Lucas M. Silva**, Franceli L. Cibrian, Elissa Monteiro, Arpita Bhattacharya, Jesus A. Beltran, Clarisse Bonang, Daniel A. Epstein, Sabrina E. B. Schuck, Kimberley D. Lakes, and Gillian R. Hayes. 2023. Unpacking the Lived Experiences of Smartwatch Mediated Self and Co-Regulation with ADHD Children. In Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23).

[3] **Lucas M. Silva** and Daniel A. Epstein. 2021. Investigating Preferred Food Description

Practices in Digital Food Journaling. In Proceedings of the 2021 ACM Designing Interactive Systems Conference (DIS '21).

[4] **Lucas M. Silva**, Roberto Araújo, Felipe Leite da Silva, Eduardo Cerqueira. A New Architecture for Secure Storage and Sharing of Health Records in the Cloud using Federated Identity Attributes. In IEEE 16th International Conference on e-Health Networking, Applications and Services (Healthcom 2014).

AWARDS & HONORS

UCI Public Impact Fellowship	**2024**
Fred M. Tonge Endowed Graduate Award	**2023**
Rob Kling Memorial Endowed Fellowship	**2021**

ABSTRACT OF THE DISSERTATION

Towards Multi-Device Ecosystems for Personal and Family Health Tracking

By

Lucas M. Silva

Doctor of Philosophy in Informatics

University of California, Irvine, 2024

Assistant Professor Daniel A. Epstein, Co-Chair
Robert A. and Barbara L. Kleist Professor Gillian R. Hayes, Co-Chair

The increasing ubiquity of personal devices and technologies, such as home displays, smart-speakers, and wearables, has created new opportunities for individuals and families to monitor and manage their health and wellbeing. However, personal and family informatics systems have not kept up with such increased ubiquity, leading to a missed opportunity in making health informatics more convenient, connected, and meaningful. Many continue to struggle to effectively incorporate tracking into their daily lives and leverage the multiple technologies they have contact with. In my dissertation, I investigate how the design of multi-device health informatics systems can better support individuals in their self-tracking practices and facilitate collaboration within families for collective wellbeing. By leveraging the diverse capabilities of smartphones, smartwatches, smart-speakers, and more, I demonstrate how informatics tools can be designed to accommodate the varied needs and contexts of everyday life, both for individual use and for family collaboration.

Towards self-tracking, I demonstrate how multi-device, multimodal systems can provide flexibility and redundancy of options for rich data capture and help individuals overcome situational barriers to tracking. Through the design and evaluation of the ModEat system, I show how supporting food journaling across smartphones, computers, and voice assistants with various input modalities can accommodate people's goals, preferences, and contexts.

Examining how to help families collaborate towards health and wellbeing management, I explore the design of multi-device systems to facilitate family co-regulation practices. My evaluation of the CoolTaco deployment demonstrates that a smartwatch-based system can mediate shared awareness and remote collaboration between parents and children with ADHD around behavioral regulation. Through a co-design study, I reveal opportunities for in-home displays to integrate family data and guide productive discussions around each member's regulation needs relating to moods, exercise, and goals. Building on these insights, my design and evaluation of FamilyBloom showcases how integrating personal and shared devices can support diverse co-regulation practices, enabling reflection and mutual care in the face of varied routines and individual preferences within families.

Through these studies, my dissertation demonstrates that multi-device, multimodal health informatics can support the needs of individuals and families in their everyday practices surrounding tracking, reflecting, and acting for self and co-regulation of health and wellbeing needs. I suggest that leveraging device ecosystems and designing for varied levels of engagement and collaboration can result in more available and useful tools. Through empirical findings and novel systems, my dissertation contributes to understanding of how to create effective tools for personal and family health tracking in everyday life.

Chapter 1

Introduction

Health tracking technologies offer the potential for people to manage various aspects of their health and wellbeing, from physical activity and nutrition to mood and daily goals. The prevalence of phone apps to help health tracking has grown substantially in recent years, with estimates indicating over 40% of U.S. adults engage with some self-tracking [7], in contrast to 21% in 2013 [8]. These technologies, also known as personal informatics systems (PI) [74, 132, 195], focus on helping individuals collect and reflect on personal data for the purpose of self-knowledge and self-improvement. In everyday life, practicing PI takes several steps that follow an ongoing process of selecting tools, collecting, integrating, and reflecting on data to take self-care actions [74]. When systems are designed for integrated health tracking between multiple family members beyond simple sharing through data export, these systems can also be viewed as family informatics (FI) [176].

Despite the potential benefits of personal informatics technologies, in practice many abandon their use before reaping benefits [51, 127, 74, 55]. Studies have shown that a significant proportion of users drop out of self-tracking soon after initial experimentation or within the first three months of use [215, 151]. One of the reasons is that, when tracking, people might often encounter situations where their device may not be present or the data collected is limited and not useful for their current or evolving needs [74, 127, 70]. This might lead to inconsistencies of self-tracking across everyday life and lead to gradual disengagement from the tracking process [55]. As a result, people may find it increasingly difficult to maintain their commitment and interest in personal informatics [51, 74].

A key limitation of current personal informatics systems is their failure to leverage the full potential of people's increasingly rich and interconnected personal technology ecosystems and the diverse data *modalities* different devices might afford. Instead, most personal informatics systems rely on a limited set of data types and are often confined to a single device, typically a smartphone. This narrow approach fails to capitalize on the opportunities presented by the widespread adoption of smartphones, wearables, smart home devices, and other interactive technologies with which people now have contact with throughout their day and across various contexts. As a result, current personal informatics tools limit the situations in which people can track data and the scope of available data, further reducing the value and utility of these systems for tracking under everyday life circumstances. Consequently, this can lead to disjointed user experiences and missed opportunities for engaging with personal informatics, making it difficult for users to fully benefit from these technologies.

Another challenge is the important need of supporting collaborative tracking and sense-making practices within families and social groups [176, 159, 57]. Systems have the potential of helping families gain awareness of each member's health needs and take collective action to improve wellbeing [176]. Many health behaviors and challenges are shaped by family dynamics and shared environments [160, 229, 205], with health management being interconnected between each family member. When family members are all engaged, families are more likely to gain and maintain healthy behavior practices [89, 176]. Yet, personal and family informatics systems have mostly failed to account for collaboration needs in everyday circumstances and opportunities for more ubiquitous connection mediated by their technology ecosystems.

For example, the work in this area often is on a single device (e.g., [202, 206]), typically a parent's phone, and with limited modality interaction options. By enabling family members to easily collect, share, and reflect on family data across their devices, there is an opportunity to foster greater awareness, communication, and mutual support around health needs.

My dissertation advances multi-device, multimodal personal and family informatics systems to explore opportunities for making health tracking more collaborative and useful. In contrast to traditional device-centric approaches, I argue that the next generation of health informatics tools should leverage the diverse features of people's everyday device ecosystems to enable more flexible, contextually-appropriate, and collaborative forms of data collection, integration, and reflection. By allowing people to track and engage with data across smartphones, wearables, smart-speakers, home displays, and other devices, these systems can align with people's natural technology usage patterns throughout the day. At the same time, by providing multiple input and output data modalities – such as automated sensing, glanceable displays, and voice interfaces – these systems can support a wider range of user preferences and contexts of use. Finally, by creating shared, cross-device interfaces for tracking and discussing data, these systems can help scaffold family communication and collaboration about health and wellness needs.

1.1 Thesis Statement

My thesis statement is as follows:

Health tracking systems that leverage multiple devices and data modalities can better support (T1) individual needs in everyday life and (T2) collaboration needs within families.

I use Lee et al.'s definition of *modality* as *"a single independent channel of sensory input or output between a computer and a person"* [131]. Therefore, I use modality to refer to a format, type, or representation of data (*e.g.*, picture, voice recording, data representation) as well as the interface interaction itself. For example, voice modality can refer to both the format of the tracked data as well as a user's interaction via conversations. I similarly use *design* and *systems* to reference digital technologies for personal and family informatics.

1.2 Thesis Overview

I detail four user studies that examine the role of multimodal and multi-device health informatics systems to support self-tracking needs for individuals (T1) and collaborative needs within families (T2). In these studies, I employed a mixed-methods approach involving field deployments of novel multi-device systems for people to evaluate in their everyday lives, and participatory methods to understand people's desires and expectations for future designs.

My dissertation investigates how to integrate technology ecosystems with social ecosystems to support personal and family informatics needs. Considering multiple stakeholders and technologies introduces complexity, so my work explores this integration through case studies that gradually incorporate devices and people as users for stages in health tracking (detailed in Chapter 2). Table 1.1 outlines the overall structure of my dissertation, aligning each chapter with the corresponding research question that contribute to my thesis claims.

In Chapter 2, I review the relevant literature on personal and family informatics, focusing on key concepts, theoretical models, and empirical findings that inform my work. I discuss the benefits and limitations of current personal informatics approaches and identify gaps in our understanding of how these systems can better support health tracking and management in everyday life and in collaborative settings. I also discuss prior research on health tracking with different device platforms.

In Chapter 3, I evaluate how multi-device systems might support the collection stage of

Table 1.1: Thesis Organization

Research Question	Addressed in
RQ1: How might multi-device, multimodal systems facilitate **data collection** for self-tracking?	**Chapter 3:** through the evaluative deployment of ModEat, a multi-device, multimodal food tracking system.
RQ2: How might multi-device systems facilitate caregiving in families via tracking while **apart**?	**Chapter 4:** through the evaluative deployment of CoolTaco, a multi-device system for family co-regulation centered on children.
RQ3: How might multi-device systems facilitate family collaboration via **joint reflection** with tracking?	**Chapter 5:** through a formative co-design of joint family use of shared tracked data about every family member.
RQ4: How might systems facilitate self and collaborative tracking and reflection **across devices**?	**Chapter 6**: through the evaluative deployment of FamilyBloom, a system that allows family tracking and reflecting on smartwatch and home displays devices.

with multimodal data. I report on the deployment and evaluation of ModEat, a multi-device, multi-modal food tracking system to support capture of data relevant to goals around eating. Through a mixed-methods analysis of food journal entries and participant interviews, I contribute insights into how different data modalities and device form factors shape people's tracking experiences and preferences in everyday life. I also identify design opportunities for developing more convenient tracking systems that support people in their shifting contexts and goals considering automation and involvement of other people during self-tracking.

In Chapter 4, I evaluate how multi-device systems can integrate tracking and collaboration from family members around goals for behavior regulation centered on a child with Attention Deficit Hyperactivity Disorder (ADHD). Through a field deployment and user interviews involving ADHD children and their parents, I explore how a phone and smartwatch-based tracking system can facilitate collaboration and shared awareness of behavioral goals. I contribute design opportunities and a novel system that demonstrates how multi-device tracking can scaffold family communication and collaboration towards behavior regulation action considering children's independence and parental involvement.

In Chapter 5, I extend the investigation of family informatics systems by engaging families in co-designing shared tracking from multiple family members for joint reflection and action. Through a series of participatory design sessions, I elicit families' perspectives and needs for integrating family data from multiple devices towards collaborative uses. I identify key design considerations for data displays in the home to support collective needs and opportunities for supporting parents and children individually, taking into account particular caregiving goals and children's contribution to the home.

In Chapter 6, I integrate the insights and design principles from the previous chapters into the development and evaluation of FamilyBloom, a novel multi-device, multi-modal system for collaborative tracking and reflection on moods and goals across devices. Through a field deployment study with families, I assess the feasibility, and impact of self-tracking and viewing family data both on smartwatches and shared home displays for family communication and collaborative support involving every family member.

In Chapter 7, I conclude the dissertation by summarizing the key contributions and insights from my research. I revisit my thesis statement and discuss how the findings from each chapter support my overall argument for multi-device, multimodal personal and family informatics systems. I discuss the broader implications of my work for the design of ubiquitous computing technologies and challenges to support health and wellbeing with this approach.

As is common in research, my dissertation work was conducted in collaboration with others. To ensure clarity and attribution, I have described my own contributions and the contributions of my collaborators within each chapter. Collaboration was essential to my dissertation work, as the complexity of recruitment, deployment logistics, health domains, and the involvement of family groups required careful coordination and shared efforts [219].

Chapter 2

Related Work and Background Concepts

My dissertation research is informed by prior work in personal informatics, family informatics, and device ecologies. In this chapter, I explain these concepts and research areas, highlighting theories and the key concepts that inform my approach to designing multi-device ecosystems for personal and family health.

I first provide an overview of personal informatics, a field of research that examines how individuals use personal data for the purposes of self-knowledge and self-improvement. I discuss the stage-based model of personal informatics proposed by Li et al. [132], as well as subsequent critiques and extensions of this framework. I then focus on the specific domain of digital food journaling, as it is a particular self-tracking domain that might benefit from multi-device support. Next, I introduce the concept of family informatics [176] and discuss how personal informatics takes on new practices and challenges in the context of family collaboration and shared health tracking. I pay particular attention to how technology can support the unique needs of families coping with Attention Deficit Hyperactivity Disorder

(ADHD). I review prior work on technological interventions for supporting children with ADHD and their caregivers, including systems for co-regulation and behavior monitoring. Finally, I examine the literature on device ecologies and multi-device interaction, highlighting opportunities for leveraging the diverse affordances of smartwatches, smartphones, and other technologies to support personal and family health tracking in everyday life.

2.1 Personal Informatics

Apps to help people monitor health parameters have increasingly become available and adopted [7], such as to track physical activity and sleep. People now have more access to personally generated data that can reflect their health-related behaviors [80]. Personal data can be in various shapes and forms such as numbers or more visual representations, such as pictures and videos, subjective memos, etc. Research in personal tracking has sought to investigate how systems can better support the collection and use of data for improving one's self [132, 69].

Li et al. [132] define self-tracking systems as *personal informatics systems* and that have the intention to "help people collect personally relevant information for the purpose of self-reflection and gaining self-knowledge." Based on a user study and a behavior-change perspective, they proposed the Stage-Based Model (Figure 2.1) to represent the process of people's generation and use of personal data. The model is composed of five stages: preparation, collection, integration, reflection, and action.

The preparation stage is characterized by people's motivations for collecting data about themselves and determining what information and with what tools they will collect. In the collection stage, people actively capture granular data on behaviors and events across different timeframes (e.g., daily, weekly). The next stage is integration, in which raw data

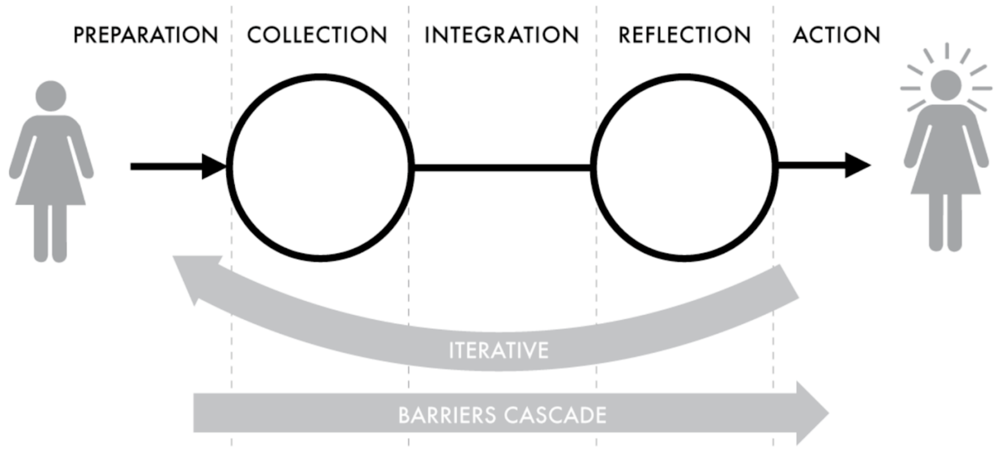


Figure 2.1: The stage-based personal informatics model proposed by Li et al. [132]. It describes the relationship between the five stages people experience when engaging with self-tracking systems: preparation, collection, integration, reflection, and action. Barriers faced in stages cascade to subsequent stages.

is manipulated to prepare it for interpretation. Data integration is highly dependent on the format and affordances of tracking tools. People then reflect on their data to understand their behaviors. Lastly, there is an action stage, where people may act upon their insights to make changes, such as adapting behaviors to meet specific goals.

In Li et al.'s Stage-Based Model [132], each stage presents barriers to tracking that can cascade to subsequent stages. For example, the unavailability of a tool can prevent users from collecting data and reflecting on their behaviors. Complex data stored in different locations and formats can also pose integration challenges, making it difficult for users to reflect on and respond to data to achieve their goals.

The Stage-Based Model has shaped over a decade of work in self-tracking research [69], but has limitations in representing people's actual lived experiences with personal tracking [195]. Rooksby et al. [195] has pointed out that it is unrealistic to expect people to act as rational data scientists who act only after carefully analyzing data and following sequentially structured stages. Instead, people's tracking strategies fluctuate, as in actuality they make and go back on choices about goals and technologies as they build meaning. This fluctuation is often driven by emotion and passion, as people focus on the future and gain benefit from the act of tracking itself instead of, or in addition to, looking at past data.

Influenced by the new understandings of self-tracking embedded in everyday life and for goals beyond behavior change, Epstein et al. [74] proposed the Lived Informatics Model of personal informatics (Figure 2.2). This model extends Li et al.'s model and adjusts how stages are associated to reflect a deeper understanding of real-world self-tracking behaviors and motivations. The Lived Informatics Model proposes the separation of the preparation stage into two new stages called *deciding* and *selecting* to specify the process of choosing what to track and how to track. Furthermore, Epstein et al.'s model accommodates the simultaneous nature of collecting, integrating, and reflecting on personal information as a continuous process of tracking and acting instead of sequential steps. Finally, the model accounts for people's life and motivational changes that lead to lapsing, resuming, or abandoning self-tracking altogether. This model has aligned the personal informatics perspective more pragmatically with people's real-life behaviors, capturing the messiness and non-linear decisions around life events and motivation fluctuations.

Both the Stage-Based Model and the Lived Informatics Model have been useful for guiding research and system designs to support different steps of people's self-tracking and personally influenced my approach for designing my studies. However, they have limitations representing social aspects and the intersection of tracking several domains together (*i.e.,* multifaceted tracking), such as emotions alongside physical activity or tracking goals [57, 159]. Nonetheless, they inspired future work on designing systems that are collaborative and target different health domains [69].

Figure 2.2: The lived informatics model of personal informatics [74]. This model extends the stage-based model to account for people's lived experiences of self-tracking, highlighting the simultaneous nature of some stages and the various circumstances under which people might stop or go back to tracking.

2.1.1 Personal Food Tracking

Food journaling, or keeping track of the food one eats, is among the most widely used personal informatics domains [79]. Journaling in any domain is typically viewed as a high-burden form of tracking. Choe et al. [43] describe a continuum from fully manual (e.g., journaling) to fully automated tracking (e.g., passive sensing), suggesting that fully manual tracking requires substantial effort. Journaling requires the person to remember to log, disengage from other activities, and match their experiences with available options [43].

Although generally burdensome, tracking food intake can allow people to be more aware of their food choices and change their behaviors [97]. Clinicians often use food journals in their care practices, recommending that patients use them as part of their health management [257, 188, 238]. Research continues to examine technology-driven strategies for food journaling, supporting weight loss [97], diabetes management [60], irritable bowel management [216], allergies [94], and more. Digital food journaling enables patients to monitor their diet while being mindful and engaging through recording and reflection. Motivations for tracking also include curiosity, having a record, and behavior change [195]. Within behavior change for healthy eating, goals range from quantitative and specific to more hedonic [163]. This range is often classified into metrics-driven goals like calorie counting [14, 108, 243, 182, 4] and mindfulness or awareness-driven goals [54, 71, 20]. Prior research has indicated that offering flexibility for data collection may better support individual tracking needs [118, 17]. Although people consider their personal goals and needs when identifying tracking tools, they are often influenced by the popularity of apps, recommendations, aesthetics, and presence of other features (e.g., social features, privacy preservation) [92, 74, 117, 44].

Digital food journaling typically have been supported through commercial systems and in research by making available one or two data capture modalities at a time. Apps in this space are typically on phones and support inputs with entry styles that might include database lookups, barcode scanning, voice logs, and photos.

Database lookups enable people to search through a food database. This method closely aligns with how experts approach making sense of paper food journals [209, 257] by looking up the food item within large data sets, such as the Nutrition Data System for Research (NSDR) [5]. Database lookups require that people find the correct description of the food they are looking up with in the database and estimate the portion size they consumed [108], but may face challenges with finding foods from non-Western cultures [55], or being susceptible to entry errors, such as confusing multiple similar types of a product [108].

Scanning of barcodes allows people to scan packaged foods such as frozen, canned, or prepared foods. They have been implemented in research tools such as Barcode Ed [217] and are widely used in commercial apps to facilitate food lookups [217]. However, Cordeiro et al. [55] highlight that barcode-based journaling can nudge people away from eating fresh foods like fruits and vegetables, which are less likely to have barcodes, in favor of store-bought or packaged foods.

Photo capture and voice logs allow for more descriptive food monitoring and have recently become available in some commercial apps, such as Ate [1]. Evaluations of food journaling systems suggest that photo and voice-based journals can help support mindful goals and normalize some burden of journaling foods that might not have barcodes or be present in food databases [144, 55, 139, 26, 184]. Also, Luo et al. found that the speech input modality in FoodScrap allowed for quick and flexible detailed food descriptions [139]. Unlike other modalities, photo-based entries typically require in-the-moment entry to capture what the person has consumed, which may not be possible or preferable if eating while socializing or when photo capture is unavailable [54, 55]. Text input enables open-ended and flexible food description, and has typically been incorporated in conjunction with photo-based food entries [54, 71, 155, 46]. Research has also examined using natural language processing to mine nutrient information from websites [241, 158].

Researchers continue to examine how sensors can passively detect eating moments [23, 22, 45, 237], identify what and how much a person has eaten [108], and improve the accuracy of approaches. Passive collection reduces the manual burden of tracking, but presents other challenges such as accuracy, physical, and privacy concerns. Choe et al. [43] argue that passive data collection removes opportunity for reflection, which is integral to people understanding their habits (e.g., being mindful of food choices) and potentially changing them.

Most food journaling research systems have been designed or developed exclusively for mobile devices, though some commercial mobile apps additionally allow journaling through a website. Expanding food journaling opportunities across multiple modalities and devices could perhaps support people's goals and journaling practices. For instance, computers might be situationally more available when being used for another task while eating (*i.e.*, desktop dining [98]), and voice assistants could allow for multitasking while preparing food or doing other activities [180, 137].

Research in Personal Informatics has recognized the importance of the social and collaborative nature of personal tracking. For example, research on self-tracking of meals, mental health, and fertility care has shown how personal tracking is tied with one's relationships and sociocultural contexts [57, 159, 138]. In truth, health management in general is rarely done in isolation, instead involving others in a support circle. Thus, more recent work has expanded to leverage family, friends, and others for health tracking [176, 69].

2.2 Family Informatics

Pina et al. [176] expanded on the personal informatics field by exploring health tracking in the family setting, coining the term family informatics. With a focus on families composed of children and parents living together, their study highlights that health management is collaborative and interconnected between each family member. Another interesting insight is that typically healthy families focus on tracking for preventive health and doing healthy activities together, while those with children with a chronic condition structure tracking around the child's needs. An important contribution of family informatics is the notion that children can also participate in tracking and collaborating with parents towards their unified health goals. Such practice can result in more sustainable tracking practices by "sharing the load" with children and lowering some burdens that often fall only on the parents. If family members are all engaged, families are more likely to maintain their healthy practices [176].

A shift to family informatics has particular implications for each of the stages of personal informatics in light of the family context, such as differences in motivation between family members for what, why, and how to monitor health. These differences can be challenging to balance and be supported at each stage. Examples include making sense of too much data from different individuals, different goals between family members, privacy concerns, tracking tools being adequate for both parent and children to use, supporting both individual and family reflection levels, and coordination actions for better health outcomes [176].

Family informatics research extends beyond the coining of the term by Pina et al. [176] and the modeling of personal informatics. Despite not always using such terms, much research is around supporting families monitor and manage health together and/or of each other [204]. Many studies focus on specific conditions, such as diabetes management [240, 114, 183], cancer [100, 99], and autism [145, 21]. Much effort has also been about general family health and wellbeing, such as increasing physical activity [201, 170], healthy eating [89, 206], better sleep routines [226, 175, 154], and monitoring child's general growth [116, 224].

Research in family informatics typically is about data collected from children and often involves collaboration but can vary in who is the focus of the technological support. Some works focus on parent's role and work in tracking and managing family health (*e.g.*, [114, 169]) while a few address both parent and child participation (*e.g.*, [240, 175, 99, 170]), and still some seek children's perspective on health tracking (*e.g.*, [255, 181]). Taken together, HCI studies highlight the benefits, tensions, challenges, and opportunities of family health monitoring for reflecting and managing health and wellbeing.

While family informatics has provided a new way of thinking and designing health tracking, there is much to uncover about how systems can support the complexities of family dynamics and the particular health needs members might be going through, especially for those with specific heath conditions like neurodivergent characteristics and other chronic conditions.

2.2.1 ADHD and Co-Regulation

Attention Deficit Hyperactivity Disorder (ADHD) is characterized by challenges with attention, organization, and impulsivity inconsistent with the child's developmental age [52]. It is one of the most common childhood mental health diagnoses [173, 253], with reports indicating that about 1 in 10 children in the United States is affected by ADHD [30, 59], and between 5.29% [179] and 7.2% [236] worldwide. Challenges associated with ADHD affect how children manage their behaviors in their daily routines and adapt to different environments.

Self-regulation refers to the ability to moderate one's emotions, impulses, thoughts, and behaviors to maintain control and focus, override automatic reactions, resist undesirable distractions, and ultimately achieve desired goals or mental states [150, 172]. It serves as a fundamental mechanism for adaptive developmental tasks across all life stages [150], but typically develops in early childhood [121, 34] and continues to develop throughout adolescence [150]. Given that ADHD is characterized by behaviors of inattention and/or hyperactivity that are more frequent, intense, and evidenced in different settings than their neurotypical peers [50, 16], children with ADHD might have intensified challenges with self-regulation. ADHD can pose hurdles to planning and achieving goals as children may face increased distractions and struggle with self-monitoring skills to assess the progress of their efforts [214, 52]. These difficulties contribute to social obstacles, with ADHD children being more susceptible to stress and fatigue that could be externalized and perceived as aggressive and rule-breaking [102, 37]. Such obstacles can lead to anxiety, depression, and difficulties in managing emotions, affecting their wellbeing [67] and quality of life [68, 232].

To support ADHD children who experience significant self-regulation challenges, caregivers (*e.g.*, parents, clinicians, teachers, etc.) can collaborate with children's regulation (*i.e.*, co-regulate) by helping them self-monitor, manage tasks and goals, set boundaries, stay motivated, refocus, and much more [160, 239]. As caregivers, parents are also important role models that help children regulate behaviors and emotions [90, 205]. Effective co-regulation strategies in the family can empower children with ADHD to move from co-regulation to self-regulation, and can enhance their confidence and parent-child bonding [85]. However, parent's might struggle with self-regulation too, especially in giving support to their children, when having challenges with mental health or being overburdened with work and family obligations [205]. ADHD is highly hereditary [77], hence many ADHD children have ADHD parents who are coping with their own self-regulation challenges.

Within HCI, research has sought to improve self-regulation for children with ADHD through digital interventions [47], such as through training with serious games [36, 225, 123] or structuring routines [246, 226], sometimes involving parents. For example, systems such as TangiPlan [246] have proposed the use of tangible objects representing tasks to help ADHD children plan and organize morning routines. Similarly, gamification techniques like storytelling and playfulness of self-regulation practices have been used to help children regulate stress and practice organizational skills, such as in Chillfish [225] and Plan-it [36]. Research has also sought to support ADHD children's learning in school settings, such as using wearables to encourage refocus when inattention is sensed [227], or cooperative positive behaviors through an ambient display of student's behavioral performance [148].

Recently, some work has started to involve ADHD families. For example, the MOBERO mobile system [226] supported children with ADHD and their parents in structuring morning and bedtime routines alongside the use of tokens and rewards. However, such digital interventions are typically instructive and fall short of offering support for tracking, reflecting, and guiding regulation based on family's lived experiences. There is growing recognition that technologies need to involve children's care networks [229] in managing and promoting regulation while empowering children's expressions of experiences and reflection in order to promote communication beyond symptom tracking alone [230]. Thus, there is still much room to investigate family-focused systems for data-driven behavior regulation that target family's specific needs, struggles, and strengths, such as leveraging self-tracking [47] and involving the whole family [176] and their technology ecosystem.

2.3 Device Ecologies and Multimodal Systems

People's device ecosystems continue to grow, enabling a plethora of interaction options people can conveniently engage with throughout their day. Lee et al. define a modality as *"a* *single independent channel of sensory input or output between a computer and a person"* [131]. Modality can denote both the interaction itself (e.g., visual, listening) and the type of information represented by a particular sensory stimulus (e.g., image, audio). People often have access to an array of devices supporting multiple modalities including mobile phones, voice assistants, desktops, and smartwatches. Multimodal toolkits often focus on supporting browsing and searching, using devices collaboratively in real-time or in rapid succession [161, 162, 42]. In O'Leary et al.'s characterization of device roles in multi-device systems, self-tracking is a task where devices play the role of a collector of data [165].

People often choose to use multiple devices and modalities simultaneously or in combination. Research on designing multi-device-ecologies emphasize that systems should support task continuity, allowing for easy synchronization of data and the ability to transition from one device to the next to complete an activity [106, 63]. This work suggests the importance of leveraging the strengths of different devices, such as convenience or physical affordances [106, 112]. Though people may have a preference for a specific device depending on context, habit, and current task [106, 112], they often find support for multi-device interactions and simultaneous use lacking, in part due to limited design toolkits and platform standards [64, 165, 175].

Although most journaling and tracking technology to date has leveraged mobile and desktop/laptop apps, researchers are increasingly exploring the utility of other technology for supporting health and wellbeing practices, such as self-tracking. For example, conversational agents, such as via smart speakers, SMS, or voice are increasingly being designed to promote health care [125, 120]. Luo et al. explored multi-device tracking in TandemTrack, combining a smart speaker and mobile app to provide complimentary visual and voice feedback to enrich people's experience with physical exercise [141]. Similarly, in Data@Hand, Kim et al. combine voice and touch input modalities in a mobile app to enable visual exploration of personal health data [119]. These rare cases of multimodal research have showed directions for combining different sensory interactions can facilitate user experiences for certain tasks with data. However, less work has developed understanding of how devices and modalities can be combined for collecting, integrating and reflecting on self-tracking data. By leveraging the different modalities and strengths of different device platforms, personal and family informatics could make health tracking and data use more convenient. For example, leveraging smartwatches for tracking alongside glanceability of information for reflection, voice assistants for multitasking while tracking, and home displays for situated and collaborative reflection could provide more convenient contact with self-tracking practices and data uses.

2.3.1 Smartwatches for Self-Tracking and Wellbeing

Research has frequently examined smartwatches as a platform for implementing health and wellbeing interventions [83, 48, 169], with sleep and physical activity tracking being particularly touted as main features in the commercial marketing of these devices. Smartwatches have also been used for monitoring behaviors (e.g., scratching, eating) [189] and recently acknowledged as a potential mediator for self and co-regulation [49]. Much of the smartwatch's potential lies in its convenient and always available nature, providing information at a glance and, for example, less disruptive than taking a phone out of the pocket [39, 178]. Furthermore, the smartwatch's body-mounted nature might be less demanding of care, and less distracting or harder to lose than a phone. These affordances might be especially beneficial for children as they rapidly shifting contexts (e.g., from home to school, outdoors) and can have self-regulation challenges.

In family informatics, wrist-worn devices have more often been used as a means to capture data automatically (e.g., physical activity and sleep [201, 175, 153]) rather than a space for interactions around subjective data collection and reflection. Parents are often the drivers of smartwatch adoption by children in expectation that it will help instill a healthy lifestyle

[169, 170]. However, most smartwatches used in research are still dependent on a parent's phone [178, 207] and Oygür et al. [169] have highlighted how this linkage can add invisible work for parents, such as for configuration and maintenance, which can undermine their original goal of facilitating parenting. Smartwatches also have limited battery life [189], which can require further regulation for maintenance or increased parental involvement.

Despite these challenges, smartwatches have the potential to support self-monitoring and delivery of interventions by leveraging their always available nature. They can also support in-the-moment reflection through glanceable visualizations [27, 87]. This has greatly motivated my work towards integrating smartwatch's use for personal and family informatics with other devices, such as to facilitate multimodal tracking and collaboration in shared tracking with others.

2.3.2 Situated Displays for Reviewing Tracked Data

Home displays are dedicated devices situating visualization in the home environment, typically as a tablet mounted on a wall or counter for convenient view [33, 249, 247]. These devices are persistently available and have facilitated reflection centered on the self and for understanding of personal tracked mood [222, 104], physical activity [76], and behaviors for health recovery [107] as people navigate their home. By positioning data review into physical environments, situated visualization can conveniently afford tracking and reflection in the context of daily living spaces and routines [33, 156]. Given how health management is rarely done in isolation, situated displays can be expanded to involve sharing of tracked data between others in the home and integrate data from multiple sources.

While most family informatics research has focused on dashboards on a parent's phone or computer, persistent and situated displays in the home are an opportunistic means of interacting with family data given the inherent ties between the living space and the data of those that inhabit it [249, 156]. Some prior family informatics works employ situated displays and have suggested it is as a way of increasing family awareness about each other's behaviors in some specific domains, with a few involving children. For example, DreamCatcher [175] displayed daily and weekly sleep tracking on a shared tablet in the bathroom, helping families track sleep habits together with greater involvement of children and promoting reflection on each other's sleep patterns. Similarly, situated displays have been used to foster family connection by tracking and sharing location information [35] or memories captured in photographs [86], leading to increased social touch and family bonding. Situated displays have also improved awareness of distributed tasks in the home through tracking and displaying household chores, such as Choreflect [191], an ambient display system showing household tasks by adult members. Choreflect was suggested to increase awareness of chores that otherwise could have gone invisible [191]. These systems demonstrate the potential of situated displays to provide a centralized interface for equal access and interaction for family members, facilitating the sharing of data within the home environment.

Generally, prior research in shared displays point to the opportunities for situated sharing of data about tracked behaviors. Home displays are a potential means of increasing awareness between people living together in a household. Questions remain on what sort of data and guidance families would want in a situated in-home display involving family data. In my work, I engage with children and parents to understand families' needs, values, and preferences for how such systems could support their health and wellbeing.

2.3.3 Voice Assistants' Potential for Health Tracking

Voice assistants (VAs), or voice-based conversational agents, have become increasingly part of personal and family's technology ecosystems, with some applications around health. VAs like Amazon Alexa, Google Assistant, and Apple Siri are available on shared smart speakers in homes as well as personal devices like phones and smartwatches. Recently, these systems have being designed to promote health care [120, 125]. Uses of VAs for health range from providing information and education to supporting therapy or monitoring patients [125].

The hands-free, voice-based interaction of VAs enables new possibilities for multitasking and can complement the capabilities of screen-based devices [180]. For example, VAs can be used to quickly set reminders or look up information while performing other tasks [24]. However, the conversational nature of VAs also introduces challenges, such as managing user expectations, handling breakdowns in understanding, and addressing privacy concerns [101, 126, 251, 25].

In homes, VAs have also been observed to affect family dynamics. VAs are typically embedded in the home environment and often intertwined with family activities [251, 25]. For example, prior work has identified that family members may work together to formulate requests, resolve misunderstandings, and decide on appropriate uses collaboratively [24, 82]. Ideally, VAs should be able to adapt to the preferences and roles of different family members [142, 171].

While VAs have the potential to play a unique role in device ecologies for health tracking, they also face limitations in their ability to understand context and engage in truly natural conversation [251]. As VAs continue to evolve, it will be important to consider how they can effectively complement other devices and support people's needs across personal and family informatics stages.

2.4 Summary

Prior research has made significant progress in understanding how individuals and families engage with tools for health tracking and management. The Stage-Based and Lived

Informatics models have provided valuable frameworks for examining the challenges and opportunities in self-tracking, while family informatics has highlighted the collaborative and interconnected nature of health management. Studies have also explored the affordances and potential uses of different devices, including smartwatches, smartphones, voice assistants, and situated displays, to support health. However, despite these advancements, people often struggle to consistently capture and derive value from their personal data and connect in support networks. Existing systems often fail to fully support the needs of families for seamless integration and collaborative use across multiple devices and contexts.

The opportunities and limitations identified in prior work motivate my research on designing multi-device ecosystems that explore how to provide convenient and connected health tracking and management. By leveraging the diverse affordances of different technologies and designing with the needs of individuals and families in mind, there is an opportunity to create ubiquitous tools for health tracking and co-regulation. In the next chapters, I gradually showcase how incrementing multiple devices and users in systems helps us understand how to support personal and collaborative health tracking in everyday life.

Chapter 3

Investigating Multi-Device Opportunities for Data Collection

3.1 Introduction

In this chapter, I investigate how multi-device, multimodal systems can better support the data collection stage of tracking, specifically in the context of food journaling. Food tracking is among the most popular forms of personal informatics, with 42% of U.S. adults having used a mobile app to keep track of their diet or nutrition as of 2017 [2], and over 165 million people worldwide using MyFitnessPal to journal their food intake as of 2016 [3]. However, despite the potential benefits of food journaling for various health-related goals (e.g., weight management [38, 243], mindful eating [168, 133]), most people struggle to consistently track their food intake due to the burdensome and challenging nature of the practice [51, 54, 72, 127, 71].

To explore how multi-device, multimodal systems can address common difficulties in food tracking, I designed and evaluated ModEat, a mid-fidelity food journaling prototype that supports data capture across various devices (mobile phone, computer, voice assistant) and input modalities (database search, text description, voice log, photo, barcode scan, URL). Through a two-week field deployment study with 15 participants, I sought to answer the following research question:

RQ1: How might multi-device, multimodal systems facilitate data collection for self-tracking?

Towards my thesis claim T1, the findings from my ModEat study demonstrated that people's goals, prior experiences, and affinities to certain devices and modalities drive a default preference for how and with which device to journal. It also demonstrated that multi-device journaling can provide flexibility and redundancy of options for data capture and help individuals overcome situational barriers to tracking, making the practice more convenient under different everyday contexts people navigate. Furthermore, the findings indicate that using semi-automation of food interpretation across modalities can be a way to integrate multimodal tracking for later uses, like reflecting on personal goals.

In regards to my thesis claim T2, this study revealed that the presence of other people during data collection can influence people's self-tracking preferences and practices. Some participants expressed a desire to use certain modalities to collaborate with others in making entries together, while others preferred modalities that offered less disturbance to ongoing social interactions. Based on these insights, I discuss design implications and opportunities for future multi-device, multimodal food journaling systems, emphasizing the importance of balancing flexibility with supporting journaling goals.

This chapter makes several contributions to the design of health tracking and indicates opportunities for involving families in co-construction of tracking data. First, it provides empirical insights into how individuals use and perceive multi-device, multimodal food journaling systems in their everyday lives. Second, it identifies key design considerations and challenges for such systems considering people's variance in journaling practices and goals. Finally, it demonstrates the value of a multi-device approach in supporting self-tracking practices and addressing some limitations of current single-device, single-modality tools.

The study of the ModEat deployment was published[1] in DIS 2021 and MobileHCI 2023 with co-authors Elizabeth A. Ankrah, Yuqi Huai, and Daniel A. Epstein. Development of ModEat was done in collaboration with Kimberly Flores, Yuqi Huai, and Daniel A. Epstein. I led participant recruitment, platform deployments, interviews, analysis, and paper writing.

3.2 Methods

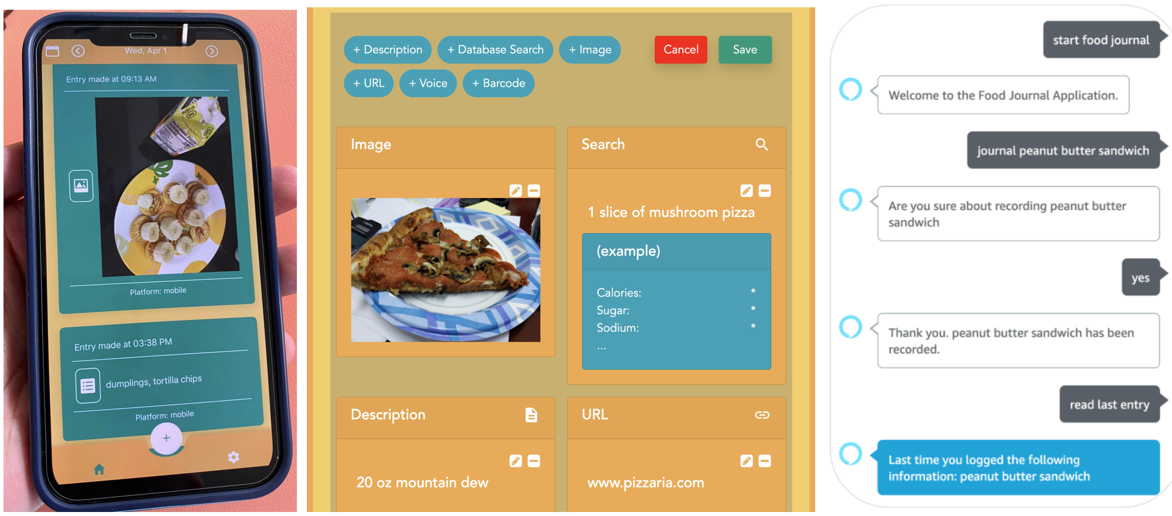
To understand how people perceive and experience multi-device support for food journaling, I created and deployed the ModEat prototype, a multimodal and multi-device system for food tracking. Fifteen participants used the system for two weeks, and I describe ModEat's supported modalities and study participant demographics.

3.2.1 ModEat Design and Implementation

ModEat is a multimodal and multi-device journaling prototype designed to capture people's desired strategies for food description practices. ModEat is comprised of apps for phone, computer, Amazon Alexa, and Google Assistant. ModEat's input modalities are informed by features in commercial apps and previous research on journaling food. It is intentionally flexible and does not incorporate suggestions for what or how to journal. The deployment focused on the collection stage of journaling [132, 74] and de-emphasized the feedback that an app might provide. Therefore, database searches and barcode lookups are simulated, with participants being instructed to suspend belief about feedback and journal as if receiving expected results (see Figure 3.1b for an example). Each device and modality have unique

[1] This study has been published in DIS and MobileHCI: [143, 220]

interaction characteristics and with varying affordances, effort of use, and sensory stimuli. For example, photos might be quick and provide visual nuances, whereas a text or voice input might take longer but offer flexible description. Likewise, the database search could provide detailed nutritional information, but might require effort in describing the right search items. Table 3.1 summarizes input modalities supported on ModEat.



(a) Phone. (b) Computer. (c) Voice Assistant.

Figure 3.1: ModEat supported food journaling across modalities and devices, including (a) mobile, (b) computer, and (c) Amazon Alexa. ModEat's mobile and computer apps allow multiple modality inputs in an entry, such as photos and text descriptions. The VAs support open-ended voice description.

Table 3.1: ModEat's Supported Modalities Per Platform (* indicates simulated results)

ModEat Platform	Database Lookup*	Barcode*	Voice Log	Photos	URL	Text Description
Mobile	✓	✓	✓	✓	✓	✓
Computer	✓	✓	✓	✓	✓	✓
Voice Assistant			✓			

ModEat mobile supports six different input modalities including open-ended text description and simulated database lookup, with a person able to choose what input modality or modalities to include with no limit on how many (*e.g.*, Figure 3.1a). The computer version of ModEat is designed to support any device larger than a phone (*e.g.*, desktop, laptop, tablet), and supports creating new entries with multiple modalities (Figure 3.1b). ModEat on the VAs Google Assistant and Amazon Alexa support open-ended voice input with the command "journal [food]" (Figure 3.1c).

3.2.2 Participants & Study Procedures

I recruited 15 participants who had various food journaling experiences and goals. Participants used ModEat for two weeks (mean 14.7 days, min 14 max 16), similar to deployments of other food journaling systems, which typically last between one and three weeks [106, 140, 254, 256, 244, 71, 105]. Table 3.2 describes participant demographics. Participant's food journaling goals were distinct, but can be classified under two general categories, quantitative or awareness. Some participants' goals related to maintaining daily calorie budget, or making sure they were eating a set amount protein or certain macro or micronutrients, thus focusing on the quantitative information. Others had goals related to general eating habits (*e.g.*, amount of snacking, eating more plant-based meals, general healthy eating), and focused on awareness of their food consumption. Participants' life stages and routines also varied, with some being married living with partner and kids, and others living with their parents or housemate; and some in collage while others had established careers. To ensure participants had access to a range of devices, they were required to own a smartphone, own a smart speaker device supporting Amazon Alexa or Google Assistant, and have access to a computer. 4 participants who did not own a smart speaker were lent a Google Home Mini or an Amazon Echo Dot via contactless drop-off [219].

I introduced ModEat to participants as a tool to help researchers reflect on benefits, shortcomings, and possible future designs for journaling with multiple modalities and devices, and positioned the participants as valuable collaborators in exploring ways for facilitating food tracking and lowering burden. Participants were instructed to journal with whatever modality and device they preferred and made sense for their personal goals and daily lived

Table 3.2: Summary of Participant Information in the CoolTaco Study.

ID	Gender	Occupation	Age	Journaling Experience	Prior Journaling Tools	Journaling Goal
P1	Female	Designer	36	4 years	Calendar	Awareness
P2	Female	Massage Therapist	35	2.5 years	Paper, LoseIt, MyFitnessPal	Quantitative
P3	Male	Civil Engineer	33	2.5 months	Spreadsheet	Awareness
P4	Male	Engineering Manager	38	1 month	Paper	Awareness
P5	Female	Student	28	3 years	MyFitnessPal, Self-made app	Quantitative
P6	Female	Student	25	10 months	Cronometer	Quantitative
P7	Female	Retail	30	3 months	Paper	Awareness
P8	Female	Accounting Clerk	27	1 month	Spreadsheet	Awareness
P9	Male	Engineer	31	None	None	Awareness
P10	Male	Student	28	2 years	MyFitnessPal	Quantitative
P11	Female	Researcher	50	2 months	FitDay	Awareness
P12	Male	Engineer	43	"On and off"	MyFitnessPal	Quantitative
P13	Female	Academic Librarian	44	2 years	MyFitnessPal	Awareness
P14	Woman	Student	33	3 years	MyFitnessPal	Quantitative
P15	Male	Drafting Design	31	2 months	MyFitnessPal	Quantitative

situations, and to think critically about these choices.

At the end of each day, participants answered a short survey to describe the journaling context of each of their food entries. The survey included questions about time of journaling relative to eating moment, presence of others, classification of eating occasions (*e.g.*, meal, snack, other), why they chose the a particular modality and device, and an open field to provide any further details, suggestions, or critiques. After the deployment, I interviewed participants about their modality choices and what about their situations and contexts influenced those choices, if at all. Participants were also asked to reflect on their experience with ModEat and envision ideal features and interactions that would better support them. Participants were compensated $30.

3.2.3 Data Analysis

I analyzed transcriptions of interviews inspired by Braun and Clarke's reflexive thematic analysis [31, 32]. My analysis approach was primarily inductive, but employed a semantic analysis of participants underlying goals, beliefs, and motivations for food journaling. A critical realist approach was also used to understand how participants made choices about food journaling in light of contextual everyday life situations and constraints. Following Braun and Clarke's six phases of thematic analysis, along with research team I first sought to familiarize with the data by reviewing each participant's journaling goals, and more deeply discussing two interview transcripts. Then, each author independently coded two transcripts. The team met weekly to discuss codes and patterns in the data to iterate on a codebook. After reaching a final codebook, me and another researcher recoded all interviews. I then used the codebook and coded data to build a thematic map to visually highlight the main themes and subthemes, their interconnections, and associated representative quotes. The resulting thematic map had three higher-level themes related to modality and device choices and preferences: factors which motivated default device and modality choice, factors which motivated deviation from defaults, and combining modalities. These had 12 sub-themes, that in turn had 68 sub-items in total. For example, the parent theme *"combining modalities"* had three sub-themes: *complementing information, one is enough, and increased effort*; and a sub-theme *"device choice"* had 13 items, such as *portability, familiarity, multitasking or hands-free, presence of others*. The thematic map became the basis of the findings here reported. I quote participants with P#.

I also analyzed each journal entry to understand how people might choose to describe foods per modality and under less constraints for accuracy. All journal entries were separated by input (*e.g.*, text description, barcode, photo), resulting in 1008 individual inputs. I used thematic analysis again with another researcher to code and derive themes about food descriptions in logs. After refining definitions and coding criteria, the final codebook contained 39 codes in 12 categories, such as how many food items were present in a log, how specifically foods were described, and if and how logs described food amounts. For example, the code category *amount* had the subcodes *numeric scale*, *numeric only*, *broad*, *comparative/reference*, *non-standard*, and *non-quantified*. To understand how participant's preferred methods of food journaling aligned with traditional approaches to food recognition, I ran participant's logs through commercially-available recognition services. I submitted database search, text, and voice input descriptions to commercially-available Natural Language Processing (NLP) services (Nutritionix [], Edamam [], and Spoonacular []). These automation services attempt to interpret foods in these open-ended modalities and also provide estimated nutritional information feedback. I also used commercially-available image classification services to understand opportunities for improving recognition of the pictures people used to represent their foods. We chose three popular services regarded in top service lists: Clarifai [], Google CloudVision [], and Amazon Rekognition []. These services attempt to interpret foods in images, similar to the NLP services.

With the help of a collaborator, we quantitatively analyzed the metadata of journal entry logs and associated survey answers to evaluate how device and modality engagement differed by journaling goal and surveyed contextual factors. Metadata consisted of the modality, device, and eating context (*e.g.*, eating with others, journaling before eating) associated with each ModEat entry. We used logistic regression models, treating each metadata as binary responses. We treated participant IDs as random effects to account for personal device and modality preferences. We corrected for multiple comparisons in post-hoc tests with Tukey corrections.

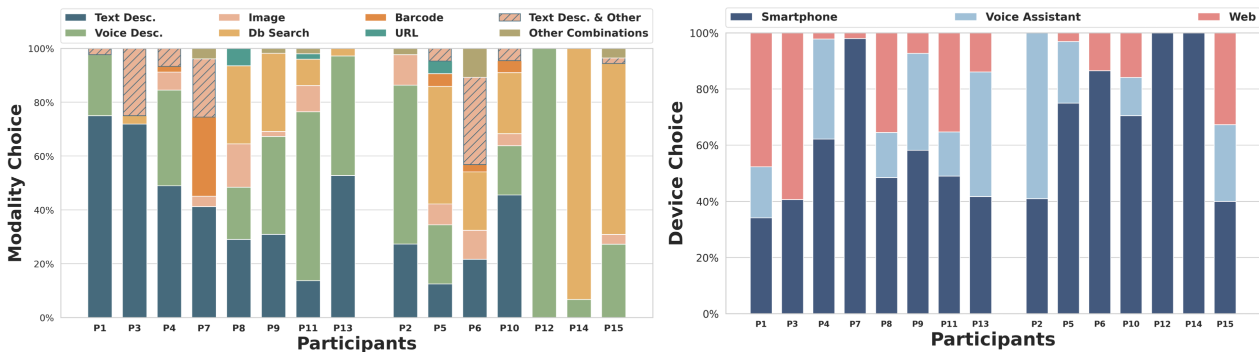
3.2.4 Limitations

Most participants' deployment period took place between the end of 2019 and Spring of 2020, intersecting with stay-at-home orders due to the COVID-19 pandemic. This impacted people's general routines, movements, and, to some extent, foods eaten and journaled. For example, participants who would often eat at a variety of different places (*e.g.*, at work, at restaurants) overwhelmingly ate at home, which likely influenced their device and modality choices. Despite this limitation, our data represents people's use of journaling tools in everyday situations that can include challenging life events. I further discuss implications on modality and device choice.

While the number of participants is similar to past deployments of food journaling systems [243, 162, 105, 109, 254, 256], a larger and more representative sample is likely to uncover further influences on modality and device preferences. Although the sample is relatively diverse in participant's gender and occupation, the findings might not generalize to older or younger participants, complex family settings, and different communities and countries. For example, cultural differences might influence social norms and personal goals around journaling preferences [136]. Also, while P4 mentioned previously journaling food to identify intolerances, none of the participants had a disease diagnosis or management goal, although it is a commonly-studied motivation for food journaling [109, 94, 257, 209].

3.3 Findings

Participants made a total of 659 entries using ModEat with 1008 modality inputs, averaging 2.98 entries per day (min 1.07, max 4.26). Participants used a range of modalities (average 3.80, min 1, max 6) and devices (average 2.47, min 1, max 3) for their entries. All participants but one explored using two or more modalities (Figure 3.2a), and all but two used two or more devices for their journaling (Figure 3.2b; P12 used voice input on the phone app for all entries, P14 used only database and voice descriptions on phone). Most participants opted to use phones for most of their entries (40.6%-100% of entries per person, 62.5% of entries in total). However, participants frequently differed between choosing the computer interface and the voice assistant. 5/15 participants (33%) chose to not use the voice assistant at all, while 4/15 (27%) used it for a third of entries or more. Similarly, 3/15 (20%) participants did not use the computer interface, while 4/15 (27%) used it for at least a third of their entries. Figure 3.2 shows (a) modality and (b) device breakdown by participant.



(a) (b)

Figure 3.2: Distribution of (a) modality and (b) device choice. In each graph, participants on the left group had food awareness goals, while the right had quantitative nutritional goals. Participants with awareness goals used text and descriptions at a higher rate, while those with quantitative goals used database searches at a marginally higher rate. The phone was used for the majority of food entries and participants varied in using the computer or voice assistant.

While participants chose to use the phone version of ModEat most often, various routine shifts in circumstances often led them to choose different devices and use different modalities, which I detail in my findings. I found that participants often had a default device and modality preference, motivated by their food journaling goals, prior experiences, and personal affinities. Nonetheless, circumstantial factors frequently led them to deviate from default preferences in exchange of more convenient journaling or situational constraints, such as contexts which influenced availability, efficiency, and emotion. I also noted high variability in how participants described or captured their foods, sometimes combining modalities and often journaling in ways not completely aligned with their original goals.

3.3.1 Default Motivational Factors

Participants reported that their default motivations for choosing modalities and devices were based on their personal goals and influenced by how they might have previously journaled. Participants expressed two default motivations for defining their primary strategies for journaling: (1) journaling goal, and (2) affinities for or aversions to specific devices or modalities.

Participants with quantitative goals often preferred modalities which supported lookup of nutritional information, while participants with awareness goals varied more in modality use. Participant's choices were often also influenced by their familiarity and prior experiences with each device. Nonetheless, goals can fluctuate over time, and changes can influence default preferences for modalities.

Journaling Goal Drives Preferences and Choices

Participants described their journaling goal as being most influential in deciding what modalities to use. Participants with quantitative goals typically preferred database search and barcode modalities because they would support learning nutritional information. Participants with quantitative goals used database searches at a marginally higher rate (Z=1.78, p=0.07, 95% CI 0.38x lower – 4.45x higher), though I observed no statistical difference in their rate of using barcodes (p=0.551). For instance, P14 explained that she mostly chose to create entries with database searches because *"at the end of the day, calorie count is the most important thing."* P14 elaborated that if she used more descriptive modalities like taking a picture, *"[I] wouldn't be getting the information I want out of it, which is the calories."* Some participants with quantitative goals imagined that the voice modality would implicitly run a database search. For example, P2 described:

> *"I would imagine with the voice command of being able to tell it, '32 grams grilled chicken breast,' like it would just populate it onto the software 'This is, according to the Internet, x many fats and proteins and whatever are in grilled chicken breast"'.*

And P12 added:

> *"if MyFitnessPal had the ability for me to speak into it and it knew from my*

frequent foods database or whatever and it would accurately pull nutrition up, I would use that all the time. They don't have that feature, and I assumed that your application did."

These examples illustrate that perspectives on a modality's usefulness were influenced by food journaling motivation, with people desiring support in monitoring and measuring progress towards specific goals.

Having food awareness goals may make using multiple modalities more appealing due to having less requirements for nutritional information. All participants with awareness goals tried at least three modalities during the study. P8 described her preferences as *"I just like having the different options."* Participants with awareness goals tended to prefer the text and voice description modalities, using text description at a higher rate than participants with quantitative goals ($Z=2.51$, $p<0.05$, 95% CI 0.46-4.42x higher) though no noticeable difference in use of voice description ($p=0.54$).

Some participants reported that their journaling goals might change in the future and reflected on how their modality preferences might change if that were to occur. P3 said he liked using ModEat to journal with description and images but considered that if he wanted to lose weight he would need to *"get even more serious about it, it would be more quantitative."* P13 currently wished to be mindful of her eating but had previously focused on nutrient information: *"If I'm just trying to be more cognizant of what I'm eating or how much, then likely I would be fine with the simpler [tracking] version. If I'm actually going to be doing my weight training, then I'm going to want the more granular,"* she also pondered that this goal shift was related to the current pandemic situation: *"if it was a better time, I would be doing a much better job of keeping track of my carbs, but the fact that we are in this [pandemic] situation, means that you shop for groceries differently, healthier attitudes or healthier beliefs are out of the window."* Other participants with quantitative goals mentioned they might shift to an awareness style of tracking after they learned the nutrient information of foods they commonly ate. For instance, P10 said, *"I would use the database search in the beginning when I was less aware of the protein content and then as I got a good sense of how much protein was in particular meals, then I would start using descriptive [modalities] so it was easier to reconstruct."* Despite participants having clear food goals during the study deployment, they indicated that life events or new perspectives could lead to new goals and modify how they journaled.

Affinities and Aversions

People may prioritize journaling with devices with which they have more prior experience. When participants journaled their foods with ModEat, they often preferred devices they used more frequently for other purposes, and perhaps avoided others with which they were less comfortable or experienced. Also, prior experience with journaling on mobile apps may influence people to continue to journal on mobile. P3 described journaling on the ModEat phone app as *"really similar to what I'm used to."* P8 agreed, *"the phone is just easier and through apps, I just think I'm so used to using apps."* Participant's familiarity with their phones enabled easy use and maintenance, suggesting that extensive experience with devices and designs can influence user's journaling affinities and choices.

A few participants explained that they chose not to use some devices due to some level of aversion for the platform, at least for food tracking. P12 considered using his Google Home to make journal entries but described it as *"a prime example of just a complete break in intent"* and *"just so jarring a juxtaposition between where you're at mentally, where you have to go to be talking to a robot."* Instead, he made all of his entries as voice inputs on his phone because it takes *"just three seconds and I'm done,"* not requiring the conversational steps to interact with the VA. P15 said that using VA *"was kind of too slow"* and P9 agreed that it required *"a lot of care"* and *"patience"* because *"[you] run through the three or four* *verbal steps to kind of make that entry."* Even participants who frequently used VAs for journaling reported concern that VAs would misunderstand or not interpret what they said. Misunderstandings could be due to some amount of accent – *e.g.*, *"it doesn't understand me because of my accent"* (P5) – but *"even in English, she [VA] has a hard time understanding some words"* (P15). Similarly, P3 did not use his VA because he did not feel comfortable with it, but considered that this might change in the future: *"I'm really not comfortable. Just, I'm not really used to using it [VA] to the point where it's second nature to me. I think I would only use it when I'm more comfortable using it, if using the voice assistant was more integrated into my daily life."* Therefore, perceptions of a platform's characteristics and a lack of experience with it can create an aversion to the device. For some participants, these elements combined with a need to learn and manage a new technology can deter from choosing them as default journaling options.

Similar to VAs, perceptions on the tasks computers intend to support may make them less appropriate for food journaling. While most participants said they enjoyed the practicality of tracking on their computers when already using it for other activities (*e.g.*, while working), other participants disregarded this platform. For P2, the computer was exclusively for school activities: *"[The computer is] not a preference at all. Once I'm done with schoolwork, the computer's closed down."* P7 described only minimally using her computer, and therefore tended not to consider it for journaling: *"I do have a Chromebook, but I don't use it all, especially since I'm not a student anymore. So, I don't really see the need for it [to journal]."* People may not want to use a particular device for food journaling due to beliefs about other tasks some technology were originally intended for, even if they own and regularly use it.

3.3.2 Factors Which Motivated Deviation from Defaults

Situational factors such as what, where, when, how, and with whom a person eats can influence them to deviate from their preferred journaling devices and modalities, in much the same way that context has been shown to influence other interaction modality choices (*e.g.*, using voice and audio for interacting with recipes while cooking [12]). In analyzing participant's experiences with ModEat, I identified six situational factors that may lead to deviations: (1) availability of devices and information, (2) efficiency and speed, (3) device affordances, (4) modality's perceived affordances, (5) presence of others, and (6) emotions and cognition. Participants described their locations and food choices as influencing which devices and modalities were most present or practical. Likewise, they described certain circumstances as leading to quicker and less detailed entries. Participant's choices were sometimes influenced by device capabilities and the data types that modalities provided, and participants had varied perspectives of how to approach journaling in social contexts.

Although participants generally reported appreciating having multiple device and modality options to accommodate their circumstantial preferences, some felt that having to choose between options increased the mental workload of journaling. For example, P2 mentioned that *"it was a little overwhelming having all the options. There was just a lot of different ways of doing it."* Likewise, P6 said, *"I am not good with choices, because if I can't figure out what is both efficient and perfect, it just drives me nuts. And having all those options is just like 'which one works best for me right now?' I could take the photo, but also the barcode, I could do that. I was just like, 'what do I do?"'* Still, participants reported that with time and practice this decision effort might lower as *"you learn the app after a while"* (P13). As described below, having multiple options was often useful to circumvent situational constraints or better journal in the moment.

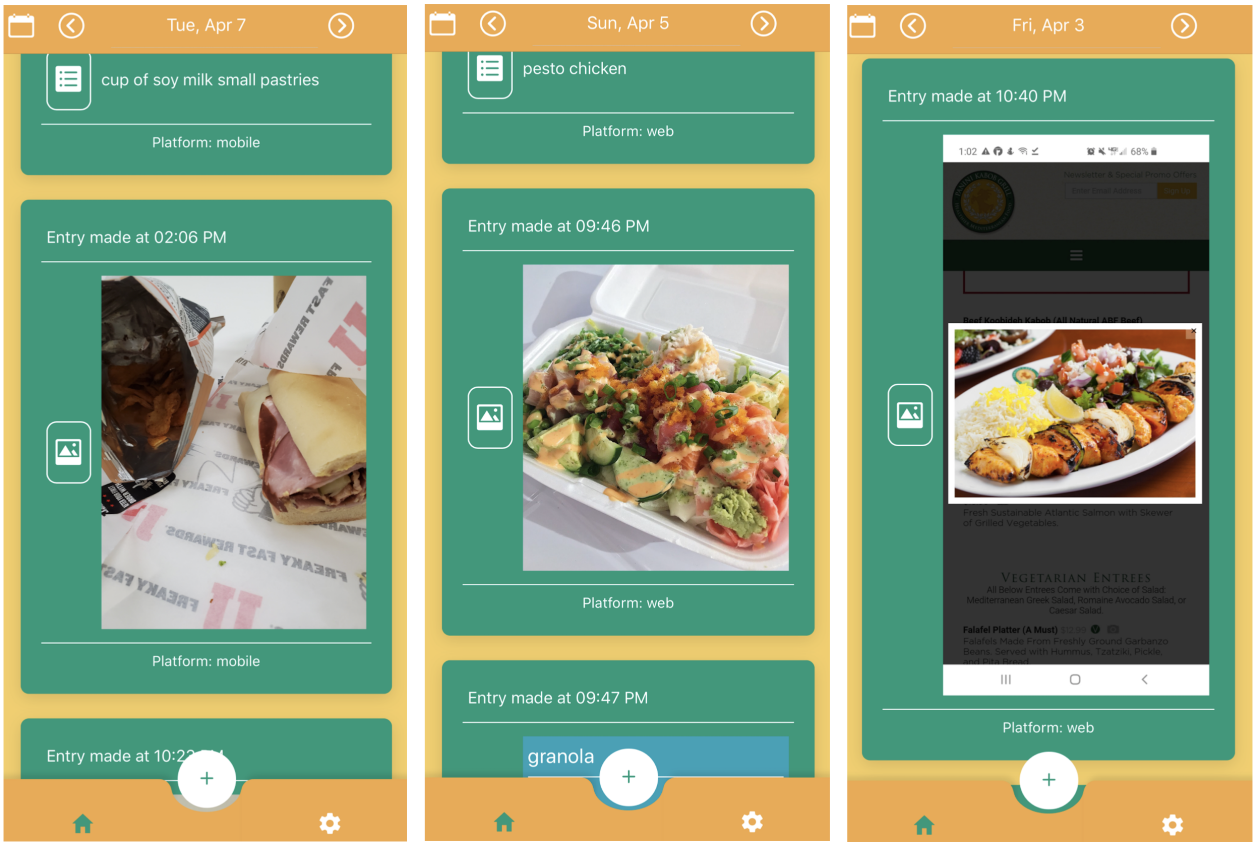
Availability of Devices and Information

Participants found that the physical location of where they ate influenced whether different devices were available for journaling at all. Some physical locations introduced clear constraints, such as eating outdoors typically limiting participants to journaling on their phones, their only available device. In contrast, VAs were used only at home. P2 described that sometimes the VA was the only available option for journaling because she was in the kitchen and the *"phone is charging on a different docking station in a different part of the house."* Participants recorded nearly all entries from home (91%) due to the pandemic, with a few journaled while at work (3%) or other locations such as in a car, at a restaurant, or somewhere else outdoors (6%). Unsurprisingly, mobile devices were used for journaling while not at home more often than other devices ($Z=3.29$, $p<0.01$, 95% CI 0.26-1.66x higher) and VAs were used while at home marginally more often than other devices ($Z=2.09$, $p=0.06$ 95% CI 0.14x lower – 2.01x higher).

Participants described the phone's portability as a factor for journaling a majority of entries this device. P14 said that *"I've got my phone with me constantly. It's with me all the time."* Likewise, P1 pondered, *"Alexa is not always nearby me and my computer is not always nearby, and the phone is in my pocket. It travels nice and it would be something that will be more dependable upon."* The positioning of devices in respect to the body is thus an important factor for availability, such as a phone in the pocket or a VA available "everywhere" in the room.

Participants also considered what device they perceived as most available, even if multiple options were nearby. P5 considered her computer available when *"studying, doing something on my PC and I want something to eat, so I might as well just start logging it."* Likewise, P13 associated her workplace with journaling on computer, although being at home for most of the study due to COVID-19: *"I'm working away in my office and I need to log something,* *then more than likely I would use the [ModEat] web version. I could also use the mobile, but sometimes when I'm at work, I'm trying to stay off my phone."* Participants generally considered computers as stationary devices, only considering them for journaling when they were nearby. For instance, P12 said *"I'm not going to run all the way upstairs to get on my laptop, type it all in, that's obviously a huge interruption and inconvenience. It's not like I have my laptop next to me."* In general, the multi-device nature of ModEat often led participants to ponder in-the-moment options and consider which one was more practically available.

Participants' modality choices were also influenced by the availability of what they ate relative to when they journaled, such as if journaling before preparing the food or long after they ate. For example, barcode scanning required that foods be packaged, and particularly that the package still be easily accessible. As P13 put it, she would *"not particularly go digging through my trash to go find the particular item that I had eaten three hours before."* Participants described similar logic when taking pictures, needing to input the entry before the meal is over. They were more likely to include images when journaling before or while eating than after eating ($Z=4.15$, $p<0.001$, 95% CI 0.92x-2.52x more likely). P8 creatively leveraged the image modality by searching online for pictures similar to her meal, especially when it was from a restaurant (*e.g.*, Figure 3.3c). P6 described difficulty journaling a food someone else had prepared and she was unsure of: *"I had no idea what was in the Ube pudding. I couldn't look up Ube pudding on a nutrition database and feel comfortable putting that information in because it probably wouldn't even be accurate. There are so many types of Ube pudding."* P6's experience echoes prior work in highlighting that database search can be a challenging modality when facing foods with uncertain ingredients [55].



(a) (b) (c)

Figure 3.3: Different ways P8 used image to journal food. (a) use of picture captured by phone camera. (b) use of stock food image. (c) use of screenshot of restaurant's menu.

Efficiency and Speed

Participants generally wanted to be able to journal quickly, and sometimes found themselves in situations where they wanted to prioritize speed when journaling, choosing whatever entry mechanism *"is most convenient or whatever would be quickest"* (P5). For example, P8 had a limited lunchtime at work, and she *"didn't want to spend that much time with just journaling. I wanted something really quick so just [journaled by] typing description."* For five participants (P2, P3, P10, P11, P15), hurriedness meant preferring to journal by taking a picture: *"I was working late, I didn't want to take a break to open the new tab and have the different entries. So, the picture is going to be the fastest way"* (P15). P10 similarly suggested that *"the other methods would require additional concentration and attention,"* indicating that situational needs for quickness could influence device and modality as well as level of detail provided in the food description.

Perception of each modality's efficiency influenced which one they used when in need to make quick entries. I found that participants saw database searches as detailed but not speedy, requiring careful description of foods eaten. When under time pressure, P4 described wanting to reduce the burden of using database searches by not recording some noncaloric items such as onions. He said, *"looking at every single ingredient of a meal is a huge pain in the butt. So, we'll often end up skipping things like vegetables, onions. The effort of looking it up is not worth it."* Despite some participants' perception of VAs requiring a lot of time, others considered that using VA was timely because *"it goes quickly to speak with [it]"* (P5) and being able to simultaneously do other activities. Overall, participants evaluated the balance between amount of time it would take to make an entry and the utility of that entry for later reflection or other needs.

Device Capabilities

Journaling may be better enabled by particular device features at particular times, such as using the voice assistant for handsfree journaling or the ability to multitask. For example, P10 had an Amazon Echo Dot in his room and enjoyed journaling with the VA *"while conducting my morning routine."* Compared to other modalities, VAs were more often used for journaling entries before or while eating than after ($Z=3.67$, $p<0.001$, 95% CI 0.26x-1.24x more often). About half of the participants (P1, P2, P4, P5, P9, P11, P13) had their voice assistant located in the kitchen and found it useful to track while eating or preparing meals. P1 said, *"I would use it when I want to multitask. If it's available right there and I'm prepping or if I'm cooking, so I'll be like, 'Alexa, journal blah blah blah'."* P5 considered that using the VA to make an entry while preparing food would also improve accuracy and avoid the risk of forgetting if done at a later moment:

P5: *"for accurate tracking [of] your food, if you want to have a specific calorie limit to stay with them, then you have to actually remember everything you eat. If you forget something then you're going to fail your goal. So, using the voice assistant while you're doing the food [preparation] and while you're actually weighing it out, you can tell the voice assistant how much of this, so that way you don't forget."*

Participants mentioned leveraging the computer platform when their foods would be easier to journal through a mouse and keyboard (P3, P4, P5, P6, P9, P10, P11, P15). For example, P15 said, *"it's easier to type on the computer than on the phone. So, if I just have the phone and my computer open, and if I'm eating right there, I would just use my computer, because I don't like texting [on phone] that much."* This was particularly useful when journaling while doing meal planning and/or following online recipes *"because if you browse the recipes online, you could easily import that, copy-paste it"* (P5) and because on phone *"It's too small to see"* (P2). Compared to other devices, participants used the computer to journal after they ate more often ($Z=2.87$, $p<0.01$, 95% CI 0.09x-1.02x more often).

Modality's Value for Future Reflection

Participants evaluated and compared modality's usefulness for later recollection and reflecting on their food choices when deciding which one(s) to use. However, they also considered the characteristics of the food(s) and what modality would be more appropriate to record it.

A modality may not effectively support some reflection goals, but can still capture information about foods that are circumstantially relevant. For example, participants expressed that images would have limited support for quantitative goals, like calorie counting, by themselves, because they are *"not a searchable method"* (P9) or could not return the desired nutritional information – e.g. *"I wouldn't be getting the information I want out of it [image],* *which is the calories"* (P14). P10 considered using the image modality as a last resort *"if it was difficult for me to get information on nutritional content of foods not commonly identified to a database [and not packaged], I would prefer to use description or took the photo."* Overall, participants reported thinking about the limitations and advantages of using images in respect to how it might or not be valuable to capture certain foods in comparison with other modalities.

Open-ended modalities like voice or text input can support flexible aspects of record-keeping, like social circumstances or memos, alongside journaling because *"because it's basically a blank sheet"* (P9). For instance, P4 used text description because *"I wanted to have a description of what I ate that included a general description. I mostly want to record what I ate. I'm not terribly concerned about the quantity or having it be exact."* Interviewees also considered this modality's open-endedness as useful to journal meal contexts and related information about specific situations. For example, P13 said she could use text description to *"make yourself a note that says, 'Never buy this again"'* and P5 made a text entry with a contextual note *"dinner at friend's house."* Participants were more likely to include text descriptions when journaling after they ate (Z=2.02, $p<0.05$, 95% CI 0.02x-1.08x more likely). The unstructured nature of open-ended modalities allowed for adaptation that might be useful for future reflection or reminiscence.

Presence of Others

Eating with family members or guests at home or in social contexts had various impacts on how participants decided to journal food. Most participants inevitably chose to journal long after such situations, with the risk of forgetting or having less detailed entries due to relying on memory. Participants had several reasons for postponing journaling in these situations, such as not wanting to interrupt *"other stuff going on"* (P3), *"stop listening to something others said"* (P10), *"trigger unwanted thoughts for those who struggled in the past with eating* *disorders"* (P14), or taking care of their kids during meal time (*e.g.*, *"kids are demanding, I need to work around their needs"*, P11). This also meant that some modalities would not be available, such as scanning a barcode or taking a picture of the food. Nonetheless, five participants (P1, P4, P6, P10, P13) pondered that in some social situations they would evaluate picking the phone for a modality that was quick enough (*e.g.*, a picture) to not hinder social interactions: *"I don't want to interrupt social activities so in order to minimize that, I would pick a modality that would be very quick to capture what I ate"* (P10). Some people feel journaling is stigmatized and avoid doing it around others [55]. Our findings suggest that fast interactions may avoid these feelings, but people often instead postpone journaling for later.

Although participants were generally comfortable journaling around others who lived with them, the presence of housemates occasionally had implications for device and modality choices. Participants found journaling with VA to be sensitive to the noise of other people in the surrounding area or potentially disrupting other's activities. P2 said, *"[when my boyfriend] does telemedicine or he's listening to lectures from his program, the Alexa just wasn't a good fit,"* while P11 added, *"late at night, I don't want to disturb other people by using [the] voice assistant."* Participants also occasionally described privacy concerns around journaling with a VA. P6 decided not to use her VA to journal because she considered that her *"family is a bunch of eavesdroppers and control freaks and I don't want them hearing what I'm doing"* and if they heard her journaling, they *"would start badgering me and trying to dig into my life."*

P3 and P12 felt that journaling aloud with the VA in the presence of a partner could seem awkward. P12 said, *"I'm making lunch or dinner and my wife's around, I wouldn't say it is embarrassing, but it's a little awkward voicing it when someone else is around."* However, other participants had different perspectives. Specifically, P1 and P5 are married and mentioned helping each other track (including using the same VA device): *"my wife* *can remind me to journal if I've forgotten, and I can do the same for her, so it ended up being a good thing"* (P5). P2 expressed interest in being able to track with and on behalf of her boyfriend using the VA: *"It would be nice if my boyfriend was also using the same food journal, of being able to tell Alexa: 'Share this meal with [boyfriend's name] So having the capability of sharing [entry], that would have been nice."* Finally, P11 mentioned that due to her accent, she would sometimes ask her partner or children to help journal with Alexa: *"Alexa does not recognize my voice well [. . .] talk slowly and clearly for VA to understand you, do take effort even for native speaker [sic]. My sons and husband, [who are native speakers], also tried."* These examples illustrate the potential collaborative advantages of journaling with multiple devices, especially with the VA as it can be commonly situated in communal spaces.

Emotion and Cognition

Emotional and cognitive states can impact journaling. Study participants described how their general state of mind, impacted by events in in their everyday lives, could lead them to journal in ways that did not align with their original goals. For example, P14 had a daily calorie budget, and mostly used database search in order to provide her desired quantitative data. However, she said, *"I keep tracking even when I don't feel like I'm on top of it and I feel crappy about the whole thing. It would be useful to have something that counts for doing effort, even if it's just a text box. I can move forward with that."* Even when she did not feel emotionally motivated to journal and reached the end of the day without making an entry, she described it still being valuable to use a text description as a fallback to make an entry about what she ate that day even if not fully supporting her original quantitative goal.

Beyond this more general influence, goals and tracking can also be influenced by state of mind in situ surrounding a journal entry. For example, P2 described having the goal of tracking macronutrients for her strength training, but found that she sometimes felt like choosing modalities which would not readily support tracking macronutrients: *"choice sometimes was on a whim, If I felt like taking a picture, I was going to take a picture. If I just felt like typing it in, then I just typed it in."* Likewise, P6 felt that often her modality choices were *"maybe it's associated with my [menstrual] cycle, it's a lot of flux and it's random. So that also will determine [choice]. One time I just was not feeling it, I was not happy, so I just took a photo."* Although P6 had a quantitative goal, her feeling in the moment led her to select a different modality.

3.3.3 Combining Modalities and Devices

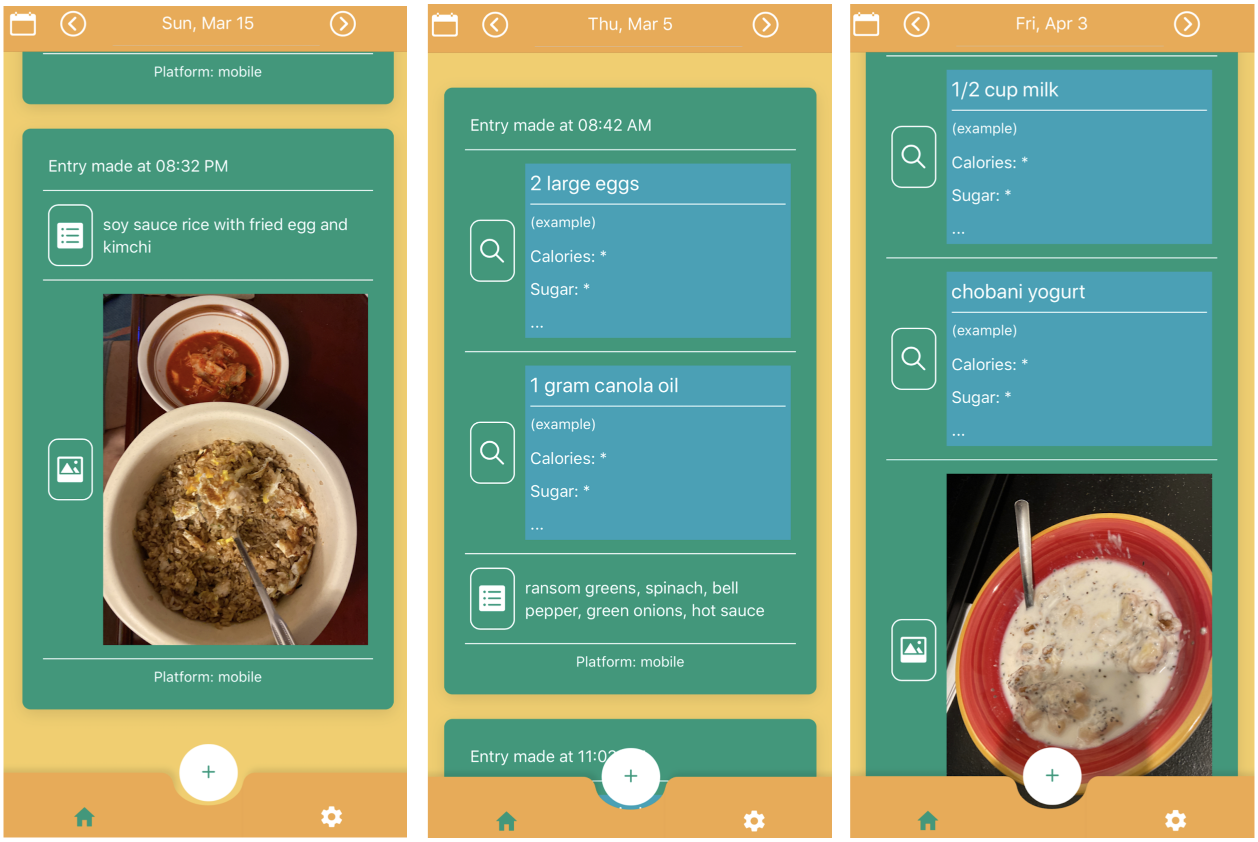
Although participants rarely used more than one modality and device per entry, their thoughts on the utility of combining modalities varied. Eleven participants combined modalities in a journal entry at least once (Figure 3.2a), consisting of 7.8% of all entries. Of these, 90% included text descriptions to complement other modalities. Participants typically expressed one of three perspectives on combining modalities: it offered little added value over a single modality, it could be used in complimentary ways, or one modality could serve as a placeholder for more detailed journaling later. Most participants did not combine modalities, reporting that typically one would be enough to capture their foods. However, some participants considered that in certain situations, multiple modalities could jointly leverage each modality's particular characteristics or serve to correct VA errors. Finally, some participants initially used a modality that required less effort, later going back to add more detail to an entry through other modalities in other devices.

Little Added Value

The vast majority of entries participants created used a single modality. Participants felt that one modality was typically sufficient to satisfy their journaling intent and to *"reconstruct* *what I ate"* (P10) under most journaling situations, such as learning the nutrient information when using a database search or having the visual feedback of a picture. For example, P7 said *"So I think just choosing one option is good enough for me most of the time. I don't feel the need to have a picture, a description, and a barcode because I'd be able to identify what I ate based on the one method that I inputted it with."* Combining modalities also implied more effort per entry and could go against a desire for *"efficiency and to do as few steps as possible."* (P6), therefore more often participants aimed to use a single input modality because *"I was aiming to make it as simple as possible" (P4) and "so I can do it in only one step"* (P6).

Complementing

Combining modalities could also be a means of capturing more food details and when *"one modality was insufficient"* (P10). Four participants mentioned using pictures to convey the amount they ate (*e.g.*, Figure 3.4a), while using text description or database search to *"annotate the picture with what specific items are in it"* (P9). P5 reserved database search for food items that would contribute to her calorie total for the day, sometimes combining database search with text description to add negligible calorie ingredients (*e.g.*, Figure 3.4b): *"when you just do a handful of spinach or a handful of kale, that's never really much, it's like four calories, seven calories, so it doesn't really matter. That's just a text description."* P4 stated that the possibility of combining modalities was *"the biggest thing I like about the mobile, or the web, over the Alexa."* Participants occasionally leveraged other devices to correct VA's entry errors. P1 had once made a voice entry that was recorded as *"care o'clock bagel bacon and roasted tomatoes,"* she noticed this as an error, and edited the entry using her phone to the correct description *"carrot lox bagel, bacon and roasted tomatoes."* Similarly, P15 had made a voice entry recorded as *"for eggs"* and later corrected on phone to *"4 eggs"*.



(a) (b) (c)

Figure 3.4: Example of screens of modality combinations for a single entry. (a) P7 combining text description and image. (b) P5 combining text description and database searches. (c) P15 combining image and database searches. Images were used to capture portion sizes and distinguish between similar foods, while text was used alongside database searches for items which had negligible caloric value.

Placeholder for Detailed Journaling

Participants with both awareness and quantitative goals occasionally used pictures for in-the-moment journaling as a placeholder for later creating a more detailed journal entry. Participants felt like doing so could help prevent skipping or forgetting to journal at all in situations where they were time-constrained, serving as *"a reminder to come back and log"* (P15) and preventing reliance on memory alone. For participants with awareness goals, this strategy could help keep a more accurate record of their food. P3, described:

"Say like, I've got three days' worth of pictures of stuff that I ate, then I can just write down. For example, I got a picture of a bowl of pasta, then I can write down that I got the pasta with the cheese on it. It will be nice to be able to bring in more information later on so that you know that you properly logged what you ate, and you're not missing things. You're not forgetting things."

Participants with quantitative goals also used this strategy, but for later searching for a food's nutritional information. P2 considered a variation of this strategy when eating out by taking a photo and later *"going online and pulling up their restaurant menu and having the macros put in that way,"* she also imagined that a future food journal could *"on a day that you just took a photo of getting an alert later in the evening of, 'Did you want to add detail to your meal?"'* P15 imagined a cross-platform approach could be useful, taking a picture with his phone and later editing on his computer to add detail (*e.g.*, Figure 3.4c). He said, *"Like when I go onto the web, go back in and edit the items that I ate. I would use the image [from phone] one then the database one. So, I'll just take a picture, and then I'll come back and I'll add the items later."* These experiences indicate that combining modalities through the use of placeholders can increase the opportunity to provide more useful and accurate entries when there is a better or less constrained moment in their routine.

3.3.4 High Variance in Food Description and Capture

Our analysis of food logs surfaced high variance in how people prefer to describe what they eat, both between individuals based on goals and among individuals based on their foods and circumstances. Food descriptions varied in granularity and specificity, occasionally captured contextual information, and indicated amounts using measurement scales or numeric values alongside subjective measures, but entries were occasionally ambiguous or unclear. Similarly, participants varied in how they used images to depict their food, such as arranging foods for aesthetics and clear amount compositions, use of stock images, and packages. This input variability had consequences for the recognition and performance of commercially-available NLP and image classification ML models, with some styles of entry more accurately interpreted than others.

Granularity: I observed that participants varied in how granular they described foods in logs (*i.e.*, quantity of food items per input). Input granularity was either of single food item, a single item decomposed into its requisite ingredients, or aggregated foods. Most food entries were composed of a single item (62.9% *e.g.*, "1 cup blueberry", "fajitas"). However, participants occasionally described single foods with decomposed ingredient descriptions, such as the ingredients in a sandwich or a salad (8.2% of inputs). Some of these inputs had a food's common name followed by its composition (*e.g.*, "breakfast burrito with a whole wheat tortilla, two eggs, bacon...", P14), while others described the ingredients without indicating a common name (*e.g.*, "2 tortilla with butter and honey", P6). Participants also regularly aggregated distinct food items into a single input (28.9% of descriptive modalities), averaging 3.09 foods per input when they aggregated (min 2, max 9).

Input modality tended to influence the granularity with which participants entered food (χ^2(2, N=890)=89.56, p<0.001), but I did not observe a statistically significant impact of food journaling goals on granularity (p=0.15). Also, participants tended to aggregate entries more often when eating with others versus alone (Z=2.04, p<0.05, 95% CI 2%-90% more likely to aggregate), perhaps suggesting that participants tended to aggregate when in social situations where they wanted to journal multiple items quickly.

Specificity: I also observed variations in how specific people described their food items as either generic, specific or varietal. A minority of food descriptions consisted of foods with generic ingredients or contents (*e.g.*, "dumplings..." P1, "veggie taco salad..." P4), comprising 8.1% of all food items. Participants instead tended to describe foods in ways which were specific enough to distinguish between foods or ingredients of prepared foods (*e.g.*, "peanut butter 14 gram" P5, "broccoli, chicken, rice..." P9; 53.4% of all food items) or further describing varietals of same food (*e.g.*, "red beans..." P12, "roast chicken breast...", P4; 38.5% of all food items). Similar to granularity, there was no statistically significant correlation between participant goal and specificity levels (p=0.83). Instead, all participants greatly varied individually in how specifically they journaled their foods.

Descriptions of aggregated foods were not always clear about how they were composed, leading to potential uncertainty or ambiguity around what was eaten. Some food inputs (92, or 27.8%) had unclear food descriptions, especially when lacking conjunctions or item separators. For example, descriptions like "coffee cinnamon rolls" (P2), "cup of soy milk small pastries" (P8), and "half apple chicken link" (P15), could be interpreted as flavors or varieties, or separate items that were combined into a single entry. For example, P5's description of "warrior chia bar cinnamon and apple" could be interpreted as a bar with cinnamon and apple flavor, versus bar with cinnamon flavor and a side apple.

Amount: For descriptive inputs, participants used different methods to articulate how much they ate, such as using formal scales (14.3% of food items; *e.g.*, cup, grams), numbers (21.0% of food items; *e.g.*, "1 roma tomato", P15), and non-standard measures (6.7% of food items; *e.g.*, serving, bowl, handful, slice). 10.1% of aggregated or decomposed food logs used more than one strategy for describing amounts. For instance, 33% of these mixed-amount inputs combined some food items measured using a formal scale with counted items (*e.g.*, "[a] baked potato with 1 tbsp butter" P15). More than half (64.4%) of mixed-amount inputs had a quantified food item alongside food items with no amount at all, such as "plain burger, fries, 1 glass dry white wine" (P5), "raisin bran [cereal] and an egg" (P4), and "3 catfish tacos, corn tortillas, salsa" (P3). One explanation is that some foods are more difficult to count or quantify than others, especially foods that are small, numerous, or liquids.

More than half (57.5%) of described food items had no amount clarification, and there was no significant difference in the rate at which amounts were clarified between voice, text, or database search input modalities (p=0.36). Participants' goals typically influenced their decision for choosing whether to describe their food amounts. Typically, participants that had weight management, nutrient, or calorie-focused goals mentioned a desire for measuring their foods. For instance, P12 said, *"If you're trying to be really, really anal and accurate, you've got to remember these grams"*. Likewise, P5 preferred measuring her foods, explaining that she *"wanted to make sure I get correct amount of fats logged"* when journaling "28 gram mozzarella" with a scale amount. In contrast, P3 was primarily interested in becoming more aware of his eating habits and explained that *"the way I would log would be more just what I ate rather than a quantity [...] I would just put what I did with some qualitative things, 'I had a small plate of this', or 'I had a couple of this.' I wanted to make it easy to log. [...] Just a description of the meal, rather than getting into, 'I had three eggs and 200 grams of ham and blah blah blah'."* P13 similarly aimed to be *"cognizant of what they're eating"* and felt less of a need to clarify the amounts they ate.

Overall, participants with quantitative goals were more likely to clarify the amount of food they ate in an entry than participants with awareness goals (Z=1.71, $p<0.05$, 95% CI 14%-328% more likely). Participants varied substantially in how often their food item descriptions included amounts, with 7 of them indicating amount in less than 25%, 3 indicating amount in more than 75%, and the remaining 5 in between.

Context: Participants included contextual information related to the food and eating event in a few entries (4.9%). 21 of these inputs had implicit or explicit indications of where the person ate the food. For example, P5 mentioned in a text input making a home-cooked meal, "quick homemade stir fry sauce; 15 calories", versus another meal in a different place, "dinner at friends house, bbq chicken with mac and cheese". Implicit locations were present in inputs with foods from restaurant, such as "Chinese takeout chowmein beef broccoli" (P2), and "WABA grill: salad, brown rice, chicken, beef,..." (P3). Other contextual information include time and type of meal (*e.g.*, dessert "Persian dessert, many", P6; lunch "lunch: slice of pizza with side salad", P13) or recurring foods (*e.g.*, "same pasta, chicken...", "leftover chashu and bok choy", P3).

Some participants (P2, P6, P8, P12, P14) indicated that knowing meal contexts would help them reflect on their eating behaviors. For instance, P6 mentioned a desire to *"explore my emotions around my food emotions [...] because I'm really interested in how food would impact emotions or how my emotions impact what I eat"*, and suggested that this could be through *"writing and answering a questionnaire or photos"*. Similarly, P14 said that capturing context was lacking in her past journaling experience and could have given more insight for her food choices. She said:

> *""I have in the past thought about when I look back on my journal, on MyFitnessPal, [that] I can identify things that I felt good about eating and things that I sort of felt like, 'well that was a bit of a waste'. [I would like] Having a bit of context, if there was a way to easily visualize that somehow to sort of know, because what I would think I might find is I eat a bunch of crap, I don't need to eat late at night or during a stressful day or something like that."*

3.3.5 Automatic food interpretation

Participants expressed interest in leveraging automatic interpretation of food descriptions logged as a way to integrate across different types of modalities, like images and text descriptions resulting in nutritional and categorical information about eating events. Nine participants (P2, P5, P6, P10-15) wished that VAs could execute a background database search on described foods during the conversation or for later reflection. For instance, P11 said, *"I wish the [Alexa] VA can figure out the total calories of the food after I tell her what kind of the food I had and the quantity of the food."* There were similar requests for interpreting text descriptions and images. P9 wished that text inputs would retrieve nutritional information, combining with database search, saying *"a blend of those two [db search and text input] would be great [...] it would give me the option of providing me the additional nutritional facts about each of the items that was in my [text] description"*. P9 suggested a similar feature for capturing food composition from images, comparing to Shazam, a popular music classification app: *"it would be like the Shazam of food [images]. I think that would certainly add additional value."*

Current automated approaches were overall successful given how participants desired journaling their foods, but had some limitations depending on how participants wished to structure their entries.

Interpretation of natural language food descriptions. Overall, food items were generally identified correctly by the NLP systems I tested, with 80.7% of descriptive entries correctly being interpreted and returning relevant nutritional information for every food item or component (*e.g.*, calories, micro and macro-nutrients). For example, the entry "eggs in cheese sauce over English muffin with coffee" (P13) was interpreted as four separate ingredients: "eggs", "cheese sauce", "English muffin", and "coffee." The remaining 19.3% inputs were not fully interpreted correctly, but 77.9% of these had at least one food item that was correctly identified. For instance, "4 oz chicken breast 3 oz spinach 125g tamaki haiga 2 tsp soy sauce" (P10) had all items identified except for "tamaki haiga". Overall, only 4.3% of inputs completely failed, either not matching any items (14 inputs) or wrongly identifying foods (24 inputs), such as "2 tablespoons salad topper" (P15) being classified as "salad". Six of the non-matched foods were direct references to brands, such as "2 square 70% lindt" (P5), while four others were ethnic foods such as, "chapaguri" (P7).

Modality impacted the rate at which inputs were accurately interpreted (χ^2(2, N=890)=36.91, $p< 0.001$). Text inputs were less likely to be interpreted correctly than voice inputs or database searches (Z=-5.70, $p<0.001$, 95% CI 49%-121% less likely). Text inputs had greater opportunity for at least one item not being understood due to most entries being aggregated foods, versus database searches and voice inputs that had a majority of single food inputs (Figure 3a). 79.4% of text inputs had at least one item correctly understood.

Specificity also impacted in interpretability of food descriptions (χ^2(2, N=890)=36.39, p<0.001), with specific foods more likely to be interpreted than either generic or varietal foods (Z=4.74, p<0.001, 95% CI 32%-98% more likely). Many varietal descriptions used adjectives to describe food names, which could lead to misinterpretations and ambiguity. For instance, the voice input "chicken eggs and avocado" (P10) was interpreted as "chicken eggs" and "avocado", but could alternatively be chicken meat (*e.g.*, "chicken and rice 4 oz" P10) and not a description of egg type. Other examples include "salmon cakes ..." (P14), "peanut butter muffin" (P12), and "banana tea" (P9). Similarly, decomposed foods that had a food name followed by individual ingredients could be counted twice. For instance, "pasta / 3 oz. edamame spaghetti, 4 variety tomato, .5 tbsp. olive oil, [...]" (P6) was interpreted as general pasta as well as edamame spaghetti, tomato, and so forth.

Most descriptive inputs had food items where amount was specified, but amount interpretability depended on how it was described. Scale and numeric descriptions had 78.7% and 80.0% of inputs completely and correctly interpreted, while non-standard measures were correctly interpreted in about half of inputs (53.8%). Some of the non-standard measures could be occasionally understood and return estimated nutritional metrics, such as bowl, spoonful, bottle, plate and scoop. However, "handful" was not captured as a measure in any of its 23 occurrences. Inputs where the amount was not clarified tended to return a default scale measure estimated by serving size, such as "cereal with milk" (P13) being assumed as 1 cup each. Similarly, "serving" was also mapped to default measures, such as "bacon .4 serving" being record as 0.4 of unit "slice".

Classification of food images. Most images had at least one food composition identified by the Clarifai service (42/54) with probabilities above 0.8, versus CloudVision and Rekognition that correctly identified components in 22/60 and 21/60, respectively. However, the latter two services accurately identified background elements in 14 images (*e.g.*, table, keyboard) and food containers in 36 images (*e.g.*, plate, bowl), whereas Clarifai did not identify these elements at all. I based the analysis on food identification on Clarifai's results and background elements on results from CloudVision and Rekognition.

Participants frequently took photos of packages, wrapped foods, or uploaded stock photos of food items, representing a third of the images participants uploaded (19/60). Non-stock images of packages were mostly classified correctly (5/7). 7/10 stock images had key components identified, but several that food names written on the package failed to be correctly classified. This may be because pictures of the food items were not prominently displayed on the packaging, although other similar packages were classified correctly. Several background elements in 14 images were correctly identified, such as computer keyboards, screens, tables, and even a kitchen oven. Food containers were also mostly identified (36/38), such as bowls, plates, cups, and a blender. As expected, images with unclear food composition (6) were not well-classified by models. However, images of foods that had clear identifiable composition and that were not stock or packaged foods were mostly classified correctly (29/33). For example, a picture of chips and salsa on a plate was classified as "salsa" (0.97 probability), "corn" (0.96), "vegetable" (0.95), "tortilla chips" (0.87), "pepper" (0.86), "tomato"(0.84), and "chili" (0.81). However, inconsistencies around recognition make the method appear unpredictable and inexplicable when not identifying all items or when suggesting wrong labels.

3.4 Discussion

Through the analysis of the deployment of ModEat, findings identified reasons behind participant's default device and modality choices for food journaling and motivations for deviating from those defaults, including journaling goal, situational constraints, and presence of other people. Results also suggest that leveraging multiple modalities and devices, whether in the same entry or for different entries, has potential to better align with people's desires for food journaling and supporting a range of goals and journaling styles. Using automation in interpreting foods in descriptive logs can be a step towards integrating information across modalities in support of nutritional goals or to incorporate some contextual information. In this section, I reflect on the implications, opportunities, and limitations of multimodality across multiple devices.

Several of the findings on default and deviation factors align with and expand prior work on people's device choices and perceptions on device affordances in multimodal ecosystems. Luger & Sellen [137] and Porcheron et al. [180] highlight that VA's are often touted for their usefulness for multitasking , but current VA applications rarely surface that potential, instead expecting full attention. Participants' use of ModEat for multitasking highlight food journaling as a potentially practical multitasking application, taking advantage of handsfree interactions. Participant's use of ModEat also align with Jokela et al.'s takeaway that people factor device's interfaces, technical capabilities, and physical characteristics when choosing which to use for a particular task [106]. Participants considered familiarity with devices and prior journaling experience when identifying default device(s) to use for journaling. However, maintaining a multi-device ecosystem can be technically demanding to configure and maintain [219]. In addition, our findings also suggest that deciding among many journaling options can add some mental effort to consider choices.

3.4.1 Multimodality and Multi-device Support for Flexible Fallbacks

For participants who typically preferred to use higher-demand modalities like database searches, multimodality enabled the ability to use less demanding input forms (*e.g.*, taking a picture, writing a brief description). This was typically in circumstances which required more casual or carefree journaling, like social situations or moments where their state of mind was such that they simply did not wish to create a detailed entry. A frequent concern with journaling systems is that long-term journaling is burdensome, and people can be demotivated to continue tracking their foods [44, 58, 19]. Participants still perceived such "light" journaling as useful, and those with quantitative goals imagined possibly improving the entry with further details of nutritional information later. Modalities that require less effort or time could serve as a flexible fallback and, although they might not completely satisfy a person's main food journaling goal, such modalities may help avoid skipping an entry altogether. Prior work has highlighted that missing entries might lead a person to lose the habit of journaling, with a day's missing record snowballing to longer-term lapses [55]. Therefore, journaling systems could make use of fallback modalities to help people maintain a continuity of tracking, even if logs are not as detailed or aligned with goals. Likewise, systems could leverage multiple devices to also increase redundancy of options, allowing journaling in situations that otherwise would be skipped due to a device's unavailability.

Participants also experienced information constraints in particular contexts that led them to fall back to a modality less desirable for their goal, such as not being able to describe a food well enough to search for it in a database. Past work has highlighted that information constraints are a frequent barrier to journaling, such as situations where food components are unknown (*e.g.*, some restaurant meals, foods received from family or friends) [55]. Likewise, complex foods and homemade or ethnic foods pose additional levels of difficulty to journal, and can be more challenging than packaged foods or fast foods [55, 108]. Such constraints can prevent someone from using their default modality preference. Ultimately, **supporting multiple modalities can enable people to select among other available modalities as an alternative to skipping journaling** or creating a less satisfying entry with their preferred modality.

3.4.2 Multimodality and Multi-Device Support for Multiple and Shifting Goals

Participants' reports and journaling choices when using ModEat indicate that goals might change or preferences might be circumstantially influenced. Modality and device choices varied even among participants with similar goals, as there was often more than one modality and device which could support that goal. For example, participants with awareness goals preferred one of a few modalities which supported open-ended description (*e.g.*, text description, voice, images), but did not consistently leverage one of these modalities over the others. While participants with quantitative goals often preferred to use database searches, they varied in which device(s) they used for entry. Participants also frequently selected devices or modalities which deviated from their goals if their journaling circumstances made those approaches more convenient or less burdensome. Even if in rare occasions, multimodality also allowed for leveraging multiple data types in a single entry, which could support one's goals with increased details about their foods. Therefore, systems which support multiple modalities and devices have the potential to simultaneously support different kinds of goals and might help with transitions between goals.

The flexibility of increased modality options could better support people when their goals change or evolve, and enable people to investigate new goals. Prior personal informatics research has suggested that systems often fail to support evolving goals, which often limits the longer-term effectiveness of such systems [74, 163]. Systems such as OmniTrack and Trackly [118, 17] highlighted the importance of designing tracking tools to provide flexible input formats to support people's varied goals. This study's findings indicate that multimodality supports entry flexibility and changing goals. In particular, in trying modalities which deviated from the ones they typically used to support their goals, participants were able to briefly reflect on the benefits and drawbacks of modalities which better supported other goals. For instance, someone with an awareness goal might try to use a database search because it is an available modality, and realize that they found the information it provided valuable. They might then decide to shift their tracking goal to more quantitative measurement. Likewise, circumstances might lead someone with a quantitative goal to fall back to a more flexible and less burdensome modality like photo-taking, and in doing so, they find out they no longer desire nutritional information.

Care must be taken in how to support journaling across multiple modalities and devices. Despite the benefits from having more options to journal with, having options can be overwhelming and add mental effort to the process. Furthermore, people might have clear aversions to some devices, such as towards smart speakers out of privacy concerns. In addition, devices themselves require maintenance (*e.g.*, charging) and configuration (*e.g.*, syncing, app installation), which may make them either temporarily unavailable or result in burden exceeding perceived added value. Food journaling systems therefore should not require all options to be available or actively maintained, instead allowing users to opt in or out of modalities and devices or prioritize some according to preferences.

3.4.3 Integrating Modalities Through Automatic Interpretation and Classification

Commercial NLP and image classification services were reasonably successful in interpreting and identifying the foods that participants logged using their preferred strategies. The results indicate that input structure influences NLP performance, with inputs with more specificity and standard amount descriptions more likely to be correctly recognized. While these services were fairly successful in interpretation for nutritional feedback, potentially satisfying quantitative-focused goals, they struggled with contextual cues that participants occasionally included in their food descriptions, such as location or social circumstances. Non-standard food descriptions referencing routines (*e.g.*, "same as lunch...") or subjective amount descriptions also posed challenges for automatic inference of logs, despite being valuable information that people wanted to record. Similarly, image recognition libraries faced a trade-off between accurately identifying the foods in an image and accurately identifying contextual information, such as the room where a person might be eating or whether they are eating from a plate or another container.

Our results, as well as others, suggest that people intend to collect contextual information for later reflection [54], perhaps pointing towards an opportunity for recognition models that comprehend not only food items, but other data. Incorporating models specifically trained for recognizing food in text and images together with other classification models (*e.g.*, optical character recognition, more general object recognition models, barcode recognizer, amount classifiers) could enable adding such context as well as supporting recognition. Even if not identified with high detail or accuracy, these models could help point to fun or personally meaningful experiences [88], such as surfacing restaurant names or household objects visible in communal dining. Further mining of information embedded in photo metadata or passively recorded (*e.g.*, location, time) could further provide context to complement reminiscence and reflection for both quantitative and awareness goal groups.

While automation is typically leveraged for food tracking towards calorie or nutrient goals, surfacing and integrating contextual elements from food photos and descriptions might also be beneficial for people with mindfulness and behavior awareness goals. As food journals become easier to collect passively through automated sensing [23, 164, 254] or with lower journaling burden [54, 43], there are increased opportunities for integrating logs towards long-term use for reflecting. Photos and text descriptions can be difficult to aggregate, but automation can promote longer-term reflection or reminiscence by mining abstract concepts from these logs. For instance, people could be provided with a cloud of words with the names of frequent foods or food categories they journaled, or display a color gradient representing how the color of these foods has varied over time.

Food journaling can also benefit from image classification for increasing detail of food consumption. People with calorie and nutrient goals could leverage this by confirming identified foods in the image, adding further specificity about the ingredient makeup, and possibly clarifying amounts. Identified and confirmed foods could then be automatically searched for nutritional data in a database. Amounts could also be suggested based on contextual information present in the image, such as text on packages or food inside containers (*e.g.*, plate, cup). This semi-automated approach might potentially lower journaling time and effort [133], while still promoting engagement [43].

There was high variance in how people captured their foods. Findings suggest that supporting flexibility during data collection through multiple options led to great variance in food description styles, some of which are not precise or introduce ambiguity. Ambiguity, in turn, can lead to challenges when data might want to be reviewed or reflected on later. Ambiguous food descriptions can lead to uncertainty about foods eaten, such as inaccuracy in food metrics or nutritional information. This leads to the possibility of hindering the reflection on progress toward a quantitative goal (*e.g.*, Did I surpass my calorie budget? Have I consumed my protein quota for the day?). Likewise, completely unstructured inputs run the risk of introducing enough uncertainty that days or weeks later, people with awareness goals (*e.g.*, learning about eating habits) might not be able to interpret their logs. To mitigate ambiguity and uncertainty in logs, food journaling systems could encourage inclusion of food granularity, specificity, and amount by surfacing what was recognized and enabling correction or incrementation. Implementations of recognition libraries could help users identify ambiguous food logs, or voice journaling could operate similarly, asking a person to confirm whether a food was correctly identified and how much was eaten. Conversational journaling is a strong potential interaction to further adapt to people's journaling styles or goals and help co-construct logs according to their goals.

3.4.4 Opportunities for Parallel and Collaborative Multi-Device Use for Data Collection

While ModEat was primarily designed to create single-device journal entries, past work has highlighted opportunities to use multiple devices for a single activity either sequentially or in parallel [106]. Our findings demonstrate the value of sequential journaling, adding a food on one device and later adding context or clarifying what was journaled on a separate device. Further research could explore the benefits and challenges of parallel device use for journaling, integrating simultaneous device use for a single food entry. For example, VAs could be used for voice input while simultaneously taking a picture on a phone to illustrate the description. Modalities could also be used together in a single interaction, such as a person describing a journal entry to a VA triggering nutritional information to appear on an accompanying ambient display device for confirmation or for awareness.

Multimodality and shared devices can also facilitate family collaborative construction of journal entries. Three participants described receiving journaling help from their child(ren) and/or partner when using ModEat. Prior work has highlighted that journaling together can help family members exchange social support [138], encourage parents and children to work together [175] to achieve goals [53], and can help distribute tracking burden across family members [176]. Multimodal and multi-device systems could further support such collaborative efforts. For example, several people using personal and/or shared devices can together co-construct entries of shared meals, perhaps using different modalities (*e.g.*, one person takes a picture, another searches for a food item in a database, others record other food items). Context-aware versions of this approach can also enable semi-automated tracking, such as a system replicating one person's journal entry of a shared dinner to the journal of others that were present. Collaborative creation of entries, such as different people speaking meal components to a VA, can be a similar manual approach. Complexities emerge when people eat together but eat slightly different foods or quantities. For example, there is the need to investigate how co-construction of food logs might combine different modalities and devices between those present, and how such a log might record both a common family meal and the individual consumption.

3.5 Summary and Conclusion

Through the analysis of the ModEat deployment, I investigated how a multi-device and multimodal system can support data collection, specifically in the context of food journaling. The findings demonstrate that a multi-device and multimodal approach can help participants satisfy their journaling needs under different contexts and with diverse data types, contributing to my first thesis claim (T1). I also observed how the presence of others might influence journaling preferences, driving people to choose between quicker and less disruptive modalities to avoid disrupting social interactions, or potentially leveraging collaborative interactions to co-construct logs through conversations. This contributes to my second thesis claim (T2), indicating that systems can leverage multimodality and simultaneous interactions for collaborative data collection.

I observed that participants' modality and device choices primarily sought to satisfy their journaling goals. However, participants also faced circumstances that influenced or restricted their choices, causing them to deviate from their preferred devices and modalities. These circumstances included device availability and their state of mind. The use of ModEat suggests that multimodality and multi-device systems can lower journaling burdens under situational constraints, such as in certain social contexts or when timeliness is a priority. Combining modalities can help add detail to entries and potentially reduce the likelihood of skipping entries altogether. Furthermore, I identified opportunities for automation to integrate descriptive modalities and contextual information that some people may desire.

By providing flexibility and choice in data capture methods across devices and modalities, personal informatics can better support individuals in their journaling practices and help them overcome barriers to consistent tracking. However, designers must carefully consider the trade-offs between flexibility and usability to ensure that the benefits of multi-device and multimodal approaches outweigh the potential challenges of managing multiple options.

Chapter 4

Investigating Tracking for Family Co-Regulation When Apart

4.1 Introduction

In this chapter I investigate how multi-device tracking systems can involve multiple people collaboratively in health tracking and promotion around behavioral goals. The previous chapter demonstrated how people can use multiple devices for self-tracking and some opportunities for people tracking together simultaneously. This chapter expands multi-device use cases to consider how tracking can be done while family members are apart. It also expands from only the data collection stage towards the action stage through a focus on goal setting and tracking for behavior regulation. Data modalities in this study revolve around goal representations, points, and rewards. Considering the case of ADHD families in particular, this project contributes towards my thesis claims by answering the following research question:

RQ2: How might multi-device systems facilitate caregiving in families via tracking while **apart**?

ADHD challenges can significantly impact children's academic, social, and behavioral functioning, as well as strain family relationships [152, 214, 52, 102, 37]. Psychosocial treatments for ADHD, such as behavioral parent training and organizational skills training, emphasize the importance of setting clear goals, monitoring progress, and providing regular feedback and reinforcement [211]. However, implementing these strategies consistently across contexts can be challenging, particularly as children begin to spend more time outside the direct supervision of parents. Smartwatches can potentially improve accessibility to children's tracking in everyday life given that they are convenient and frequently available [39, 178, 15, 48]. These devices have substantially been adopted by children year over year, with the child-focused wearable market having reached USD 1.63 Billion in 2023 and expected to more than double in the next decade [62]. This chapter demonstrates how integrating tracking of goals through these devices might help scaffold parental support for co-regulation as a positive reinforcement strategy.

To address RQ2, I deployed and evaluated CoolTaco (Cool Technology Assisting Co-regulation), a novel application on the phone and smartwatch connecting family co-regulation around goals centered on ADHD children. The objective was to understand how families might practically experience and perceive integrating parent's and a child's device for co-regulation in their everyday lives. Ten households with ADHD children aged 8-15 (10 ADHD children, 17 caregivers) used the system for 3 weeks to over 6 months (average 3 months). CoolTaco implements a basic task and reward strategy to support positive reinforcement for children's behavioral skills [149, 103]. With CoolTaco, parents and children create activities, children report activity completion, accumulate points, and redeem points for rewards. Through analysis of system usage logs, pre-post surveys, and semi-structured interviews, I investigate how CoolTaco shaped families' goal-setting and progress monitoring practices, parent-child interactions around behaviors, and children's self-regulation skills and behaviors. My findings highlight the potential of multi-device informatics to scaffold co-regulation and promote more consistent behavioral support across contexts. However, I also identify key challenges and tensions, such as limitations with remote tracking for families negotiating the boundaries of parental involvement and supporting children's gradual development of independence.

This chapter makes several contributions to the design of multi-device systems for health and family collaboration. First, I extend prior work on family informatics by investigating design opportunities for children's self-tracking around goals and progress of efforts, contributing towards my thesis claim T1. Second, I demonstrate how multi-device systems, such as parent's phones alongside children's smartwatches, can serve to mediate family co-regulation for a child without the need of being co-located. This approach supports the child's independent involvement while also providing opportunities for parental oversight and collaboration, highlighting the importance of considering the perspectives and roles of both children and parents in the design process and contributing towards my thesis claim T2. Finally, I discuss design implications of my findings for family informatics systems to account for parental involvement variability and limitations of tracking while apart.

This project was published[1] at CHI 2023 with co-authors Franceli L. Cibrian, Elissa M. Monteiro, Arpita Bhattacharya, Jesus A. Beltran, Clarisse Bonang, Daniel A. Epstein, Sabrina E. B. Schuck, Kimberley D. Lakes, and Gillian R. Hayes. Armando Beltran implemented the code for CoolTaco. I developed interview protocols and conducted participant interviews alongside Franceli Cibrian. I led the study analysis, writing and revision of the paper.

4.2 CoolTaco Design

CoolTaco is designed as a multi-device system for remote goal setting and tracking centered on the child and in collaboration with parents. CoolTaco comprises two apps, one for iPhone to be used by parents, and one for Apple Watch to be used by children. The system implements a token economy behavior intervention [149, 103] for positive reinforcement by

[1]This study has been published in CHI: [220]

rewarding the completion of tracked goals. In this section, I overview the process that informed the design of CoolTaco, and detail CoolTaco's main features of supporting parents' and children's collaboration for regulation.

4.2.1 Design Foundation and Process

The design is informed by Cibrian et al.'s [48] co-design research with ADHD children (N=24) and their caregivers (N=9 staff, N=4 parents). This prior work surfaced opportunities for smartwatches to support self-regulation by scaffolding consistent contact with tasks and rewards. The co-design work surfaced three categories of activities useful for planning and tracking via smartwatches: social, health, and school. Regarding the planning of activities, Cibrian et al.'s findings [48] indicated the interests of both children and parents in setting goals and monitoring progress. Figure 4.1a-c shows some of the sketches that informed the design of CoolTaco.

(a) Example of a social goal. (b) Tracking goal completion. (c) Desire for rewards. (d) Storyboard sketch of available tasks. (e) Storyboard sketch of points being awarded.

Figure 4.1: The design of CoolTaco is inspired by findings from Cibrian et al.'s co-design study [48] (sketches shared here with permission). Children ideated that the watch could show (a) goals for the day (b) tracking of goal completion, (c) and possible desired rewards. Storyboarding was also used (d & e) as part of the design process for CoolTaco.

Informed by these design requirements and sketches, we considered multiple design directions through storyboarding for involving family members in collaborative tracking with a child [242]. For example, three sets of storyboards described the design idea of creating daily goals (*e.g.*, Figure 4.1d) and receiving points for achieving them (*e.g.*, Figure 4.1e). Other storyboards described mood tracking and dealing with stress. We used these storyboards in a fun-sorter survey [187] with 24 children with ADHD about how much they liked them and thought them pretty, easy, and fun (more details in [235]). These design phases led us to identify four design objectives, which is included in CoolTaco: (1) include a *goal-reward dynamic* to enable positive reinforcement, (2) allow for *goal and reward flexibility* (*i.e.*, not tied to a specific domain or setting), (3) enable *joint involvement of parents and children*, and (4) allow for *asynchronous collaboration* via tracking versus requiring family members be co-located. I describe below how these design objectives were achieved in CoolTaco.

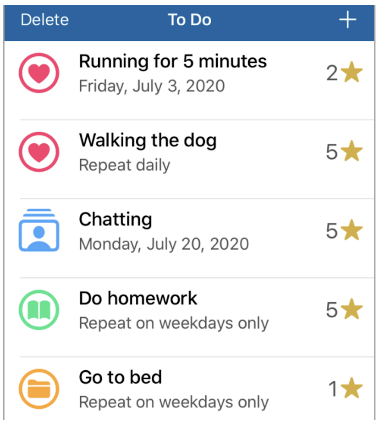
Finally, before the study deployment, CoolTaco was piloted with 2 children and their parents for 2 weeks. These participants generally understood the flow of the smartphone and watch apps, but surfaced some bugs (*e.g.*, database errors) and a need for clearer feedback for user actions (*e.g.*, confirmation or error messages, indicator for synchronizing) that were then corrected prior to deployment. Pilot participants did not participate in the rest of the study.

The final version of CoolTaco implements a token economy for the *goal-reward strategy*, a well-established evidenced-based approach built on positive reinforcement [149, 103]. Token economies are purposely customizable and based on principles of collaboration for positively reinforcing behavior by awarding tokens in response to targeted actions. This method is commonly implemented in schools (*e.g.*, handing out stickers or "school dollars" to be redeemed for rewards) [166, 212, 148] and has particular therapeutic effectiveness for some neurodivergent children [149, 234, 210]. Self-monitoring is a known strategy to foster self-regulation with ADHD children [190], thus combining positive reinforcement alongside tracking of progress has the potential to benefit regulation. Token-reward systems stimulate children's thinking about future consequences of their efforts, such as completing activities to accumulate points in expectations of future rewards (*i.e.*, delaying gratification). Ideally, such artificial token economies created as part of behavioral interventions would eventually fade, being replaced by internal rewards or natural consequences [147] in ways that are ethical, empowering, and developmentally appropriate as children grow.

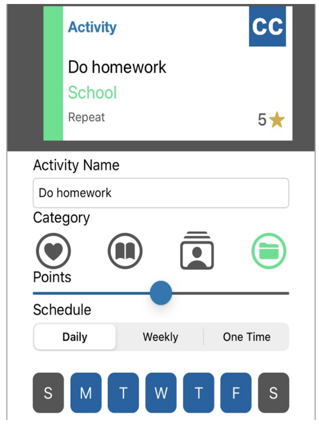
4.2.2 CoolTaco for Parents

In seeking to support *joint involvement* for parent's co-regulation role, CoolTaco on the phone is designed to enable positive reinforcement and motivational incentives through setting and tracking *flexible goals and rewards* (Figure 4.2). CoolTaco allows parents to manage activities (Figure 4.2a). Parents can flexibly create any activity by describing a name and choosing a category between wellness, school, social, and general (categories identified by children in Cibrian et al.'s [48] study). Parents also determine if the activity is a one time event, weekly, or daily (Figure 4.2b). Activities have a point value between 1 and 10; and a regularity, such as one time event, weekly, daily, or specific days of the week. Activities can later be modified or deleted. Once the child reports through the watch app that an activity has been done, it will appear in the "To be approved" screen (Figure 4.2c). This tracking can happen *asynchronously*, without family members needing to be co-located. Parents then have the option to approve the completion report and award the point(s). Points can be earned each time the activity is completed.

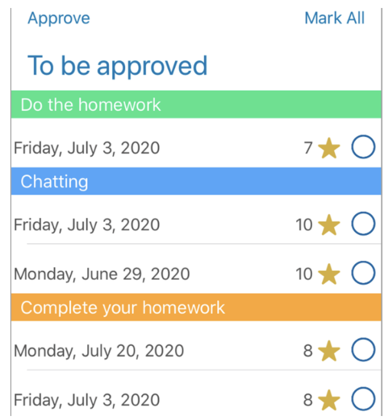
The system allows parents to *flexibly create rewards* as motivational targets, with any description and between 1 and 10 point cost (Figure 4.2d). Rewards can be edited or removed (Figure 4.2e-top). When a child chooses to spend their available points to redeem a reward, these requests appear in the "Redeem" screen of the phone app, where parents can approve or decline the request (Figure 4.2e-bottom). Finally, parents can see a summary of the child's goal activities and their state alongside the child's point balance (Figure 4.2f).



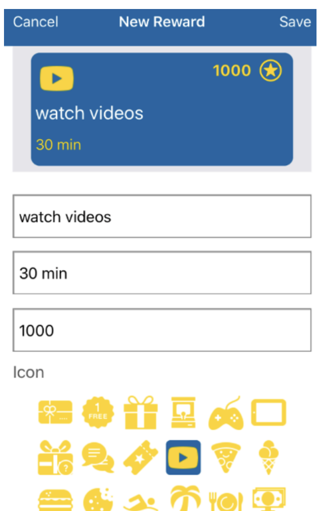
(a) Manage activities.



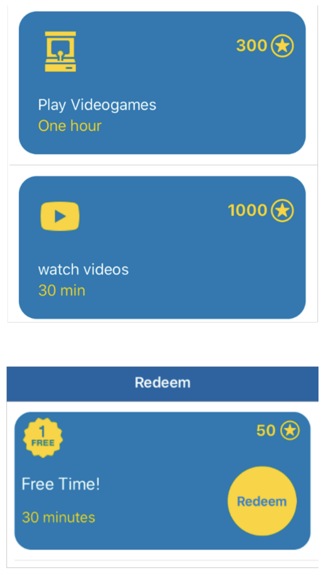
(b) Add an activity.



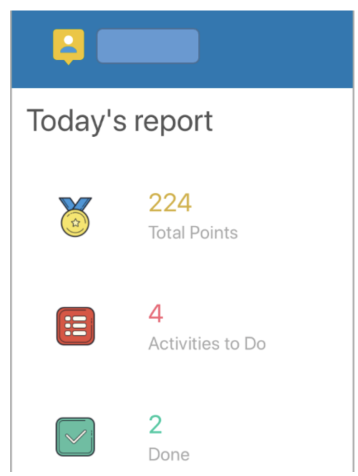
(c) Confirm activity completion reports.



(d) Create a new reward.



(e) Manage rewards (top) and approve redeem request (bottom)



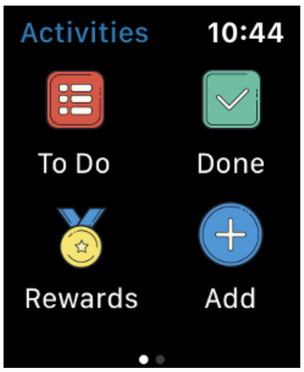
(f) Daily report.

Figure 4.2: CoolTaco on phone enables parents to (a) manage activities, (b) specify activity details, (c) approve or deny a child's report of activities being completed, (d) add rewards, (e) manage rewards, and (f) view summary of a day's available and completed activities.

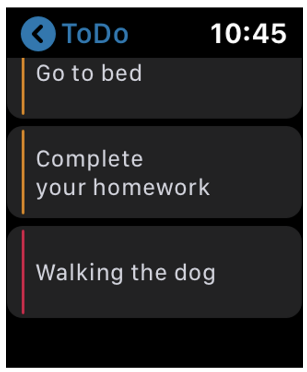
4.2.3 CoolTaco for Children

In addition to involving parents in the technological care ecosystem [229], children play an active role in *jointly* managing CoolTaco, following advice from prior work [229, 228, 49, 123]. CoolTaco offers similar features for children to those of their parents, via a smartwatch app (Figure 4.3a). Parents and children can use CoolTaco *asynchronously for collaboration*, and data in the system is replicated between the phone and smartwatch apps. The "To Do" screen lists all activities available for the day (*e.g.*, Figure 4.3b), and activities can be marked as complete (*e.g.*, Figure 4.3c) and viewed later (Figure 4.3d). The Rewards screen displays the current point balance (Figure 4.3e) and available rewards which can be redeemed (*e.g.*, Figure 4.3f, 4.3g). Finally, the child can add new activities themselves by selecting a category and description (Figure 4.3h) via voice-to-text, drawing each letter, or using emojis.

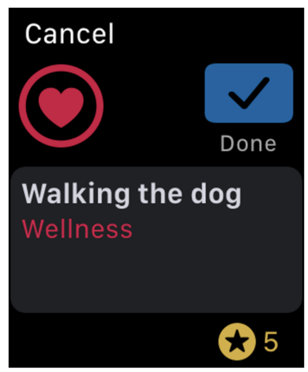
To offer children agency to *asynchronously collaborate* in the process, they can create their own activities through the smartwatch, which can also be tracked by parents. Child-created activities value zero points as a caution to limit potential deleterious effects on the positive reinforcement related to "gaming the system." Long-term, there is interest in better exploring how child-generated goals could be used to even further engage and empower children in their own progress. Likewise, children cannot create rewards in the system. Therefore, child-created activities take the form of goals for the child's intrinsic motivation and the opportunity to internalize the reinforcements [197]. Aware of this design tension, I incorporated related inquiries in interviews with children and parents and report it in the findings. Recognizing the potential risk of notifications disrupting children with ADHD and exacerbating their attention challenges [48], CoolTaco does not trigger notifications on them smartwatch app.



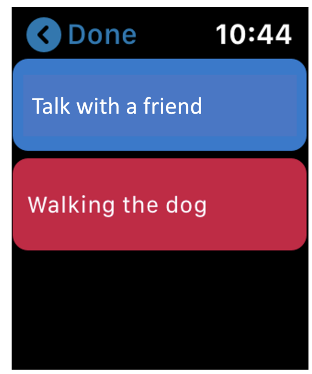
(a) Initial screen.



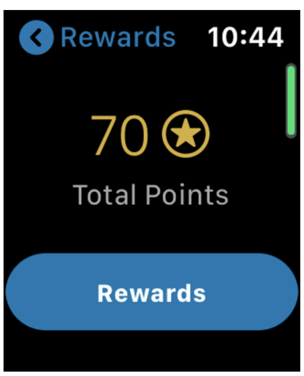
(b) Viewing activities.



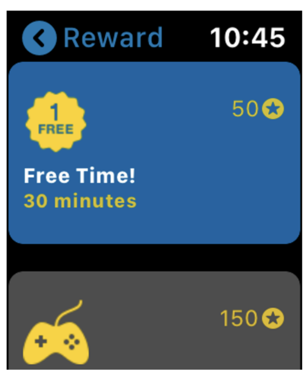
(c) Completing an activity.



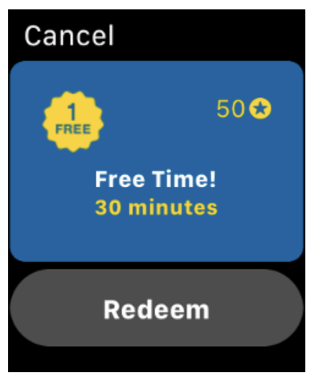
(d) Reviewing the day's finished activities.



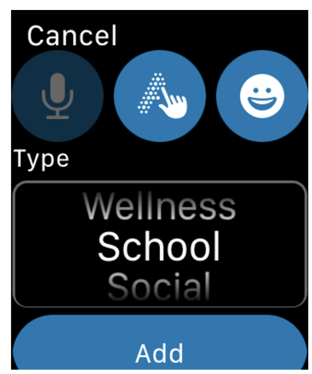
(e) Viewing point balance.



(f) Viewing available rewards.



(g) Spending points for a reward.



(h) Adding a new activity.

Figure 4.3: CoolTaco on Apple Watch had features analogous to the phone, and allowed children to (a) navigate between available activities for the day; (b) view and select an activity; (c) mark an activity as "done"; (d) view the day's activities already marked as completed; (e) view balance of points acquired and not spent; (f) view rewards; (g) use points to request a reward and (h) create their own activities without a point value.

4.3 Methods

I conducted a field deployment study to understand family's perspectives and uses of the novel smartwatch mediated co-regulation in their everyday setting, which is an effective methodological technique for eliciting feedback on a new kind of technology and providing new insights about how people's lives were impacted by its presence [194]. The deployment study took place in the US for a minimum of three weeks (average 12 weeks, SD=4) with ten families with staggered enrollment during the COVID-19 pandemic. In this section, I detail the project's recruitment and participants, procedures, data analysis, and limitations.

4.3.1 Participants

10 Children and 17 parents from 10 families participated in this deployment study between October 2020 and January 2022. To enroll in the study, parents consented by signing a form and children consented verbally. I was careful to be clear that both children or parents could decide to opt out of participating at any time. Participant recruitment was done in collaboration with a local school that specializes in education for children with ADHD, but were severely impacted by health mandates for social distancing related to COVID-19 [219]. Parents became even more burdened with new routines of managing their remote work and their children's education. Consequently, many families that once consented to participate in this study opted to delay or cancel their involvement, including three families that had already consented and received loaned devices but later decided to opt out. Therefore, the research team expanded recruitment efforts by word of mouth between friends of participants and clients of local behavioral clinics, and more flexibility in the child's age range. We initially aimed to recruit children between 10 and 15, but expanded to include those between 8 and 15. Despite these challenges, members of 10 families fully completed participation in the study deployment. Table 4.1 details participating families.

Child participants were composed of 9 boys and 1 girl. This gender distribution aligns with the diagnostic ratio for ADHD [157, 248] and the student population in the collaborating school. The children were between the ages of 8 and 15 (mean age=10.8). Three families consisted of a single-parent household (F5, F8, F09), seven had mother and father caregivers, and four had non-participant sibling(s) (F02, F03, F06, F07). All participating children were mostly engaged during remote interview sessions but occasionally needed parental help to refocus or clarify interview questions.

All children presented ADHD symptoms according to parent reports. Additionally, participants completed two validated assessment tools: The Strengths and Weaknesses of ADHD symptoms and Normal-behaviors (SWAN; [233]) and the Behavior Assessment System for Children - Third Edition (BASC-3; [203]). The SWAN scale classifies the behavior dimensions of Attention and Hyperactivity/Impulsivity in a range of +3 (far below average) to -3 (far above average) and the BASC-3 classifies 12 behavior dimensions as average (41-59), at-risk (60-69) and clinically significant (above 70). The SWAN assessment indicated above average attention difficulties in 8 children (mean 1.69; SD=0.83) and hyperactivity/impulsivity in 5 children (mean 0.86; SD=0.65). On the BASC-3, 9 of 10 children scored at-risk (5) or clinically significant (4) for attention (mean 66.9; SD=6.51), and 7 out of 10 as at-risk (4) or clinically significant (3) for hyperactivity (mean 66.2; SD=8.91). A table with scores in other BASC-3 and SWAN dimensions is available in the supplementary material.

Three families (F01, F03, F06) concurrently used an analog token economy (*e.g.*, jewel or coin token in a jar, points and rewards on a whiteboard) and three other families (F02, F05, and F08) had previously used one. Participating families received $100 and were offered the option of keeping or returning loaned phone and smartwatch devices after study procedures were concluded [219]. Throughout the rest of this chapter, I use F# to refer to a specific family, C# to reference a participating child, and P# to reference a parent.

Table 4.1: Participating families and summary of CoolTaco use

Family ID	Child's Gender, Age	Caregiver Participants	Activities Planned	Completed Activities	Rewards Available | Redeemed	Days with at Least one Activity Completion	Days Between First and Last Completed activity
1	M, 10	Mother, Father	8	39	2 | 0	15	41
2	M, 11	Mother, Father	32	153	5 | 2	12	107
3	F, 10	Mother, Father	29	203	10 | 2	37	93
4	M, 10	Mother, Father	3	0	2 | 0	0	0
5	M, 9	Father	6	13	1 | 0	6	13
6	M, 8	Mother, Father	6	19	4 | 0	12	62
7	M, 9	Mother, Father	24	321	5 | 21	48	235
8	M, 15	Mother	5	11	3 | 0	6	96
9	M, 15	Father	4	1	0	1	1
10	M, 11	Mother, Father	30	458	7 | 49	87	206

4.3.2 Study Procedures

CoolTaco runs on iPhone 8 and Apple Watch series 5. I also offered textile-type wristbands alongside the watch in response to some children's sensory sensitivity [84]. Participants were originally to be onboarded in group workshops at the school to configure parents' phones alongside loaned Apple Watches and to give general instruction on study goals, participation, and app use. Due to the pandemic and social distance guidelines, I had to change plans and opted to deliver and loan pre-configured phones and watches to participants' porches [219].

For participant's onboarding, I offered optional 30-minute instruction over video calls in addition to instruction manuals included in the delivery package of devices. Families were not required to set up any particular number of activities, but the manual suggested 3-5 per day, that parents should monitor completion reports regularly, and reflect on the balance of activity's point value and reward's "costs." CoolTaco came with a pre-registered activity ("wash your hands") as an example with a 1 point value, and a pre-registered 1000-point "surprise" reward as an example. Three families adopted this reward and others deleted it.

Participating families were asked to use CoolTaco for 3 weeks before being remotely interviewed. Families were allowed to keep using the system even after the final interview, averaging 12.2 weeks of usage (SD=28.3 days; min=6; max=87 days). While some families (F04, F09) engaged minimally with the system, others used it often and continued for much longer than requested (*e.g.*, F10, F07), as detailed in Table 4.1. For example, F07 has continued to use the system a year after onboarding in the study. The final interview had two main phases. I first focused on talking with the child, with the parent present to act as a mediator to help maintain the video conferencing infrastructure and the child's attention. This phase lasted 20-30 minutes and aimed to understand the child's perspective on the smartwatch's affordances, their experiences with CoolTaco, their experiences with self and co-regulation, and desires or suggestions for an ideal version of CoolTaco.

For the second phase, I interviewed only the parent(s). Like with the child, this phase was aimed at understanding the parent's perspective and experiences around the use of CoolTaco, supporting co-regulation with their child, potential and shortcomings of the smartwatch, and suggestions for future designs of CoolTaco. During this phase parents also clarified or complemented the interview with the child. For example, P01 sometimes helped *"fill in the gaps regarding [C01]'s questions. Obviously, part of it is that he's shy"* (P01). At least two researchers were present during interviews, with one leading and the other being in a supporting role and taking observational memos.

4.3.3 Data Analysis

Interview recordings were automatically transcribed by the video conferencing tool and later reviewed and corrected by an undergrad research assistant collaborating in the project. My qualitative analysis of interviews followed reflexive thematic analysis [31, 32]. My analysis approach was primarily inductive and conducted with collaborators through several iterations to roughly follow Braun & Clarke's six phases: familiarization, coding, generating initial themes, reviewing themes, defining and naming themes, and writing up. First, read interview observational notes alongside the research team and we inductively separated excerpts deemed representative of participants' reported experiences. We then met virtually and used Miro[2], an online digital whiteboard tool, to discuss interviews and conduct affinity diagramming with the excerpts. The outcome of this iteration was a group of topics that became codes in an initial codebook. We then used the initial codebook to independently code one full interview transcript. I met weekly with others to discuss and review the codebook, eventually concluding a final version of the codebook that consisted of 11 parent codes and 42 sub-codes. For example, the parent code "strengths of CoolTaco" had "supporting regulation," "role modeling," "negotiations," "checking task completion," and more. The final version of the codebook was then used to code all ten interview transcripts. I used coded data and the codebook to inform the thematic mapping [31] of CoolTaco's impact on children's self and co-regulation, the perspectives of parents and children about the system design, smartwatch mediation, and desires for future technology design. Themes were further refined during the writing process to highlight the potential and shortcomings of technology intervention for cooperative care for ADHD children and the families' *in-situ* experiences.

In addition to the interview analysis, I analyzed children's and parents' registered activities and rewards, following a semantic and latent approach [31, 32]. Although the system provided four categories of activities to the users (*i.e.*, wellness, school, social, and general; Figure 1a), I identified additional nuances in how activities were described, coding them as chores, educational, desired behaviors, exercise, or routine. Likewise, rewards were coded as familial or individual, and either material, event, or screen-based.

4.3.4 Limitations

Circumstances surrounding the COVID-19 pandemic deeply impacted onboarding of participants and data collection procedures. In particular, it became impossible to meet parents to install CoolTaco on their own phone due to social distancing requirements. This led us to lend a separate phone to families with the app already installed as a workaround. The

[2] https://miro.com/

requirement of using CoolTaco on a phone not truly personal might have impacted the regularity of parent's engagement with CoolTaco, as it is less convenient than using their own phones (*e.g.*, in-between opening their other apps).

The pandemic also impacted participant recruitment [219], with us needing to broaden the original age range target. Involving neurodivergent children is a known challenge in the field due to recruitment challenges and it is "generally acceptable to have 5-10" participants with a disability [128]. I sought to mitigate this limitation by involving the caregivers and for an extended period. The participant cohort, therefore, offered breadth of experiences, and I would not have observed some system and family dynamics had we only enrolled older children. For example, the broad pool enabled observing how families managed ADHD differently, particularly around expectations for independence. Future work could add further understanding on use and perspectives of a particular age group.

The findings might not represent perspectives of dissimilar family dynamics and household makeups. Participants typically had access to a range of supportive resources, including educational, material, and behavioral therapy resources, reflecting their financial stability. Families with less resources and lower socioeconomic status might have different perspectives on smartwatch-driven behavior support. For example, Saksono et al., [201] have identified that concerns and neighborhood safety can limit efficacy of physical activity trackers and efforts for healthy behaviors, which may extend to other smartwatch-based wellbeing interventions. It is also likely that cultural backgrounds influence perspectives and attitudes for co-regulation and preferences and practices in adopting smartwatches-mediated support. For example, research has indicated that emotion co-regulation is affected by different socialization practices among cultural groups, and parents and children who react, discuss, and express emotions more may lead to more social and regulation competence [186].

4.4 Findings

Overall, most participants used CoolTaco extensively, even if not every day. Participants varied greatly in the number of days they used CoolTaco (Table 3.2). Families that engaged with CoolTaco averaged 27 days of actively completing activities in the system (SD=28.3; min=6; max=87 days). Families averaged 106 days between the first and last completed activities (SD=77.2; min=13; max=235 days). Most families reported benefits from using CoolTaco and described seeing the potential of smartwatch meditation to help with the self and co-regulation of children with ADHD.

Participants created a total of 39 rewards and 147 planned activities, out of which 92 were recurring activities and 55 were one-time activities. Parents created 93 of the activities (mean=9.3 per family), and 6 children (C04, C10, C09, C03, C07) created activities themselves (54 activities; mean=9). Parent-created activities averaged 4.4 points (SD=2.7). C04 did not complete any activity using the app, and C09 completed one. The other children averaged 152 reports of activity completions (SD=166.7; min=11; max=458), combining for a total of 1218 reports. Nonetheless, 224 of these where not approved by parents, indicating some disagreement about their completion or parents forgetting to approve them. As for rewards, parents other than P09 combined for 39 rewards, averaging 4.3 rewards per family (SD=2.8; min=1; max=10). Rewards cost an average of 249 points (SD=325.9; min=10; max=1050). Surprisingly, most children (N=6) did not redeem any rewards using the CoolTaco, with C07 and C10 redeeming rewards routinely (21, 49), and C02 and C03 redeeming only two each.

CoolTaco was perceived as providing useful asynchronous co-regulation support via goal setting and tracking, with children having a persistent reminder for daily goals via the smartwatch component and evaluating their progress of efforts. This empowered children to take on some of the co-regulation work themselves and be more actively involved, while still supporting parent's supervision. Conversely, families faced challenges using the system due to a high technical and social dependency on parents' attitudes and actions, labor and expectations for documenting lived experiences in the system, and integrating with analog token economy systems some already had in place.

4.4.1 Benefits of Co-Regulation Via a Smartwatch

CoolTaco's use of open-ended activities allowed families to use multiple strategies to structure and track daily habits and responsibilities for regulation with the smartwatch. Both children and parents used activities to organize children's self-care and contributions to the family environment by setting goals for daily functioning (*e.g.*, chores, routine tasks) and desired positive behaviors (*e.g.*, healthy habits, positive social interactions). Activities like *"Hug mom"* (C10), *"Tantrum free day"* (P07), *"Followed directions from adult on the 1st time"* (P02), and *"Show getting along"* (P01) emphasize the desired behaviors that promote wellbeing and need not be constrained to a specific time. Similarly, routine and physical exercise activities reflected desires for a healthy way of life (*e.g.*, *"Practice Soccer for 20 minutes"*, P02) and necessary habits (*e.g.*, *"Hygiene- shower by 8:30pm"*, P08). Parents generally used these strategies to *"teach them responsibility"* (P08) and life skills. Overall, activities highlight desires for regulating positive behaviors and healthy routines for children's shifting contexts and independence (Table 4.2).

Most families (N=8), described the smartwatch component of CoolTaco as useful to expand co-regulation to moments which children and parents were apart. Families reported several ways that the smartwatch was beneficial: as a persistent reminder and co-regulation support while children moved across multiple contexts, enabling children to keep track of daily goals for themselves, and taking on some of the *"blame"* of enforcing parenting rules.

The Smartwatch Went With the Child, Enabling Support in Different Contexts

Table 4.2: Examples of activities created by parents and children with CoolTaco, organized by an inductive categorization.

Category of activity	Example: Parent	Example: Child	Total #
Desired Social Behavior	“Act of kindness to Daddy” (P07)	“Be Accepting.” (C07)	37
Educational	“Homework 2pm” (P05)	“Do math” (C02)	31
Chores	“Feed cat’s dinner” (P01)	“Walk Finley” (C10)	23
Unclear	-	“Poop Face” (C07), “Q” (C02)	21
Routine	“Brush Teeth (morning)” (P06)	“Take bedtime pill” (C10)	22
Exercise	“10 Squats /10 Push-ups /10 sit-ups” (P08)	“Ride New BiKe” (C03); “🛴” (C10)	13
Total #	93	54	147

and Persistent Tracking of Goals

With CoolTaco, the smartwatch helped assist parents in co-regulation by supporting children in becoming more independently organized. Several participants (N=06; F01, F02, F03, F06, F07, F10) reported that the persistently-available list of activities helped the smartwatch serve as a pervasive reminder for children to track their responsibilities and progress towards them. They also reported that being able to acquire points and *“watch all my stars just grow and see how much I get”* (C10) at any time through the smartwatch component of CoolTaco motivated executing planned activities. For example, C03 said she liked *“the ability for you to add a task so that you can remind yourself to do things that you want to do,”* and her mother agreed, saying that the list of activities was useful *“to be a reminder for her [C03] to do it”* alongside the star points for reinforcement. Similarly, C02 said that CoolTaco *“it kinda reminded me,”* with P02 complimenting that *“having that reminder on him is helpful.”*

Families often wished the smartwatch component of CoolTaco contained additional self-monitoring or reminder functionality to support the children. Some parents thought that activity notifications could offer additional support for timely reminders. For example, P01 said that *“an advantage would be to set the alarm system so there’s a prompt”*. Similarly, P05 pondered:

> P05: *“The main addition I would make is, if you could build in reminder times, [for example,] if it has something that said at seven in the morning: ‘take*

medicine' or 'you're supposed to be doing your chores' at three o'clock, and a little alarm went off on the watch to remind them. I think that would probably be the best addition."

Ultimately, the smartwatch combined with positive reinforcement strategies was seen as a useful pervasive intermediary for children to benefit from co-regulation efforts with less need of parental presence and their active nudging of reminding each goal.

Some participants described that the smartwatch going with the child helped lower the burden of tracking activities in CoolTaco, enabling co-regulation across a range of different contexts than if it had to occur with the parent present. For example, children were still receiving co-regulation *"in the other room"* (P05), and while *"outdoors playing"* (C03), and parents valued *"being able to remotely set up certain goals and prizes that would then sync up with something that's on [C06]'s wrist"* (P06). Support could also be across bigger context shifts, such as longer stays in a different home. For example, C08's parents were divorced, and P08 mentioned that CoolTaco could help with co-regulation even with separate households. P08 contrasted the digital and pervasiveness of the smartwatch could be an advantage over their previous analog token system:

> P08: *"[My previous system] was manual, and you have to be always on top of stuff and noticing things. Especially when C08 was with his dad, it was hard to manage something in both households that was manual like that. CoolTaco seems to be the easiest to manage, setup and keep track."*

Likewise, F02 had similarly compared digital tracking with their previous system that used coins: *"It's hard to keep track of that coin token, I always had some in my pocket [...], but it requires you to be a very hands-on present parent."* Some families also prepared different activities for different contexts. For example, F03 explained how they planned specific activities for when C03 went to a sleepover at the grandparents' house, with some input from the grandmother:

> P03: *"We changed CoolTaco to be specific for grandmother's house. I called grandma to ask what sort of things [C03] would want to help with around the house or what kind of tasks. Normally it was walking and training 'Blue', that's our dog, so we changed it to walking grandparent's dog."*

Families appreciated preparing activities in advance for children to leverage the smartwatch and execute on their own later (*e.g.*, *"take medicine 7am"*, P05), or to track on their own (*e.g.*, *"20 minutes reading"*, P03; *"Close all three [Apple Watch] rings"*, P02).

Overall, families enjoyed how the smartwatch was easily integrated with everyday life shifts of contexts, from big changes in location (like houses) to nuanced movements in the home, such as being in separate rooms from the parents or while they are at work.

Enabling Children to Take on Some of the Co-Regulation Work

Alongside serving as a persistent reminder, the smartwatch enabled children to take on some of the responsibilities associated with co-regulation. For example, the children frequently used the smartwatch to assess their progress and track pending goals. C10 appreciated that he could *"check off tasks [...][the CoolTaco app] it helps me get my work done"* even when his parents are *"at work"* (P10). C10's parents added that he *"has challenges with executive functioning, having difficulty structuring tasks, being organized,"* but CoolTaco helped because *"he pays so much attention to getting the points, that the list becomes routine, and the routine becomes habit."* (P10). C02 similarly mentioned that he *"wanted to get a lot of points."*, with P02 adding that *"he was very motivated to check off [activity completions]."* Thus, having persistent access helped some children become more empowered to reflect on goals and behaviors on their own.

Some families, particularly those with younger children (N=08), reported that CoolTaco invited their children to be shared owners of the co-regulation process, lowering the burden on the parents. For example, P02 said, *"I like that it transfers the responsibility for me to him."* Parents mentioned that much of their previous co-regulation work went into mentally keeping track of activities, observing if children did the activity, or manually maintaining tangible token economy systems (*e.g.*, on a whiteboard or paper, via a jar with coins). The smartwatch helped the children contribute some of this tracking and observation, making them more active participants in co-regulation. For example, P07 said:

> P07: *"In our own [analog token] system I was very inconsistent in keeping track of things and had to just really simplify for myself. I love that the watch is just all on there and on it's him [C07], he requests, I approve [reports]. It's so nice I don't have to have a chart on the wall and I don't have to remember anything. I don't have to remember to mark stuff. It's him being accountable."*

P02 similarly reflected that the smartwatch in CoolTaco helped their child be more responsive to co-regulation. She said that C02 would monitor their own tasks like *"get up in the morning, ... brush your teeth, ... eating healthy food and snacks, getting along with your family... having [CoolTaco] would help us be able to do all of those things."* The family would then review what he did *"at the end of the day, sitting down with him even and saying 'oh you did all this stuff you've had a great day today', like, this is good!"*

Families described the smartwatch component of CoolTaco as valuable in involving children to take on some of the work in evaluating pending activities, doing and reporting them, and requesting rewards themselves. In summary, most families perceived the multi-device and cooperative nature of CoolTaco as easing some of parents' physical and mental efforts, and increasing the child's involvement, empowerment, and accountability in co-regulation.

The Smartwatch Could Become the Focus of Regulation

Parents reported that the smartwatch could take some of the attention for "haggling" and "blame" for a child to reach a desired outcome. For example, several parents (N=4; P01, P06, P07, P10) sought to leverage CoolTaco as an entertainment mediator: *"when he wants to play video games, I say 'okay take a look at your [CoolTaco] app, see if there's anything that you can accomplish to earn screen time"'* (P06). This allowed some offloading of the burdens that often surround family technology use [96] and other kinds of family conflicts.

Thus, offloading moderation to the smartwatch could reduce some family strife. For example, P07 said that *"It just made things go a little bit smoother for us. He always used to fight me over taking out the trash. Now he doesn't fight it."* Similarly, P05 had confiscated his son's phone due to undesired behaviors. He then added a reward, *"Earn phone"* (10 points), as an attempt to offload to the system the motivation and mediation to CoolTaco of C05 acquiring it back. This is similar to how previous work has indicated technology mediation can reduce family conflict (*e.g.*, technology moderating behavior instead of parents being the ones saying "no") [95, 96]. However, parents noted that they still need to help their children internalize the smartwatch as a tool to help them become more independent from their parents while still being responsible for their tasks and role within the family. For example, P04 described: *"I think the watch would help him, but we have to teach him too that the watch is a helpful thing. If the watch is asking me to do something, then I should do it, not like 'oh, let me turn it off', you know?"* Ignoring the smartwatch's prompts might ultimately result in returning to a state of heavy parental interaction and oversight, which may not be desirable for parent or child.

4.4.2 Challenges and Tensions to Co-Regulate with Technology

Despite overall perceived benefits from using CoolTaco, participants encountered difficulties surrounding high technical and social dependency on the parents to drive system use and information veracity, maintaining tracked data "true" and consistent with lived experiences, providing positive reinforcement during shared moments or when time-sensitivity was important, and challenges with integrating with tangible systems already in use.

Technical Dependency on Parents for the System to Work

While some aspects of CoolTaco supported children in contributing towards their co-regulation (see Section 5.1.2), other components interfered with their ability to do so. One major tension was that it often fell to parents to maintain devices and troubleshoot apps and connectivity issues. It often fell to parents to charge and remind children to wear the watch daily. This reinforces findings from prior work [169], but also sheds light on some of the challenges with maintaining multi-device health tracking systems.

Another tension was that only parent-created activities in CoolTaco would provide points. The original decision for children's activities not awarding points was based on it possibly undermining the parent's role in positive reinforcement. Consequently, children had mixed perspectives about their self-created activities being useful. Most children acknowledged that self-assigning points could circumvent the role of rewards and parenting support. For example, C03 said, *"You don't want me to give myself 200 points."* Still, others were frustrated with this limitation, such as C10, who understood the reasoning but complained: *"something I don't like about the [CoolTaco] App is when I add the activity it [gives] zero points, not one single point!"* He then suggested that a balanced alternative could be that *"the parent can set the maximum of what points you can add. It would be great to get like 100 points, but there should be, like, a maximum."* Still, C10 created several activities for his self-regulation: *"I added the 'get the mail' because that reminds them [parents] that I love them, and the 'science studies' to enrich my work."* As for the parents, they generally understood these constraints, but some sought to give children more initiative within the system. For example:

P10: *"There is merit to the discussion of the child coming up with a task, and then we have a discussion saying okay well is that [activity] really one that should be on there, or is it not? And if so, how many points? That whole negotiation process of how many points that should be worth and all of this has led to some interesting discussions."*

P10 appreciated the control over deciding whether and how many points an activity was worth, but decided to collaborate with C10 on tweaking some of them or creating new ones. Family discussions sometimes led to mirroring a child's activities with ones worth points. P03 explained that *"because it was created by her, she couldn't make it worth any points, and so I went and created one [similar activity]."* For example, the "🐠 *water*" (C03) activity became *"Fish water"* (P03) (clean the aquarium) worth 1 point, and *"Language arts"* (C10) was mirrored to be worth 3 points. Overall, despite the constraints on children's self-created activities, it proved useful for some parents and children to jointly reflect on self-regulation necessities and responsibilities, engaging in reflexive analysis stimulated through CoolTaco's iterative use. Still, since *"there's no follow up, other than approving [activities]"* (P06) much of this joint reflection was not directly system driven thereby potentially limiting how much families might stimulate and support child-led engagements and reflection on data together to evaluate goals, progress, and regulation outcomes.

Although remote reporting of activity completion benefited co-regulation and empowered some children, CoolTaco's use brought new labor for parents to maintain consistency and veracity between in-system data and families' lived experiences. Some parents took upon themselves to evaluate whether activities were actually done, noting *"it's so easy to click 'yes' without [actually] doing it"* (P04). Further, families often struggled to use CoolTaco when family members disagreed about whether an activity was completed. For example, P06 mentioned that some activities were not in a binary state of "done" and "not done." P06 stated, *"sometimes he does the task but not completely. It [CoolTaco] could maybe [allow to]* *give part of the points [...] You know, something is worth 10 points and you only get 7, but [CoolTaco] doesn't have an option for that."* In this scenario, children could thus execute a task and receive points for it, but if the result is not up to their parents' expectations, the points are reduced. Filtering between these situations could then introduce further monitoring and evaluation efforts for the parent. For example, P03 mentioned that:

> P03: *"There are times that she [C03] would check off a task as completed, and it would be accidental or she didn't actually do it. [So] when I have to approve a list I had to keep trying to remember what she actually didn't get points for."*

These reports indicate a need for higher flexibility in evaluating and rewarding efforts towards completing activities, such as assigning points and allowing feedback for activity completion reports. However, care must be taken not to create complex back-and-forth flows of requests and resubmit between parents and children, which would add significant parental burdens.

Parents also desired flexibility for awarding points for unplanned positive reinforcement. The structured and multi-device flow of CoolTaco led to rewarding planned goals, but was less adequate for regulation mediation during shared moments or to reinforce spontaneous positive behaviors after the act. For example, P05 said *"The only time [CoolTaco] wouldn't be useful is if you had something you wanted to do in a time sensitive manner."* Likewise, P06 mentioned that *"if we're on a car trip or something, you know, and I'm telling him hey I'm going to award you 30 points later, you know that doesn't quite work, he needs to see it like right now."* Sometimes parents reflected on past situations and wished to give points as rewards after the fact, such as after the child displayed a warm social interaction (*e.g.*, *"If I see him [C07] do a random kind of act of kindness"*, P07). Similarly, P02 said that she would like to be able to give *"some extra bonus points, like [for] 'you were kind to your brother', or so."* Parents reported that higher flexibility for assigning points in CoolTaco could be useful to reward children's more autonomous positive behaviors. P03 sought to circumvent this limitation by creating a one-time *"free points"* activity. Overall, families desired flexibility to adapt positive reinforcement to their different lived experiences beyond depending only on parents' planning beforehand.

In some families, parents had to drive system use to ensure that children were able to receive their rewards. For example, P07 noticed that their child sometimes did not report on their school-related reading, *"but [C07] does read, [C07] just sometimes doesn't put it in [CoolTaco] right, so I said, 'you should probably put it in so you can get your points,' so we do have conversations when I notice things."* Conversely, activity completion reports were also dependent on parent approval and some children reported being upset when their parents did not put in the labor for approvals and point handouts. For example, P06 reported on C06 demanding them to check the system on pending reports: *"I did get chewed out. I got chewed out a couple days ago because he's like 'I did those things [activities] and my points didn't change!' So [I responded] 'Oh, I know, honey, I have to approve them' so yeah." P06 considered that their labor could be decreased if "there was a way to just automatically, you know, give them points you know, like a quick reward."* These practices indicate that CoolTaco, while mediating some co-regulation, also involved a level of effort that must be balanced with the benefits families receive and should be improved in future designs.

Social Dependency on Parents for the System to Work

Relative to children-driven interventions, closely involving parents in the workflow of CoolTaco resulted in the need to be motivated and involved for system-mediated co-regulation to happen. However, parents had different expectations for how involved they wanted to be in CoolTaco, and families in which parents wanted to engage less benefited less. Older children (age=15; F08, F09), in particular, often had parents who sought to limit their co-regulation efforts as a means of *"pushing"* (P09) their children for more independence. P08 said that her intention was grounded in her desire for C08 to *"not rely on us as much, or on other people."* She explained that C08 is *"almost 16 so he doesn't have too many more years be-*

fore he is an adult." P09 took a more radical approach to *"being hands-off on purpose"* and avoided co-regulation through CoolTaco altogether:

> P09: *"As much as possible, I am trying to push him away. I wanted to see to what extent he could adopt it [CoolTaco] as his own thing and use it to his own benefit without being force-fed. I didn't check in on him or constantly remind him to put the watch on. I had accepted that he was responsible to do it. again, [C09] is 15 [years old]."*

C09 perceived himself as fairly regulated in regards to chores and said, *"the [chores] ones I do every day because those are habits, I already formed habits for most of my chores."* Yet, P09 said that C09 has challenges with time management and emotion regulation. P09 pondered that if he was to change his parenting approach to provide more co-regulation, he:

> P09: *"I would certainly invest time and energy to do it. For example, [C09] is in a martial arts class and supposed to be practicing on his own but I could certainly see myself creating a schedule with him so that he works out 5 days a week for 30 minutes. That would help organize things."*

These experiences illustrate how family tracking is subject to expectations of independence and parental involvement that establish boundaries of supporting roles in the family. As children grow and are expected to be more responsible, parents might be less inclined to be involved and drive system use. Systems will have to adapt to these types of changes to be successful over the long-term.

Some children might need to be more actively supported by parents and have challenges with independent use of systems like CoolTaco even when parents are more involved. For example, C05 had trouble using the smartwatch independently in addition to difficulties with being motivated by co-regulation, with P05 saying that he needs much effort and involvement to *"make him start. [...] once he gets into it, he'll get it done, schoolwork and everything."* C05 receives both parental and specialist support daily beyond organizational structure and motivational incentives.

In addition, some parents reflected that it was dependent on them to gradually adapt activities and rewards in CoolTaco over time for children's growth. For example, P06 said:

> P06: *"[Activities] needs to be revamped because it's [currently] geared more towards where he [C06] was at last year versus now that I need to add some responsibilities. Because it's great that he can now brush his teeth, but you need to get your clothes, you can now get your own glass of milk. So, I'm gonna add more stuff."*

Parents then had to adapt and create rewards to motivate their children. For example, P10 said *"we need to spend more time on the rewards system to make them more meaningful."* Similarly, P02 said they would routinely ask themselves *"'what can we give him [C02] as a daily award that is not electronic?"'* but *"it became hard to come up with [CoolTaco] rewards that wouldn't be electronics based [because] we had an incident where he 'stole' electronics in the middle of the night, we'd catch him and he just got into a lot of trouble. So he lost all electronics."* In summary, parents found it burdensome to think through meaningful ways of engaging their children with the system, such as setting motivational rewards.

Some situations further required social coordination among multiple adults, which had limits within CoolTaco. As previously mentioned, C03's sleepover at her grandmother's house prompted adaptation of tasks, but the grandmother was not able to engage with the system herself and needed to do it via P03. In another example, the mother of C07 mentioned a communication breakdown with her husband about requiring points for rewards, and he *"freely"* awarded a trip to *"Chuck E. Cheese,"* an entertainment and food center, without C07 using his points. She concluded that *"my husband and I need to be on the same page."*

P05 had a more permanent communication challenge, having limited interaction with his ex-wife after gaining custody of their son, and because *"[C05] is not allowed to bring any of his technology to her house."* These reports highlight the social labor required to coordinate co-regulation beyond what CoolTaco enabled in-system and that depended on the adults.

Not Every Co-Regulation Needs System Mediation and Tracking

Some families' positive reinforcement routines, which previously happened outside of any form of digital mediation, now became routinized by the structured creation of activities, checking them off as completed, and claiming rewards. For some of these situations, families did not always perceive enough benefit to balance the labor of using the CoolTaco system.

Families often questioned whether particular activities or rewards needed to be tracked in CoolTaco, such as tasks and rewards that were considered to be normal parts of family daily life. For example, F03 tended to offer screen time as an immediate reward for timely prep in the morning, not needing to track related tasks and their completion in CoolTaco: *"So in the morning I wake up and I get ready for the day. I brush my teeth, I put on clothes and all that. Once I'm ready I'll tell mom and she will say I can have screen time."* (C03). Routines like these are reinforcement strategies deeply ingrained in the family's structure and that successfully modeled children's behaviors. Children still needed co-regulation in these situations, but there were no perceived benefits in doing it through the smartwatch mediation nor documenting it for later reflection.

Families also often avoided the labor of documenting reward redemptions, largely underusing the in-system redemption feature in CoolTaco. In practice, parents often pragmatically used activity completions and amount of points as a threshold to evaluate handout of rewards while not necessarily being strict about them documenting point expenditure in the system. For example, P04 said, *"we give him the awards because he's doing it [activities], not because he's really accomplished it."* Similarly, during the interview with F10 and discussing the use of rewards, C10 whispered to P10 about not spending points for their visit to a restaurant the previous day, to which P10 answered *"it's ok, that's on me."* Similarly, P07 explained that they were more *"used to say 'Okay, if you got green [achieving goals] all week' than come Friday, that's when C07 would get something [reward]."* Thus, families were mostly concerned with the system reflecting their lived experiences regarding activities, and used rewards mostly as a *"motivation and a purpose"* (P07) rather than for keeping a detailed record.

Families further had conflicting attitudes about whether to redeem certain in-system rewards because they were seen as more family-oriented than individual. Although most registered rewards were for the child's individual use (N=24) (*e.g.*, a toy, screen time), many were to be enjoyed as a family (N=12) (*e.g.*, family meals, playtime with parents). Rewards were also typically material (*e.g.*, money, food) or events (*e.g.*, *"go bowling"*, F02; *"Manicure by Mom"*, F03). Parents still wanted to encourage these family events and were more lenient with point expenditures or having to document their redemption. For example, P04 explained that establishing rewards was challenging *"because he does get a lot of stuff as a family,like going camping and eating ice cream."* Routinely redeeming individual-level rewards was an exception, and mostly done by C10 and C07 for screen time. Parents also could deem it not worth enforcing some smaller in-system reward redemptions, because children could be *"hesitant to spend points"* (P10) and feel a sense of loss while *"saving up for the most priceless thing"* (C02). Overall, these reports illustrate that the redeeming process could be counterproductive for parents' goals of enjoying the smaller rewards alongside the child (*i.e.*, family time) or children's longer term targets (*i.e.*, higher costing rewards). Consequently, families were flexible with handing out family level awards (*e.g.*, *"dinner with Mom or Dad"*, F03) and less rigorously enforcing redeeming through the system, even if that part of the data became inconsistent with lived experiences.

Integration with Concurrent Physical Token Systems, Which Have other Benefits

When families used existing tangible token systems (N=04; F01, F03, F06), they sought to use CoolTaco concurrently with their established systems due to the perceived benefits of tangible interactions. They saw benefits in using CoolTaco (see Section 5.1), but reported that their tangible systems had the unique benefits of being *"palpable"* (P01) and *"flexible"* (P06), indicating that multimodal interactions should be explored in the future. For P06, the main advantage of the tangible economy system is the ease of reinforcing good behaviors and unpredicted events by *"easily adding [a] handful of jewels"* to the jar. P01 believed that the physical nature of tokens going into a jar was *"more collaborative"*:

> P06: *"It's also the feedback that we have for encouragement, like 'okay good job!' CoolTaco is more for the routine tasks to get that on a regular basis, like brush your teeth, get dressed. That's a little different than how our reward system is. What we have is more for recognition for something positive, spontaneously, or redirecting what happened at the moment."*

P01's report indicates that their analog system could help with emotional co-regulation. Nonetheless, they wished to integrate with CoolTaco to *"keep track of the tokens when we don't have physical tokens"* and vice-versa to *"translate over that more palpable and motivating"* visualization of digitally attained tokens. Both P03 and P01 wished to use CoolTaco to bolster their systems so that *"it might actually remind [the child] to do them [activities]"* (P03) and to *"set the alarm system, so there's a prompt on the watch."* (P01), also indicating expectations for notifications for time-bound goals.

Overall, these reports indicate the potential benefits of integrating tangible and pervasive systems. Co-located and shared visualizations of tracking activities could also benefit shared moments to reflect on behaviors and responsibilities together.

4.5 Discussion

The results of the deployment of CoolTaco with ten households indicate that multi-device systems can mediate co-regulation and tracking practices while *apart*, providing benefits to families. The multi-device nature of CoolTaco allowed for remote connection and collaboration between parents and children, enabling them to leverage tracking of efforts without having to be co-located, demonstrating a way to answer RQ2. Overall, most participants perceived CoolTaco as a valuable tool for promoting children's responsibility and involvement in the co-regulation process. However, the high dependency on parents' involvement interfered with enabling children's independence, and increased social and technical burdens on the parents for the system to be useful. Additionally, while CoolTaco supported remote collaboration, its multi-device design and asynchronous workflow limited opportunities for joint use and co-located uses. Participants' experiences also highlighted the need for more flexible delivery of positive reinforcement and better support for children to increase autonomy gradually. I now discuss (1) tensions families faced to collaborate in a multi-device system to co-regulate, (2) design opportunities for better joint reflection and reassessments, and (3) to foster children's self-regulation with gradual independence.

4.5.1 Tension Between Fostering Parental Involvement and Independence

The involvement of a smartwatch worn by children helped them to be more active participants in co-regulation, monitoring their activities and points as they went about their days. In designing for remote tracking and pervasive co-regulation when apart, I found that the smartwatch was able to serve as a proxy for parental assistance, while enabling children to be more autonomous and responsible for part of the process. Autonomy is important for children to internalize the extrinsic motivation from positive reinforcement [197], and the smartwatch allowed children to receive guidance from parents while gaining some independence to execute tasks, track goals, and assess progress on their own. CoolTaco's support for autonomy was valued by some families, and those with older children were interested in using the system to foster self-regulation.

However, the results further indicate that the multi-device nature of CoolTaco led parents to experience tension between wanting to foster this sense of independence with wanting to be highly involved in CoolTaco's use to assist with co-regulation. Some parents who were interested in being more highly involved in their family's use of CoolTaco used the system for joint reflection activities typical of family informatics systems [176], discussing tracked data together and to improve activities, point values, and rewards. These families valued how joint reflection led to discussions about the importance of particular behaviors and negotiations about point amounts or future rewards, and even wished that CoolTaco did more to encourage them to come together. But for families who did want children to be more independent, the design of CoolTaco sometimes hampered children's self-regulation by needing parents to create point-worthy activities or approve completed ones. For these families, the requirement that parents be involved in these decisions made the system a gatekeeper that limited higher levels of autonomy.

Even when desiring to be more involved, parents reported challenges, such as creating effective goals and rewards, and remembering to track goal completions. While CoolTaco's open-ended nature enabled families to tailor tasks and goals however they wanted, parents were sometimes at a loss on how to co-regulate efficiently (*e.g.*, unsure what activities and rewards to suggest) or could have self-regulation challenges themselves for consistent system use (*e.g.*, forgetting to approve completed goals).

In light of these tensions, there is an opportunity to tailor or offer different co-regulation strategies to accommodate families' varying desires for more or less involvement and control. Such accommodation could be made possible by allowing families to choose which aspects of co-regulation tasks are completed by the parent, the child, or a mixture of both. Much like how personal informatics research has indicated benefits in allowing people to adapt systems on what and how to track personal health parameters [118, 17], family informatics for co-regulation could allow families to choose flavors of roles in positive reinforcement each family member can have. For example, such systems could allow children to suggest rewards or create them, request additional points or self-assign them, require parental approvals or be automatic. This could support children's developmental stages, such as shifting to more autonomy focus as children grow. However, designing for changes in roles and levels of control between family members, particularly as families better understand their needs [176], requires further research.

Since parents that wish to be more involved in co-regulation might need more structured guidance on doing so, I envision that systems could provide education and structured suggestions for how to better support their children. For example, systems could give more suggestions on regulation strategies alongside coaching parents about coping with ADHD. Often parents of ADHD children might be struggling with their own self-regulation and be undiagnosed themselves [77]. Therefore, parent coaching could be paired with notifications and be adaptive to enable real-time collaborative suggestions based on parent's or children's contexts as they go about their day (*e.g.*, reminders to check children's daily goals, suggesting parents congratulate or help the child refocus). Future research is also needed on how systems can deliver such parental support concurrently to assist the children without overburdening the family with complex and constant technology dependence.

4.5.2 Better Supporting Joint Reflection

A challenge for parents who wished to be heavily involved in using CoolTaco was that the multi-device approach required them to consciously and intentionally think about jointly coming together as a family to review and discuss tracked activities, points, and how co-regulation was going. By separating interaction with CoolTaco into separate parent-centric (*e.g.*, phone) and child-centric (*e.g.*, smartwatch) interfaces and interactions, the system tended not to encourage joint use. While separation helped children to be more independent and both stakeholders to participate in co-regulation while apart, it missed out on moments for joint reflection found in other family informatics systems where interaction is largely with a shared data dashboard [175, 199] or a shared conversational voice interface in a public space in the home [180, 171]. A valuable direction for future co-regulation and family informatics systems could be integrating both approaches, with separate devices supporting collection and everyday monitoring with a shared interface for joint reflection.

My findings also highlight that technology can limit the ability to involve multiple and diverse caregivers in coordinating co-regulation. CoolTaco's design supported some parent-child collaboration, but was limited in coordinating efforts from different people in the child's care ecosystems, such as grandparents and parents, and between divorced parents. Communication and coordination between caregivers is important to establish consistent co-regulation support with the child [192]. When there are communication breakdowns and lack of coordinated reflection, caregiving mediated by systems can be hindered and lead to ineffective co-regulation. Since coordination between children's care ecosystem is crucial for technology to better enable them to thrive [229], there is a need for systems to better stimulate shared reflection and integration between stakeholders that are part of the co-regulation.

Coordinating review of regulation data for meaningful understanding and action can be challenging [74, 175, 192]. One specific improvement opportunity is around joint reflection about rewards, as parents mostly leaned on point acquisition for positive reinforcement and gauged out-of-system reward handouts by looking at the point amounts. Explicit reflection prompts after spending points for rewards might help children make sense of their regulation, expand on the reward from a prize to a deeper understanding of the positive consequences of persistence and delayed gratification. Similar some prior work's use of questions to stimulate reflection about physical activity [200], co-regulation systems could stimulate reflection by highlighting or summarizing goals that were achieved alongside question prompts about the consequences of regulated behaviors. Such support can potentially help internalize motivations by children's self-efficacy and sense of competence [197], or a moment to coordinate what activities and rewards should be system mediated versus a family-level effort.

Joint reflection can also be a means of synchronizing efforts and perspectives from multiple caregivers involved in the child's co-regulation. For example, systems could stimulate coordination by supporting increased awareness between stakeholders via notifications of goals completed and reward requests, activities created, pending report approval, etc. Reminders could also be sent to multiple caregivers to stimulate them to discuss joint collaborative efforts and necessities. Coordinating efforts from caregivers not living together (*e.g.*, some grandparents or divorced parents) could also be supported by asynchronous shared dashboards working on their personal devices. However, the findings indicate several tensions between parent-child dyads, and such tensions can potentially be even more complex as more stakeholders are directly involved. Additionally, technical challenges emerge when involving multiple users, roles, and devices.

Joint reflection for regulation could benefit from integrating tangible and digital positive reinforcement systems, as families often perceived analog systems as more flexible (*e.g.*, can quickly give jewels/coins after a spontaneous positive behavior) and appreciated their physicality (*e.g.*, a physical jar's volume gradually filling up). Parents imagined such integration would benefit them to lower the mental and physical labor of maintaining analog tokens while children moved through different contexts. This physical and digital integration resonates with prior personal informatics work suggesting that digital solutions can be useful to extend analog self-tracking (*e.g.*, pictures of a paper journal) for recordkeeping and to share with others online, while enabling people to still benefit from interacting with physical materials [18, 10, 246]. Some participants similarly reported enjoying the benefits of the physical materiality of palpable tokens as they filled a container to represent progress and goal achievement. Therefore, there is opportunity for family informatics systems to benefit from digital and asynchronous support via smartwatches alongside the physicality of analog tokens. One potential approach is for digital systems to encourage joint reflection moments at the end of the day, and guide families by giving credit with physical tokens in accordance with tracked efforts of when family members were apart.

4.5.3 Designing for Children's Gradual Independent Self-Regulation

To support families working towards greater autonomy and independence for their children, systems could allow the balance of co-regulation to shift by enabling children to incentivize and reward their self-driven efforts themselves. For technology to enable more independent regulation for ADHD children, it would be helpful for it to serve as a co-regulation partner that substitutes some parental practices [48]. Much has been discussed how systems for improving children's wellbeing might introduce additional parental labor that is counter to its supporting role (*e.g.*, [169]). The design of such a system could largely follow principles of goal setting and tracking for independent use, such as including the ability to (1) self-set goals, (2) help track progress and review summary feedback, and (3) stimulate self-reflection and sensemaking for internalizing efforts and assessing their behaviors, possibly alongside self-driven positive reinforcement. Understanding how to tailor these approaches to support children, particularly those with ADHD, is a valuable direction for future research.

Furthermore, as children grow and potentially increase their technology ecosystems (*e.g.*, acquire a phone of their own) there is opportunity to further increase technology mediated support alongside the smartwatch for increased autonomy. While parents are generally concerned with perceived risks on increased technology use for young children [167], particularly with phones [124], parent participants were generally comfortable with the smartwatch for younger children given some limitations in the form factor (*e.g.*, limited internet browsing). Still, for the older child participants, use of phone and other devices was less constrained. As demonstrated in Chapter 3, contact with multiple devices and modalities of technology interaction is a similar opportunity for children to self-track and self-regulate.

In many families, the move from co-regulation towards self-regulation requires greater scaffolding that technology could assist with. To foster children's gradual independence, parents could be involved in setting parameters for some aspects of self-monitoring, such as setting default limits to point values. Another potential approach is to separate parent and children tokens and rewards, allowing children's tokens to be spent to acquire self-created rewards which are more hedonistic (*e.g.*, digital stickers) while parental rewards are more material (*e.g.*, purchases, family activities). While family involvement can be beneficial in these steps, some of them could be automated, such as automatically approving or acknowledging some goals when using the smartwatch's stopwatch (*e.g.*, "reading for 20 minutes"), or captured through it's sensors (*e.g.*, physical activity goals). Designing effective strategies for balancing desires children might have for digitally reinforcing their own motivation, automation, and family constraints requires further research and understanding.

Future systems could make use of children's growing technology ecosystem, providing them greater abilities to configure and use such systems for gradual independence. My study indicated that the body-mounted nature of the watch helped with pervasive regulation support, but the more complex system manipulation (*e.g.*, setting recurring activities and configuring rewards) relied on features made available on parent's phones. If systems gradually allow for children to manipulate and configure their own self-reinforcement strategies (*e.g.*, manage their points and rewards), some features and interaction modalities can be added to their phone, tablet, voice assistant, etc., to be used alongside the smartwatch. Thus, systems could evolve from more dependent on parents and their devices, to more independent when children acquire their own. Still, not every family will be able to or will wish to acquire multiple devices or child-specific devices, and care must be taken to still provide gradual independence support for children in families of different economic means or social practices.

There are still open questions about measured efficacy of interventions like CoolTaco towards promoting children's self-regulation. There is a particular need to further investigate how efficacy might be impacted by varying levels of parental involvement. There is opportunity to think about how measured improvement in self-regulation could be incorporated into the function of systems themselves, such as adaptively suggesting or stimulating parental involvement. For example, adaptability could gradually support children's independence as they grow, while allowing additional caregiver help to return when self-regulation via technology is insufficient or otherwise lacking.

4.6 Summary and Conclusion

The findings from the deployment of CoolTaco demonstrate the potential of multi-device family informatics systems to support both children's independence and collaborative tracking practices, directly addressing RQ2 and my thesis claims around personal and collaborative needs. By leveraging smartwatches and phones to a mediate co-regulation, families were able to extend support to children even when parents were not physically present, promoting autonomy while still enabling shared tracking.

My findings also revealed tensions in the use of multi-device systems for co-regulation, particularly in maintaining devices and balancing the benefits of parental involvement with the potential hindrance to children's developing independence. The high dependency on parental engagement for the CoolTaco system to work sometimes diminished children's autonomy or benefits from the system when parents were less motivated to be involved. These findings highlight the importance of designing multi-device systems that can adapt to the varying expectations and desires for parental involvement across families and as children progress through different developmental stages.

To address these challenges and further advance the design of multi-device family informatics systems, I propose potential directions for family informatics systems that center collaborative tracking on the child. Systems can be designed to support the selective allocation of co-regulation tasks among parents, children, or automatically through a system itself. By allowing families to customize the distribution of responsibilities based on their unique needs and preferences, such systems might foster a more flexible co-regulation environment adaptable to unique family dynamics. As children grow and develop, these systems could also adapt to their evolving needs, capabilities, and device ecosystems, gradually shifting more responsibility to the child while maintaining an appropriate level of parental involvement and support.

There are opportunities to enhance multi-device family informatics systems in both high and low parental involvement contexts. In families where parental involvement is more intense, systems can be designed to promote joint reflection and collaborative sense-making, facilitating more meaningful and productive co-regulation experiences. Conversely, in situations where parental involvement is desired to be lower, either by necessity or choice, systems can be designed to provide more autonomous self-regulation, reducing the dependence of direct parental engagement.

Chapter 5

Designing for Joint Family Use of Tracked Data

5.1 Introduction

Building upon the findings from Chapter 4, which explored multi-device family systems for remote collaboration centered on the child, this chapter expands on how family informatics might involve data from multiple members for joint use. It expands previous chapters to examine how various health data modalities (*e.g.*, steps, moods, goals) collected from multiple people and devices can be leveraged for integration, reflection, and action stages of personal and family informatics. Specifically, I studied the design of situated displays for sharing smartwatch-tracked data and facilitating family collaboration through joint reflection, seeking to answer the following question:

RQ3: How might multi-device systems facilitate family collaboration via joint reflection with tracking?

My study with CoolTaco revealed the need for better ways to support joint reflection and collaborative sense-making around shared data, given limitations with remote and distributed tracking on personal devices. Prior work has investigated the use of family data dashboards, which provide visualizations of family data on mobile apps, typically a parent's phone (*e.g.*, [202, 200]), or more rarely on situated displays in the home (*e.g.*, a tablet on a counter). Prior research has also indicated that personal information visualization in situated displays can foster situated reflection about personal behaviors [33, 156]. Such displays might be additionally beneficial for children's access to family data given that many families are reluctant to give children their own phones due to perceived risks to safety [113] and distraction [213]. However, our understanding of how situated displays in the home could integrate data from individual health tracking and support guiding members to improve their collective wellbeing is more limited. This chapter provides understanding of how families envision home displays to support taking collaborative action in light of the complexities around health and health coordination [192, 176, 9], especially for those with chronic conditions like ADHD [176, 48].

To answer RQ3, I conducted a series of co-design sessions with families with ADHD children to explore their perspectives, needs, and preferences for shared tracking of health and wellness data using situated displays. The co-design approach allowed for the active involvement of both parents and children in envisioning potential solutions, ensuring that the resulting design insights were grounded in their lived experiences and collaborative needs.

Findings from this study indicate opportunities for leveraging situated displays to make family time more productive beyond awareness and towards co-regulation practice and skill-building based on shared tracking data from other devices, like personal smartwatches. Families expressed a desire for system-guided activities and prompts that would facilitate reflection, discussion, and problem-solving around moods, exercise, and goals from everyone. These insights contribute towards my thesis claim T2. Findings also contribute towards my thesis claim T1 by indicating that family members wish for displays to also seamlessly tailor to their individual needs and interests when used beyond family time, such as tailoring data views and suggestions on how to contribute to collective regulation. Children wish to be able to comprehend personal and family data independently, while parents seek more complex data manipulation to understand their family data in order to support their parenting practices and assessing risks to children's health.

This project was published[1] at CHI 2024 with co-authors Franceli L. Cibrian, Clarisse Bonang, Arpita Bhattacharya, Aehong Min, Elissa M. Monteiro, Jesus A. Beltran, Sabrina E. B. Schuck, Kimberley D. Lakes, Gillian R. Hayes, and Daniel A. Epstein. I developed the co-design protocols and conducted sessions alongside Franceli Cibrian, Arpita Bhattacharya, and Elissa M. Monteiro. I led the study analysis and the writing and revision of the paper.

5.2 Methods

I conducted three co-design sessions with each of eight participating families at a time (24 total sessions; 23 participants, 8 children with ADHD, 15 parents). In this section, I explain the study recruitment and participants, procedures, qualitative analysis process, and limitations.

5.2.1 Participants

Participation eligibility required families to be participating together, consisting of at least one caregiver and one child aged 8-15 with either a clinical or self-reported ADHD diagnosis. I targeted this age range given that pre-teens and early teens are typically going through significant cognitive transformation around social and emotional growth, gaining independence while still needing significant caregiving support, and at risk of internalizing self-regulation

[1]This study has been published in CHI: [218]

Table 5.1: Participating Families in the Co-Design Study

Family ID	**Child Demographics (Gender, Age)**	**Caregiver Participants**	**Non-participating siblings**
1	M, 10	Mother, Father	0
2	M, 11	Mother, Father	1
3	F, 10	Mother, Father	2
4	M, 10	Mother, Father	0
5	M, 9	Father	0
6	M, 8	Mother, Father	1
7	M, 9	Mother, Father	1
8	M, 11	Mother, Father	0

problems on top of ADHD challenges [196]. Participants were recruited in South California. Recruitment occurred in large part through a partnership with a local school specialized in education for neurodivergent children. Overall, 8 children and 15 parents participated in three co-design sessions per family (24 sessions in total). Participant demographics are presented in Table 5.1. All caregiver participants were biologically related to their children, and 7 out of 8 had both parents living at home. I did not recruit siblings of children in participating families. Siblings were typically below the age range of the IRB approval for participation. I was further concerned that involving multiple children in remote co-design session, especially using the same computer, would add challenges for both us and parents to coordinate. The gender distribution is proportional to the school's demographic and general ADHD diagnostic ratios (*i.e.*, overwhelmingly male) [157, 248]. Families were compensated $100 for their participation.

In the rest of the chapter, I use F# to refer to a specific family, C# to reference a participating child, and P# to reference a parent.

5.2.2 Study Procedures

In this study, I leveraged co-design, a participatory method that collaboratively engages and empowers people in shaping better technologies intended for them [115]. It can also be a means for greater involvement of neurodivergent populations, whose perspectives and needs are often ignored in the creation of supportive tools [250, 228]. Following an initial phase during which children used Apple Watches to help surface tracking opportunities to the family, families participated in three co-design sessions.

Apple Watch exploration prior to co-design sessions

To stimulate families in envisioning opportunities for behavior tracking and sharing, I asked them to explore collecting different types of data on Apple Watches. All families had at least one parent that owned some smartwatch device themselves, with the exception of P05, and all had some familiarity with self-tracking apps on their phones (*e.g.*, step count and physical activity). Participating children used the watch for at least four weeks before scheduling co-design sessions. Prior work has indicated that children can understand and benefit from some self-tracking (*e.g.*, [15, 230, 170]), so I encouraged families to explore specific apps which supported different tracking features. I suggested that they could use the built-in passive sensing of movement alongside active exercise tracking, such as for step-counting, bike riding, etc. Children could also use a simple custom app that asked how they were feeling by offering colored button options according to the Zones of Regulation Framework [111] three times a day (*e.g.*, blue for when having feelings of low energy, like bored or tired). Finally, they could use CoolTaco for goal-setting and tracking. While the exercise tracking used automated sensing, goal and mood was manually tracked. Current cognitive tracking capabilities are still maturing [208], so my goal with this phase towards the design sessions was to stimulate families in thinking about tracking and sharing different types of data that might be useful to represent some regulation-related behaviors.

While gathering detailed usage data from this exploration phase was not the focus of this study, conversations with the families indicate that children experimented with tracking steps and specific exercises (*e.g.*, biking), and most used CoolTaco to establish some routine and chore goals. Children occasionally used the voice recording app for goal and mood memos, and answered their mood in the custom app every day. Engaging with self-monitoring helped parents and children consider a mix of automated (*e.g.*, steps, movement) and subjective tracking (*e.g.*, moods, goals) that could represent regulation, building confidence to explore designs and discussions about integrating and using shared data for family collaboration.

Co-design sessions

Similar to prior work [75, 130], I conducted remote co-design through video conferencing (over Zoom). A primary motivation for remote co-design was that a majority of the study was conducted during the COVID pandemic and with social-distancing requirements in place. In addition, prior work has indicated that remote synchronous co-design can help diversify and include youth participants [130], although requiring complex logistic and child-adult collaboration dynamics [75]. To account for this complexity, I conducted three separate co-design sessions with each family and sought to (1) build familiarity with the tools and co-design process, (2) accommodate time for disengagement (*e.g.*, taking breaks) or distractions, and (3) be flexible given family busy schedules and to not burden them even further. Between one and two other researchers were present with me during sessions to take notes and help manage activities. I used Miro, a virtual and collaborative whiteboard that runs in the browser. To support neurodivergent children in contributing to the co-study remotely, parents and researchers often co-regulated with children in order to co-design, such as redirecting attention through challenges with timers (*e.g., "let's try to create this [component] in 5 minutes. Do you think you can do it in that time?"*) or allowing structured distracted time when children where particularly curious about a feature or needed a break (*e.g., "You can [draw/cut/paste] anything you want for this time [3 minute timer...] OK, now let's get* *back to [design activity]"*).

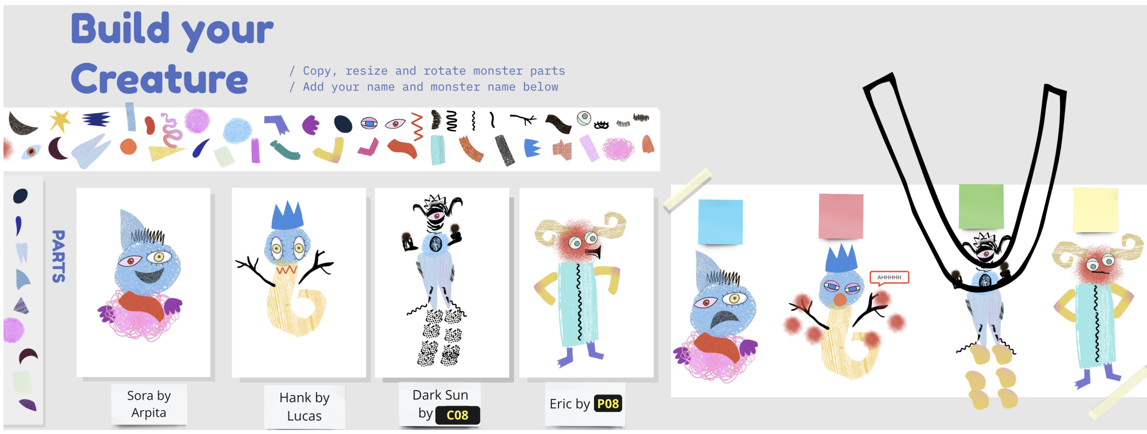
I explained to families that the aim of our study was to co-construct "ideal" displays that could be positioned on a wall or counter in the home and that made use of shared tracked data about behaviors. Over three sessions, we co-designed for different regulation domains (*e.g.*, moods, goals), potential representations of different data, family needs around each domain, what they ideally wished systems could provide or do for them, and why they envisioned such features or uses given their family dynamics specifically. All sessions were recorded and transcribed automatically through the video-conferencing tool.

In each co-design session, I typically engaged with the child and parent together in the first half (30-40 minutes), thanking and concluding children's participation when they naturally disengaged from the process after several iterations with design activities. I then engaged only with the parents. During each session, I initially shared our screen with the participants to instruct and demonstrate tool use, and explain the design activities. Next, participants shared their own screen while engaging with us in Miro for the co-design procedures. Children typically started sessions with the control of the mouse and keyboard, leading manipulation while discussing with parents. As sessions went on, they alternated control with parents depending on the activity and perspectives being discussed regarding co-regulation roles and preferences. Overall, I conducted three sessions with each family to design situated displays of shared family data about emotions and moods, exercise, and goals. Sessions averaged 59 minutes and 39 seconds (SD=10.69; min=43, max=81 minutes).

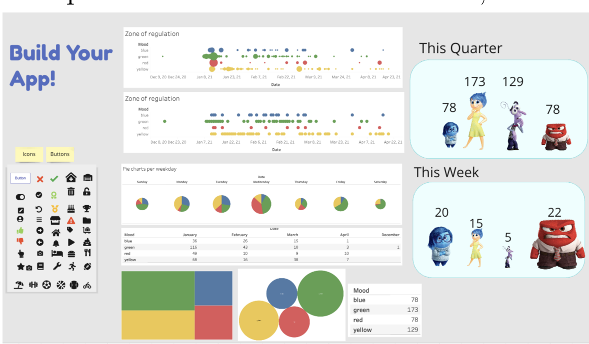
Session 1: *Designing mood representations and familiarizing with the co-design tool through playful creature creation.* In the first session, I primarily sought to (1) provide collective understanding of the design goals and process, (2) provide opportunities for the families to develop familiarity and comfort with the tools and co-design techniques I would use, and (3) discuss mood tracking and design mood representations. I first explained the design goals and encouraged families to explore the digital whiteboard by discussing mood representation and regulation, referencing self-tracking as exemplified by wearing the smartwatch. The design activity for this session was adapted from a popular Miro icebreaker template where users collaborate to create digital creatures. During sessions, a researcher first demonstrated the whiteboard features by creating a creature (*e.g.*, creation and manipulation of shapes, copy and paste of elements, drawing). Then, the child and parent(s) would build their own creatures. To discuss moods, I then engaged with the child about how the creatures might be feeling and how they would change if feeling something different (*e.g.*, Figure 5.1a).

Session 2: *Co-designing use of family's shared mood data.* In this session, I focused on understanding how families imagined opportunities to use daily tracked moods given the importance of emotion regulation in children's development [81], ADHD challenges in this space [67], and strategic possibilities for interaction design and technology's role in family emotion regulation [221].

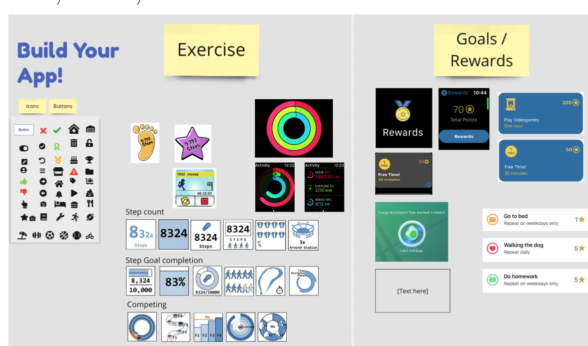
To ease and encourage participant brainstorming, I offered some starting mood visualization components that described mood inputs in various forms, such as numeric tables, colors to represent moods, timeline-based views, abstract shapes with proportions, or characters (Figure 5.1b). Inspired by the Bags-of-Stuff technique [252], I then asked the children to pick their favorite components, explain their choices, and move them to a virtual box area on the whiteboard. Next, children and parents optionally integrated those components into a wireframe of a tablet or created their own, suggesting interactive elements by drawing, adding shapes, buttons, icons, or elements they found on the internet (*e.g.*, a cartoon character). I then facilitated family discussion and iterations on the design focused on desired information and ideal features for a home display. Throughout the session, I asked about each member's specific emotion regulation behaviors and family dynamics. I also asked what, if anything, they would like to see about themselves or of each family member, and to imagine and then design anything a situated display could help them with about emotions. I specifically probed for understanding about how families would like to use an interface to jointly reflect



(a) Creature creation activity allowed exploration and learning how to co-design remotely. Families explored manipulating objects while discussing mood and could use any of the shapes available or create their own, increase sizes, draw, and more.



(b) Initial mood visualization examples utilized colors, proportions, tables, characters, and timelines with tracked data to kick-start co-design. Components were starter ideas and families used them as well as created their own. *Inside Out* image ©Disney PIXAR.



(c) Initial example components for exercise visualizations (*e.g.*, sticker, collaborative, comparative, progress-focused) and goal/reward components from prior work like CoolTaco [220], fitness data representations [11], and ephemeral data sharing online [73] which families used to create further components together during sessions.

Figure 5.1: Co-design sessions had initial examples of components alongside wireframe for tablet displays. These were useful starting points for families to create app designs and think about what data was important to them and the support they wished to receive from technology.

on and/or visualize each member's data and opportunities for features to influence their collaboration, such as if it should do anything in addition to showing shared data.

Session 3: *Co-designing use of family's shared exercise and routine goal data.* During this session, I explored display designs to support collaboration with particular interest in exercise and daily goals given the benefits of exercise and goal-setting for managing ADHD [41, 214, 52]. This session was structured similarly to the previous one. I drew some visual components from prior work on visualizing exercise tracking [11, 73] and CoolTaco for goal setting for ADHD children with extrinsic rewards. The range of starter components was meant to encourage families to consider different approaches to data use during co-design and towards co-regulation benefits. During the session, I asked families about their goals and exercise routines, any individual struggles in these areas, and to design and explain what they would want to see about each other. Similar to the previous session, I also asked about what a system on a display should do, if anything, in addition to sharing data.

5.2.3 Analysis

My qualitative analysis of the co-design sessions drew inspiration from the reflexive thematic analysis process [32, 31]. I and two other research collaborators first familiarized ourselves with the data by reviewing session memos and design artifacts. We then individually observed recordings of six sessions for what participants said, designed, and behaved. We met and brought observational notes, design artifacts, and session excerpts to be used in affinity diagramming, which resulted in an initial codebook. I met with collaborators regularly to code the remaining co-design sessions and refine the codebook. The final codebook had 6 higher-level codes and 33 sub-codes. For example, a higher-level code was "co-use", that had sub-themes like "reviewing", "coping with challenges", "nudge family time", "learning with data". I used coded data and codebook to inform themes of needs and opportunities for situated displays in supporting family and ADHD co-regulation. Themes were then refined during the writing process and in regular meetings with collaborators.

5.2.4 Limitations

I recognize that the limited number of families may have constrained the extent of my findings. Recruiting neurodivergent populations for research poses known challenges, with convention allowing as few as 5-10 subjects with disabilities [128]. I sought to mitigate the breadth of participant experiences by recruiting both parents and children together as well as extensively engaging with participants over multiple co-design sessions. I also see importance of further understanding co-regulation needs among siblings, as ADHD siblings can have heightened conflict in relationships [152]. The findings showcase some opportunities for sibling co-regulation, and investigating how the different power dynamics as well as opportunities for system mediation between siblings is valuable for future work.

My findings may not fully reflect families that differ in configurations and relationships. Family socialization practices vary culturally [185], and it is likely that results differ for families with and without ADHD from different locations and lifestyles. Study participants were also typically upper or middle-class in the U.S. and had access to external resources like therapy and school support. Families had supportive attitudes, generally wishing to help each other's growth and health. Some parents mentioned receiving some sort of parenting training. These prior experiences, while useful to inform their preferences, could have directed how they envisioned using situated displays, such as integrating some expertise or previous strategies they had experienced. Families with fewer resources, severe conflict, or parental indifference might have different perspectives of technology's role and that of situated displays in particular. All but one family had father and mother caregivers, and while involvement from extended family was reported to be frequent, most families did not have extended family members living with them in the same household. It is possible that different makeups of families could impact perspectives on how situated displays should involve others in the household.

5.3 Findings

The qualitative analysis of design sessions and artifacts revealed opportunities to better support family co-regulation by promoting collaborative data engagement during shared time while enabling personalized use when alone. These strategies differ from existing family informatics approaches that typically offer the same interaction and data usage for any family member. In the next section, I detail needs for nudging collaborative reflection and discussion for joint use while enabling learning about and support for ADHD. I then report on needs for technology to empower individuals in their self-reflection and in service of family collaboration.

5.3.1 Making Family Time Useful for Co-Regulation

As part of co-design sessions, families suggested that shared displays could help make family time more productive for co-regulation. They envisioned it could help overcome the normal hectic family routine and facilitate planned joint use, which would not typically happen with individual tracking. At the same time, aligning system design and use with educational goals could enrich collaboration for building self-regulation skills for better wellbeing.

Nudging Joint Use Amid Daily Disruptions

Participants described busy daily routines with limited current practices around discussion of how the family is doing. Design sessions indicate that technology could guide them to come together and review tracked data as a family to support their co-regulation needs. In particular, a situated and glanceable display in the home could allow for quick insights to *"make sure everybody's being active"* (P06) and how *"the family is doing throughout the day"* (P07). Parents in this study further noted that, while helpful, the glanceability of in-home displays alone may be insufficient for facilitating regular joint use and deeper interactions with and about the data. For example, P01 highlighted that *"In-the-moment discussions with the display can be complicated because we've got a ton of things that we're doing. We have our own agendas and we're all trying to coordinate it."* P08 expressed that this challenge goes against their *"need to have more discussion with [C08] to make things more meaningful."* P06 speculated that a solution *"would be something that would have to be prompted, like 'Hey, let's check in and see how we did today'."* These reports indicate that combining subtle ambient nudges with more active ones could empower families to engage in data-driven collaboration while accounting for the distractions of daily life.

Informed by having been tracking with Apple Watches prior to the co-design studies, some parents were concerned that remote and asynchronous tracking could focus on an individual level instead of *"overall overview of the family"* (P06). On the other hand, families pointed out that nudging towards joint use of shared in-home display could add support for co-regulation in addition to or instead of remote tracking on children's watches by providing a *"display about the group... the family as a whole and about how we are all doing, for everybody to be healthy."* (P03). Similarly, P01 considered how ubiquitous tools like smartwatches could give the impression of connection but may lack deeper co-regulation engagement. He shared:

> *"I'm hesitant with ubiquitous technologies. The human quality interaction is*

> *degraded with technology. It is like high tech and low touch, versus low tech and high touch. I think there's a sweet spot somewhere in the middle. [Kids and parents] they interact remotely. I'm thinking, 'Just talk with each other!' So, if it [display] is designed in a way that we are reminded, 'Hey, look you guys, these things you did through the day, or week, or whatever,' we can review what happened together. Maybe like lightning [quick] events and discussing. It's a solution that is data-driven."*

In summary, by suggesting that technology could help with coordination of shared moments for joint use, families pointed to the opportunity for systems to act as co-regulators themselves, guiding family time around data for collaboration.

Guiding Joint Reflection Towards Regulation Practice and Learning

Much like in other family informatics systems, families often pointed out the benefits of awareness of each other throughout the day (*e.g.*, *"they can see how I'm doing... it would be helpful to talk about it,"* C02). Further, families pointed to opportunities to move from awareness to learning and regulation practice based on tracked data, particularly about family values and building skills for behavior regulation of self and others, emotion socialization, and self-evaluation.

Family values: participants indicated that an in-home display could direct learning family values about supportive relationships, such as empathy and connection. For example, P07 said C07 *"is a bit self-centered right now"* and wished for practical support for creating connection, speculating that the shared display could *"direct conversations about the rest of the family"* by highlighting *"how we're all doing."* P08 wanted the system to emphasize learning to be *"grateful and appreciative."* P08 suggested that a home display could support this practice through guiding questions like *"is there anything that you were grateful for* *today?"* and C08 suggested displaying answers alongside tracked moods for family discussion at the end of the day. In another example, F02 wanted to emphasize empathy between family members, and the mother said *"we're trying to teach compassion for others, for what others are feeling too. So it'd be nice for him to see and understand that his brother had a difficult day or if I'm having a tough day. I think that's interesting because it would really make the whole family kind of buy into doing this as well. It will be teaching him empathy with other children and his family."* Overall, families saw opportunities for reflection to align with educational nudges about family values and improve attitudes for co-regulation in the home.

Self and co-regulation skills: Participants envisioned a display helping families jointly review data towards building regulation skills, like problem-solving and comforting others. Families mentioned that guided joint use should help address problems and teach how to resolve them depending on what happened throughout the day. For example, P01 said *"we can look at it [data] back, and then reflect with him [C01] to say things like 'Okay, we see this, you know, do you want to talk about it? Was there something happening around [this time] we're seeing?"* C08 envisioned joint display use could help constructive resolution *"when I did something wrong"* or, for emotion regulation challenges, lead to opportunities for providing coping or comfort *"by asking 'Why did you feel this way?', 'What happened?' and, like, if it is for mom, I could help her feel better."* In essence, families envisioned joint guided data review as an opportunity to constructively target and resolve daily challenges together, which would help teach resolution of regulation issues and nurture emotional support skills.

Emotion socialization skills: Families envisioned that shared displays could be a useful space for discussing each other's emotions and help mediate, promote, and practice emotion socialization skills. Families reported how some children are reluctant to discuss their emotions, perhaps due to challenges in regulating feelings. C05 said that he does not like to talk about his emotions but would want his dad to see them on a home tablet after tracking with his watch. In these cases, a display could be a mediator of emotion socialization. P05 explained:

> *"[C05] has a hard time controlling his temper. It's a coin toss... [C05] just won't talk [about and] express emotions. The thing that popped into my head is, while he may choose to not interact with me, he does interact with systems."*

Beyond providing a tool for communicating emotion, families envisioned that using a shared display system together could help normalize the topic by guiding shared discussions. For example, P04 said *"[C04] is a good kid, but when he gets frustrated, he doesn't really talk about that. For instance, [when I ask] 'how was your day?' [he answers] 'good'. There's no 'oh, I struggled' or 'had a bad day.' What's helpful would be to know his real feelings."* P04 then suggested that tracked data could be used to promote *"conversation, like, 'around nine o'clock looks like you were frustrated, what do you think happened?"'* P01 considered that having minimal emotion socialization practices could result from *"huge amount of emotional dysregulation and just closed off between us [parents and] with the teenagers, it is a very vulnerable time...maybe a system could help the parents understand and have an assessment to then strike a conversation, it'd be helpful."* Fundamentally, jointly reviewing emotion data through systems could facilitate family socialization and conversations around feelings, enabling greater mutual understanding and internalizing socialization skills beyond system use.

Families described how taking and sharing notes about emotion regulation states on a shared display could help practice emotion socialization that could lead to fruitful conversations around their data. P08 said *"What if there was this thing on the app where you can add notes to how you feel?"* after selecting from the mood options; P01 considered the possibility of *"somehow asking 'why?' the mood ... and then using that later to look back at it and reflect together"*; and C03 said a system could stimulate to *"save the reason"* for moods to be *"shared to the family as a whole."* Our discussions often highlighted that parents also sometimes struggled with emotion socialization. C08 said that often parents *"just say they are 'fine', but they aren't... [Dad] there was this one time I asked you, [and] you said 'fine' but I don't think you were...,"* to which his dad responded *"Oh, so the system could then be to make sure how we are feeling, right?"*, C08 *"Yes."* Emotion regulation can be a difficult but necessary topic to address in families, as people might be avoiding sharing emotional distress or dealing with struggles. Overall, by stimulating emotion socialization practice, systems could nurture necessary yet challenging discussion about feelings, and reflection for parents and children alike.

Self-evaluation skills: Families envisioned in-home displays to help promote self-evaluation skills. They described how these skills could be developed if reflection and family discussion were to be guided towards fostering goal-setting, self-monitoring, evaluating progress jointly, and motivating continued efforts. Families explained that highlighting progress could help *"understand performance"* (P07), *"check if being consistent in doing a task"* (P02), and *"talk to [children] about it and mess with the goals. Like, 'did you set your goal?' 'Did you meet it?'."* (P03). Families thought that motivation, a core component of self-evaluation, could be targeted in a display by highlighting progress and recognizing when a family member is effectively self-regulating. For example, participants imagined rewards for effective self-regulation *"If it is a really good day it could be like 'reward: TV', and the parents see this,"* (C04) or congratulatory messages (*e.g.*, *"If it is a good thing, say good job,"* C08). For F03, progress evaluation would be especially beneficial *"for my kid [C03's brother] who doesn't want to do anything, not to shame him. Because it's really just based on improvement."* C03 speculated that giving *"awards to who improved"* could also lead to family motivation, and P03 complemented that *"Maybe there is one goal overall where we are all meeting and not competing."* Overall, families' suggestions for fostering self-evaluation varied, such as cooperative versus competition for exercise (*e.g.*, Figure 5.2 vs. Figure 5.4) or using points and awards for goals. Ultimately, most strategies revolved around being presented with opportunities to reinforce the importance of behaviors for regulated lifestyles, reflecting on outcomes of efforts, and applying lessons learned on planning goals for what is next.

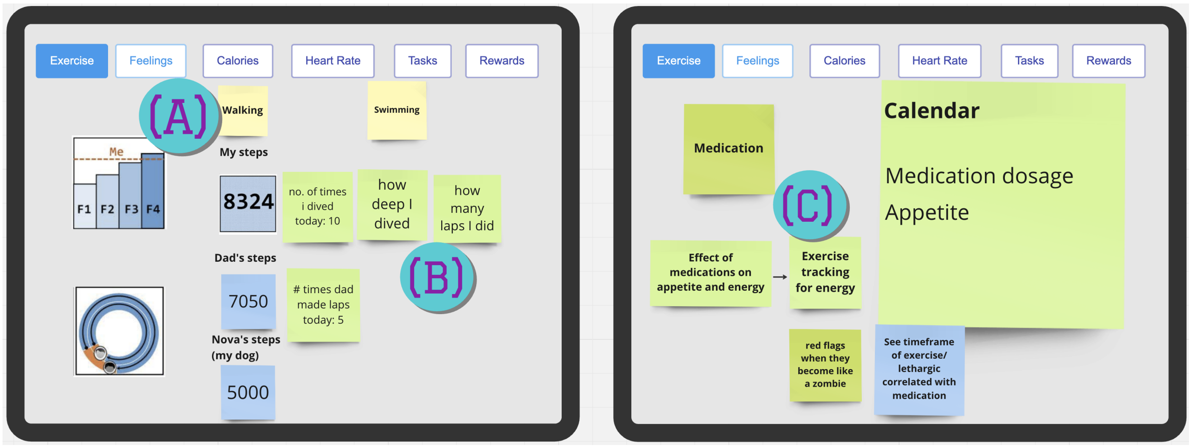


Figure 5.2: Example of distinct goals between the collective and individual use of situated displays. F05 created an interface to compare everyone's step count (A), including the family dog, alongside swimming-specific (B) metrics (*e.g.*, dives, laps). In contrast, P05 reported his personal interest in exercise tracking was to evaluate any negative side-effects of medication to the child's energy level and appetite (C).

5.3.2 Family Members Need Individualized Support for Their Involvement In Co-Regulation

Beyond using an in-home display for joint use, I observed ways that both parents and children wished to use the device individually. Family members reported wanting to leverage their family's data conveniently on a situated display to understand how they could better support the collective wellbeing and growth, as well as self-reflect on their own regulation and their impact on the group. While it is somewhat expected that each member of a family might have slightly different interests regarding the same data, what we see here is the way in which families coping with ADHD, in particular, consider how a shared display might usefully contribute to both their own self-regulation and the kind of co-regulation that happens across family members. Independence and autonomy are clear goals for children in families, while self-care and self-regulation in the face of parenting challenges tend to be priorities for parents. Taken together, the designs that families suggested point to opportunities for both shared and individual reflection on family data with these various goals in mind, which further supports my thesis.

My findings primarily highlight differences in needs relating to the caregiving role, particularly parents and children. However, I also observed that needs differ between family members based on data interests. For example, the father in F03 said:

> *"There are things that matter to her [wife] that don't matter to me. There are things I want to see that she doesn't. She is way into sleep tracking, and that really matters and how much... but for me, exercise is the thing that I really want to see. I mean, there would be some core piece, like family metrics, but then everything around it is customizable for each person."*

Parents envisioned that it could *"change depending on who [is using]"* (P03) and had different data emphasis due to perspectives on what behaviors were more challenging and in need of greater attention and care. As the mother in F01 mentioned, *"children are different and might have different conditions on top of ADHD. Maybe some needs are more relevant."* In contrast, for independent use, I found that children have individual preferences and needs about interpreting personal and family data and could need guidance on how to use the data to inform their support of others. Overall, families envisioned in-home displays could adapt to intentions and preferences of who was using them and in what circumstances, such as for joint use, casual glances while passing by, or dedicated individual use according to specific co-regulation needs.

Next, I detail particular needs I identified for using a family display between different members, especially but not limited to adults and children, given their typical roles in the family.

Supporting Parents' Independent Reflection and Caregiving

Parent participants envisioned that home displays could help them to reflect on ways to better provide co-regulation with their child(ren) separate from joint use. While they acknowledged that some independent use could be on a personal device, like a phone, they saw value in redundant access to shared data through a situated home display. As P06 explained, *"it would be a little bit easier because it is in a centralized location"*, P02 said *"it is just nicer to have more room over a phoned and watch,"* and P08 noted it could enable coordination between caregivers because *"me and my wife want to talk about his trends and patterns."* Parent participants also felt that situated displays could help promote accountability for monitoring their children's data. P03 explained:

> *"one of the problems with me is that her tracking [data] is sitting on the phone... and I just don't look much at it because it's not front and center, but if that was on a wall, right in front of my face... I would use it more, like, if it was sitting propped up on our counter, it would keep me accountable."*

Participants described that situated in-home displays could help them in *"being consistent"* (P01, P03) in providing co-regulation. By being persistently being available in the home environment, these parents considered displays would help them remember to review the data to inform their next actions.

Overall, parents had three objectives related to caregiving that they hoped a situated display could help them with, separate from joint use: First, parents wanted to reflect on their own data to evaluate their self-regulation to inform co-regulation efforts. Second, they wished to intricately review children's data to identify potential risks. Third, they hoped to share data and collaborate with experts on caregiving strategies.

Supporting self-reflection to aid co-regulation actions: I found that parents wished for in-home displays to guide them in reflecting on their co-regulation abilities by helping them review their own health, wellbeing, and caregiving efforts privately while still referencing data from other family members. P01 suggested a home display could support *"a second overlay that's internal to the parent side."* He considered that comparing his own self-regulation against his son's could help him consider *"what is going to be helpful and useful for [C01]"* because *"I struggle a lot. The more regulated I am, the better I'm able to help [C01] process appropriately and developmentally whatever is happening with him."* P01 considered that he could improve his role modeling by *"recognize my own internal dysregulation so that I can be more measured"* for co-regulation with others. Parents considered that tools could help reflection by revealing connections between their own behaviors and those of their children. P05 shared how his own behaviors are often mirrored by his son's: *"this is the most stern child I've ever met in my life. I am stubborn too, so that's why."* P04 explained that having such insights could help him consider the impact of his self-regulation on the rest of the family: *"It is also about how I'm feeling and not only about him. Like, if at work I'm frustrated, at least he [C04] can see [on the display] that when he gets frustrated that it's also okay and, you know what? I got through it... so it's not just a lesson for him, it's a lesson for me and him seeing life!"* Parents explained that reviewing their data in light of the family could highlight *"co-regulation consistency in supporting our child"* and because *"the problem is when I stopped, she [C03] stopped"* (P03) tracking and reflecting on goals with the watch. By thinking about their own struggles individually, parents described opportunities for a system to help them improve their participation in co-regulation.

While parents valued personal insights about their self-tracked moods to better understand their role in regulation, they worried that sharing all their mood data on a family display could risk other's wellbeing. They believed that the risk of unintended consequences could hinder opportunities for achieving role-modeling benefits. P06 mentioned how sharing in the family would benefit C06's learning as well as her own self-regulation but was wary that sharing certain aspects of her day could be detrimental. She said: *"I would love to track*

Figure 5.3: Children's co-design outcomes were aligned with their understanding of data over time and preferences for visual representations. C04 envisioned mood tracking similar to a point system used at his school, with emotion regulation events assigned points that accumulate over time into color-coded graphs for the day (A) and week (B). C05 wished for character prizes to encourage his goal completion (C), but thought his dad would be less interested in this interaction mode (D). Image ©The Pokémon Company.

my emotions, like, see why I was so angry that moment. But it would... I'd be subject to censorship, absolutely! I wouldn't want to share with [C06] things too upsetting at work, you know, I'm not going to put that on him." Similarly, P01 explained how sharing could be a risk to children when parents are facing severe mental health issues, such as depression. She said, *"if a parent is depressed, what do you do? How far do you really want to go on sharing information, like if depressed or suicidal? That can be dangerous."* Fundamentally, while sharing parent's self-tracking may benefit family functioning through affective expression and involvement [231], parents may want nuanced control over what tracked data is displayed in a family display to prevent negative impacts on their children.

Help identifying risks to the child: In contrast with "family time," which may be reserved for learning and joint reflection, parents described wanting to spend "alone time" to explore children's data and to identify potential health and behavioral risks. Family displays were envisioned as guiding parents toward a deeper understanding of risks based on patterns in children's tracked information. In particular, the complexity of data analysis and insights across time led parents to envision using family displays for these tasks on their own. For example, P02 explained:

> *"I want super granular data and be able to study it. It'd be nice to be able to decipher all that. Like 'at this certain time of the certain day of every week, he's always struggling'. That's why I would want more data. Or if the app was able to pick up on a trend, like [e.g.,] 'it seems like he's really struggling at like 9:30 am on Tuesdays,' so I could go to the school and ask what he is doing at that time and then find out, like, it is PE, and he is struggling with that. [Timeline] It is more than just the week because we are trying to pick up on all the trends."*

In a similar fashion, P08 said:

> *"I am a data nut, and we were talking about trends and trying to look at the data and see if there's a point at which we're hitting fatigue that might impact behavior. Or if it is because of a medication given at a certain time of day or if there's a change in environment at a certain time of day. So being able to drill down, not just in the day or patterns over a period of weeks, but also the time of day, that would be helpful."*

P08 explained that results from this exploration phase could later be used to inform parenting and *"to discuss with [C08]."* Parents had specific questions about their children's data that they sought to answer and also wished for systems to identify patterns and trends based on the data. They envisioned that these insights would then drive them to act in ways that mitigated their children's health risks.

Facilitating collaboration with experts to inform actionable interventions: Parents envisioned that an in-home display could help integrate techniques recommended by the experts who were involved in their child's care. These points corroborate previous work on families' desire for improved collaboration support with clinicians [146] and children's

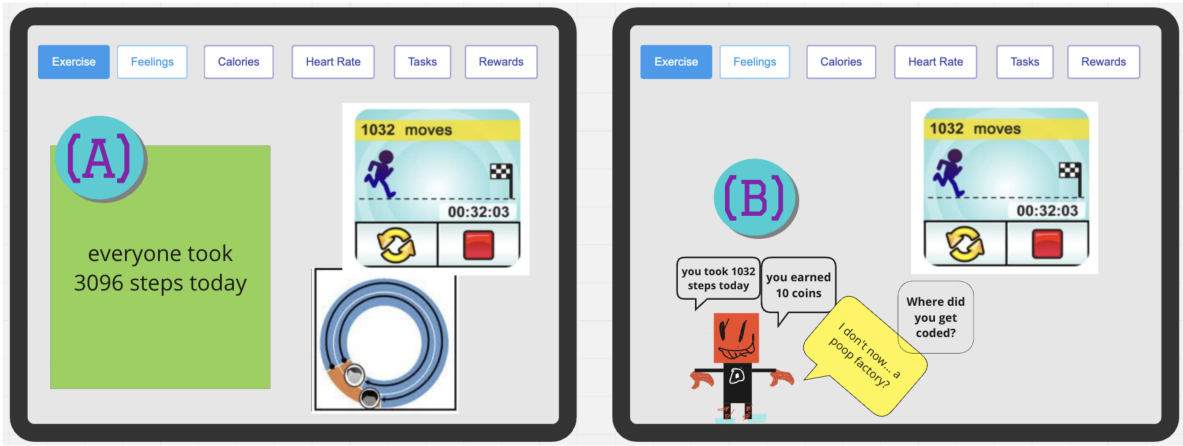


Figure 5.4: F02 created two separate designs for collective versus individual use of each other's exercise data. In (A), exercise contributes to a shared family goal, whereas in (B) C02 envisioned a chatbot designed as his *"alter ego character, Owltechno"* (P02) to explain his exercise, answer questions, handout points for achieving goals, and tell occasional jokes. C02 explained that the chatbot was for his use alone and not available to others.

care networks [230, 229]. P01 mentioned that *"these kids do need occupational therapy, behavioral therapy, psychological therapy, educational therapy, it's a lot of therapy [laughs]"* and suggested incorporating into a shared display ways of *"working with a therapist... like for a plan of things to think about and things to help them [children], and linked to executive functioning and the bigger picture of things."* In another example, P05 was interested in using a shared interface to view everyone's exercise tracking during joint family use (Figure 5.2), but at an individual level was interested in reviewing exercise to evaluate *"[C05]'s energy level"* because *"the psychiatrist said that if it's affecting the energy level, if they become [like] zombies, that's when there's something wrong with the medication."* P05 suggested that the home display could further support collaboration with experts by *"taking the information to the psychiatrist and having historical data to go over. We can adjust medication [...] That could be good information if you have a psychiatrist that's willing."* P01 similarly suggested that the home system could help a *"specialist to gauge what's going on and to give feedback."* Overall, participants wished that the family health data on their in-home displays could be communicated to and integrate information from specialists to bring expert guidance into the family's support system.

Supporting Child's Independence and Contribution to Other Family Members

My analysis revealed the need for additional scaffolding for family displays to support meaningful independent use by children. Children may require extra guidance to comprehend personal and shared family data and identify concrete actions to help support others based on the data, which ideally does not always need to be supported by parents. Rather, children who are appropriately supported by technology can learn to interpret data about themselves and others directly, interact with these data, and respond to what they have learned.

Helping children co-regulate others: Some of the children participants wished to help other family members and considered that in-home display systems could potentially help them independently review parents' and siblings' information to be a part of their co-regulation. For example, C03 said she wanted to review family moods so that *"if they felt sad, I could help them"* or *"assign rewards to them"* as encouragement for goals to be met. P03 complemented, *"she is a leader to her brothers... She can help the rest of us."* Some children desired system advice on how to co-regulate, such as C02 who said *"You could select a parent. If they have yellow or red [emotions on the display] a lot, it shows something you can do with your parents for them to feel better. Like this: [types in the mock-up] 'Give a hug.' So it should give a different suggestion every day to do something with parents to make them feel better."* By providing a personalized review of family data and co-regulation suggestions, systems could empower children in their active role of supporting family members' wellbeing through thoughtful co-regulation strategies and bonding.

Supporting children's independent use: We found that for children to interact with family displays by themselves, they would benefit from guidance that lines up with their data interpretation skills and presents data relevant to them.

Families described the need for children to be able to understand data about their regulation presented on an in-home display for it to support their independent use. P06 described C06 as *"he's more visual, he likes Minecraft and Roblox characters, I don't think he really grasps numbers and graphs."* Similarly, P01 explained that C01's *"focus is really not on a lot of his data; it's more on higher-order stuff right now. He's learning."* Some children might have higher comprehension and be better able to make more sense of graphs and timelines depicting the progress of behaviors. For example, C08 said *"you can look back almost every month, then it will show us like oh I've been sad for this, this, and this..."* Similarly, C04 designed a mood visualization (Figure 5.3-left) that not only shows the current day's tracking but also accumulates and graphs the data over the week, with a summary of each day, to help evaluate regulation over the period. Overall, supporting independent use of family displays requires accounting for varying interpretability skills and adaptable designs that guide comprehension and reflection based on differing developmental levels.

Children participants had individual interests in data that they wanted to reflect on by themselves, typically relating to exercises they did or specific goals they were pursuing. For example, Children designed visualizations other than step count that highlighted exercise specific to sports they practiced, like water polo (C07), swimming (C04), baseball (C06), trampolining (C02), and diving (C05). This contrasted with family-level discussions, which primarily utilized abstracted metrics, like steps, to enable comparisons, competitions, or collaboration toward a shared exercise goal. To motivate goal assessment when alone, children brought up the use of extrinsic rewards. For example, C05 wanted to *"unlock different Pokemon"* when achieving goals, *"like when I do the laundry or clean my room, I could get one Pokemon each."* He was skeptical that his dad would have a similar interest in reviewing data and motivation in that same manner (Figure 5.3-right). Other children similarly embedded game and cartoon characters that they liked into self-directed interactions to motivate their engagement and personal interest in the display.

Families considered that a shared display could supplement children's independence by replacing some parental scaffolding, expressing that *"we don't want kids to be only dependent* *on adults to organize their life forever"* (P01). They considered that individual reflection and action for co-regulation could be supported through system guidance on *"suggestions on what to do"* (C02) or an *"initial set of actions to take"* (P03) given their personal and family data. Some considered that the guidance could be through automated features or conversations. P01 mentioned that given C01's challenges with data interpretation, a display could be useful to explain *"in a way that is ADHD friendly... what to do with the data and the purpose of what this is all about."* Similarly, C02 considered that his alone time for reflection could be supported through a playful chatbot (Figure 5.4) that makes jokes and explains data in a more adaptable manner than numbers and graphs, but that parents *"they don't have access to"* (C02) during family time, which would emphasize collective exercise goals instead.

These experiences highlight the need for personally meaningful modes of interaction for children that can potentially support self and co-regulation when alone. By accommodating children's diverse interests and developmental needs through personalized interactions, visuals, and guidance, technology can play a key role in nurturing reflection and building regulation skills during independent use. Customizing modes of engagement to each child's motivations and capacities can strengthen their ability to comprehend and learn from data on their own terms, laying a foundation for increasing self-sufficiency alongside their agency to support others in the family.

5.4 Discussion

The results of the co-design study with ADHD families reveal opportunities for in-home displays to guide reflection and family co-regulation through both shared and individualized modes of use, addressing the research question on how multi-device systems can facilitate family collaboration via joint reflection with tracking (RQ3) but also indicating how these devices can support individual needs with interacting with personal and family data. Past work shows family tracking can promote health via parent-facing systems (*e.g.*, [40, 93]) or by promoting awareness of health states (*e.g.*, [202, 174]). My work builds on these past findings by exploring how in-home displays can be supportive of co-regulation needs and responsive to the context and intentions of use by family members. My findings indicate that families envision such displays as a means of guiding their learning and practice of self-regulation and co-regulation. For instance, they see these displays as tools to resolve issues related to goal progress or the roots of emotion-regulation problems. They also anticipate that the displays will help them re-evaluate their goals and provide comfort to others during key moments. Key needs and opportunities exist for situated home displays to promote joint reflection and action during family time and personalized use for individual regulation and co-regulation when alone. Such systems could foster both co-located collaboration and the opportunity for individual use centered on personal needs and preferences.

My findings indicate that families envision such displays as a means of guiding their learning and practice of self-regulation and co-regulation. For instance, they see these displays as tools to resolve issues related to goal progress or the roots of emotion-regulation problems. They also anticipate that the displays will help them re-evaluate their goals and provide comfort to others during key moments.

In the next subsections, I first describe these opportunities and explore how the findings from this study augment and expand existing considerations for the design of family informatics systems. I also specifically focus on design opportunities for supporting ADHD families in co-regulation as a case of moving families from knowledge to action.

5.4.1 Guiding Family Convergence for Co-Located Learning and Co-Regulation Practices

When involving children, family informatics approaches to system designs often either focus on guiding tasks for specific routines (*e.g.*, bedtime [226]) or promoting general awareness about specific domains, some through glanceable displays (*e.g.*, for sleep [175]) or parent-controlled dashboards (*e.g.*, for physical activity [169, 202]). These approaches can be helpful to families for gaining awareness about each other or motivating certain behaviors. My findings build on these past works by highlighting participant's expectations for home displays to provide additional benefits by helping guide use of shared data. Parents and children indicated that collaborative reflection could be more useful if situated displays help direct joint co-regulation and learning skills to be used in regulating subsequent behaviors. ADHD people and anyone who struggles with self-regulation may benefit from co-located and learning-focused reflection. However, all families would likely benefit from informatics systems that support their journeys from awareness to action through knowledge and skill building.

Moving beyond general awareness to intentionally cultivating learning and growth through data requires new ways of thinking about shared displays that leverage what we already know about dashboard use in families as well as in other contexts. While prior work shows that sharing health-related data in the family can enable communication, accountability, and motivation [53, 202, 114], participants revealed expectations for home displays to nurture specific values, social-emotional abilities, self-evaluation, and regulation skills. Thus, in-home displays could support families by guiding joint reflection on lived experiences towards collaborative learning and practice of regulation skills. By targeting learning and skill-building for growth, reflection may avoid shaming and emphasizing regulation challenges or failures that can unintentionally happen when comparing family members' data [89, 202, 198] and promote healthy practices for moments beyond system use.

My findings reveal that family informatics systems could support intentional, productive family time focused on collaborative data use. Situated displays might remind people about their data and offer self-reflection [33]. Participants indicated that for complex health coordination, such as co-regulation, family joint use would benefit from additional nudges beyond reliance on the pervasiveness of home displays. One strategy proposed by prior work is to leverage times when families already gather, such as mealtimes, to use family interfaces to promote awareness [89]. However, families explained that the complexity of co-regulation requires deeper and more frequent coordination, which bears with it the potential for distraction and reducing the value of moments during which families already gather. Intentional coordination for collaboration that uses health and wellbeing data requires some self-regulation and thoughtful action to plan around routines. The parent participants revealed how they often struggled with these practices themselves and reported that because of the normal hectic family life, important co-regulation needs and opportunities may be overlooked, even if family tracking persists and data are available. Traditional passive and glanceable family informatics approaches might then fall short in providing the support needed for families to **converge** for joint co-regulation with the display.

In light of the need for family convergence around shared data, I see the opportunity to design technology to nudge members to use in-home displays together. As one participant suggested, a system could stimulate "lighting events" to call family members for moments of togetherness to reflect on regulation efforts over days, weeks, or months. In such a scenario, a system might leverage family member's distributed devices. For example, smartwatches could be used to nudge family convergence through glanceable cues on the home screen or proactive notifications. Displays could similarly make use of glanceable animated nudges [129] to highlight the opportunity or need for family time for co-regulation, such as whenever there is an opportunity for role modeling based on positive regulation occurrences or if someone has faced self-regulation challenges and could benefit from family support. Such nudges could particularly be beneficial for people with ADHD to help call attention to a family-level co-regulation opportunity, but care needs to be taken for them to be subtle and not disruptive of other tasks [48].

Family displays have the potential to guide reflection towards learning and practice, specifically around self-regulation and co-regulation skills. In particular, family displays could proactively suggest specific regulation strategies or simply share information at opportune moments to help family members learn how to deploy these strategies themselves. A scaffolding approach might naturally provide such proactive suggestions for a time during family joint use and then slowly wean the collective group from this support over time on an individualized basis. Similarly, tracking regulation has the opportunity to highlight when goals are not being met consistently, exercise is not practiced, and moods indicate emotional struggles, and then provide reminders for family joint discussion and educational information. When jointly reviewing moods, a display could highlight subjective notes about tracked moods and contextual automated data, like time and location, to help guide recall of events and consequent regulation. As some families suggested, this contextual information could be useful to understand reasons for behavior outcomes and support dealing with problematic situations. This information support will be particularly important as advancement in passive cognitive sensing continues to develop [208] and to lower dependence solely on memory for recall. Beyond simple reminding, situated home displays could build on research in learning systems, educational technologies, and regulation development [221, 258]. For example, reflection in the form of imagining alternate outcomes [122] can provide opportunities to learn from mistakes or situations with regulation struggles. Thus, such systems could support learning by not only reflecting past data but also helping families to commit to future regulation objectives. Finally, reinforcement of learning for both individuals and the family as a whole can be enabled by surfacing successes to be celebrated and shared just as challenges are part of a comprehensive learning ecosystem for the family.

5.4.2 Guiding Individual Use of Family Data with Home Displays

Prior family informatics work includes studies of dashboards and situated displays that offer the same type of interaction and data representation for every family member [175], often catering to children [202, 223, 135]. This has some benefits during joint use to promote inclusion of all members and foster connection with one another [202]. However, study participants revealed that this approach does not fully support their individual goals for understanding and interacting with shared data. I observed that families want to share the same data about themselves to enable shared moments promoting co-regulation but have different preferences on what to see and how to use data individually that might relate to their role and functioning in the family. For example, parents largely differed from children in expecting a situated display to support them in assessing risks and ties between their role-modeling and co-regulation efforts. Conversely, children provide their own interpretations of their health data [15], which can constrain how they might use the data or create spaces of misunderstanding between them and other family members. I noted that for children's individual interaction with family displays, some would require additional scaffolding and support for use. Similar to how personal informatics has leveraged situated displays to incentivize reflection focused on the self [33], my findings suggest that a family-centered approach could benefit individuals and families by adapting to independent use in addition to modes for joint family engagement while still highlighting shared data.

My findings indicate that caregivers might benefit from guidance in navigating family data to understand behaviors deeply, comprehensively assess risks, and critically self-reflect on their contributions to co-regulation. I observed that parent's interests for independent use are in line with motivations typical of quantified-self [44] or self-experimentation [61] aspirations for using self-tracking data in hopes of uncovering insights useful to improve health decisions and quality of living, such as identifying triggers and needs not easily observed. Parents could benefit from guided use of family data to inform their parenting [114] and refine the support they provide their children as part of co-regulation by receiving insights about children's needs and struggles over time. This approach has the knock-on benefit of tying data to their own self-regulation, thereby improving their parenting.

While a parent's personal device (*e.g.*, phone, computer) could suit individual usage, parents in this study expressed that a situated display could additionally provide consistency and deeper engagement with family data due to the ties between system use and their living space. Some parents further explained that they often forgot that children's data was available on the phone app, and a display could be a more convenient way to remember to access the data. Situated displays have the potential to serve as communal mediators for parent partners to use together when discussing care for their children. Overall, while embedded in the home ecosystem, family displays could better support parents with interactions beyond what might be immediately understandable or relevant for children and joint engagement during family time, but still useful for later normal family interactions for co-regulation.

Children similarly have personal interests, as well as constraints, for using family displays independently. Past work in personal informatics for children has suggested that they can prefer fun and entertaining uses of data [15, 193, 13], such as using exercise data as a form of competitive or collaborative game [170, 153, 202]. They might also have differences in their ability to understand health data [15, 170], which highlights that guiding children's reflection in a developmentally appropriate manner is crucial for their engagement with health-related systems. Child participants in this study did not own phones, and many other families might have similar preferences given perceived safety and distraction risks [113, 213]. As such, participants considered that a home display could be a means for children's individualized access and use of family data. Still, I observed that data interpretation skills and understanding of self-regulation influence children's expectations for how the display can support their independent use. Child participants explained that systems could help them in making use of family data, especially how and when they could co-regulate others in need.

When alone, children do not have the interpretation support that others can provide during joint use [65]. Sensemaking might then be constrained if systems do not provide appropriate levels of interpretation or guidance on how to use family data.

In light of the opportunity to benefit both parents and children as individuals as well as the family as a unit, in-home displays could be adaptable to both individual and collaborative uses. These kinds of adaptations likely require multiple modes of interaction, including, for example, rapidly glanceable displays or short spoken summaries as well as engaging multi-level decision support systems [155]. For children's independent use, data must be adapted to be comprehensible for different developmental levels, graphical literacy, and both literacy and numeracy. Some children might enjoy comics and playful avatars for data explanation and storytelling, while others might tend towards interactions that allow for self-experimentation or long-term data tracking more in line with traditional adult behaviors. Over time, to help reduce burdens in families, systems might also take on the co-regulation mediator role [48] that is more commonly associated with a parent, grandparent, or older sibling. In these cases, the integration of proactive suggestions for emotion regulation and support for greater wellbeing would be essential to supporting children, their co-regulation partners, and the entire family.

5.4.3 Incorporating Expert Guidance Into the Home Display

My findings indicate that co-regulation at home would benefit from display systems that incorporate collaboration with school teachers, clinicians, and other experts. Families seek a comprehensive understanding of their data, taking into account external influences that extend beyond the confines of their homes. This collaboration within the care ecosystem can offer valuable insights, fostering increased involvement and engagement by both parents and children within the system [28, 29]. Past work has suggested the need to consider designs to improve communication between children's broader care ecosystem [230, 146], and the study findings specifically highlight the opportunity for situated home provisioning of personalized regulatory recommendations and assessments for managing behaviors.

In-home family displays have the potential to act as a bridge to integrate key guidance from clinicians and educators into the family's everyday co-regulation practices at home. Study participants considered that regulation at school were relevant to their in-home co-regulation. Some also engaged in clinical care, like therapy, and saw an opportunity to integrate clinician guidance into a home display to enhance family co-regulation practice. This resonates with prior work on improving patient-provider collaboration through data sharing [80] and work for pediatric care that posits teens could have more access to health data and participation in their own care partnership with physicians alongside parents [100]. However, feasibility barriers exist [80], including privacy regulations (*e.g.*, FERPA [78] in the U.S.), avoiding information overload to clinicians, and establishing appropriate bidirectional sharing between families and external experts.

In-home family displays could integrate expert input for family co-regulation practices. Especially considering children's regulation, contexts about tracked data during school time could be displayed when needed and informed by educators' lived co-regulation events while the child was in their care, such as adding contextual notes about positive or negative regulations moments in a class similar to notes commonly sent home by teachers. Similarly, clinical experts could have input on actionable co-regulation suggestions for families to practice. Such input could come at moments when expert evaluation identifies intervention needs or opportunities for growth, such as through evaluation of medication to exercise frequency or challenges regulating emotions under certain circumstances.

5.5 Summary and Conclusion

This chapter has presented an analysis of ADHD family's co-design of situated home displays for sharing tracking data towards co-regulation. In support of thesis claim T2, the findings revealed opportunities for in-home displays to make family time more productive for co-regulation practice and skill-building based on shared tracking data from other devices like smartwatches. Families expressed a desire for system-guided activities and prompts towards reflection, discussion, and problem-solving around each family member's behavior regulation related to moods, exercise, and goals. These devices could then provide a situated and centralized interface available for the whole family to jointly engage with health data for mutual support.

The findings also contribute to my thesis claim T1 by highlighting that family members have individualized needs and preferences for engaging with personal and family health data. Children wished to be able to independently comprehend this data in personally meaningful ways, possibly needing more guidance for interpretation and how to co-regulate others. Parents sought more complex data manipulation capabilities to identify risks and assess their own caregiving efforts. This suggests that multi-device family informatics systems could provide contextualized features and interactions depending on who is present to support the diverse goals of individual family members alongside the joint use mode.

In summary, this study demonstrates the potential for multi-device ecosystems, particularly those incorporating situated home displays, to facilitate both personal and collaborative use of health tracking data within families. By providing opportunities for co-located engagement as well as individual reflection and guidance, such systems can better support the varied health and wellness needs of families, especially those managing chronic conditions like ADHD.

Chapter 6

Investigating Family Tracking and Reflection Across Devices

6.1 Introduction

Building upon the findings of Chapters 4 and 5, this chapter investigates how integrating both personal and shared devices can facilitate personal and family informatics. In the previous chapters, my findings underscored the importance of seamlessly integrating personal and shared devices to support a more comprehensive co-regulation ecosystem. By leveraging the unique features of smartwatches for convenient contact with data, and home displays for situated reflection, there is an opportunity to investigate both individual and co-located reflection of family data while still highlighting personal data with self-tracking for self-regulation. Therefore, this chapter seeks to contribute towards my thesis claims by answering the following question:

RQ4: How might systems facilitate self and collaborative tracking and reflection across devices?

To address this research question, I designed and evaluated FamilyBloom, a multi-device system that integrates tracking of multiple family members using their smartwatches and an in-home tablet display. The smartwatch app enables family members to track their moods and goals throughout the day. Both the smartwatch and the in-home display apps provide glanceable views of personal and family data on the device's home screen. FamilyBloom was designed with the objective of involving multiple users and multiple devices in family co-regulation of goals and moods. These domains can be challenging for any family, but even more so for ADHD families, who can face heightened difficulties with goal management and emotion regulation [214, 52, 102, 37, 67].

By analyzing data from a nine week deployment of FamilyBloom with twelve families, this study contributes novel understanding of benefits and tensions of providing self-tracking alongside shared tracking within the family for collaborative support.

Towards my thesis claim T1, results indicate that glanceable representations for moods and goals on multiple devices can help individuals remember to self-track and reflect opportunistically in-between activities and regular routines, both in the home and otherwise. However, sometimes people prefer to change their watch's visualization according to context, either to track or display different information, or for simple and less distracting screens, like photos and calendar. Additionally, the results highlight there can be a tension between providing uniform goal tracking for both children and adults, and more robust goal management tools, such as tools tailored to adult's personal productivity preferences, or to incorporate extrinsic motivation strategies for children (*e.g.*, the CoolTaco system in Chapter 4).

Regarding T2, the system's multi-device design enabled diverse family co-regulation practices, supporting individual and joint reflection about family wellbeing. The home display proved to mediate some family joint discussions including the opportunity of involvement of non-participant members not engaged in self-tracking themselves. The watch component, although typically a personal device, enabled some joint use when families came together outside the home (*e.g.*, coordinating goal-setting while commuting to school) and individual reflection around each other's needs when apart. Overall, results indicate that such family shared tracking is useful to identify support needs and health risks, mediating collaborative efforts. However, there are challenges related to shared sensemaking with mood representation modalities, which could lead to some worry when family members are unsure about the intensity of perceived negative moods.

This work is under preparation for submission towards conference/journal publication and was done in collaboration with Franceli L. Cibrian, Aehong Min, Jesus A. Beltran, Evropi Stefanidi, Sabrina E. B. Schuck, Kimberley D. Lakes, Gillian R. Hayes, and Daniel A. Epstein. I designed and developed FamilyBloom, study protocols, and conducted the deployment and family interviews. I led the study analysis and writing.

6.2 The FamilyBloom Design

To answer RQ4, FamilyBloom was designed as a multi-device system to support personal and shared tracking of moods and goals within families. It comprises a smartwatch app and a tablet app for a situated home display, connected to a cloud database for data synchronization and sharing. FamilyBloom leverages glanceable visualizations across devices for reflection when family members are apart and together. Building on the insights the CoolTaco and Co-design studies in Chapters 4 and 5, FamilyBloom positions every family member as an equal user with access to the the same self-tracking features and sharing capabilities.

In this section I give an overview of the process of designing FamilyBloom and detail the main features relevant to RQ4, supporting self-tracking and sharing data with the family across devices.

6.2.1 Design Foundation and Process

FamilyBloom's design is guided by design principles that surfaced from two preliminary activities: co-design (Chapter 5) and an iterative series of low-fidelity prototyping. Low-fidelity prototyping is useful to explore many design directions with less effort than programming, evolving good ideas and quickly eliminating alternatives [245, 91].

I opted to use the Apple Watch and iPad as the platforms for FamilyBloom after evaluating current wearable device options and their APIs. Therefore, I base some of the sketches on Apple's standards and the watch's screen limitations. In particular, the Apple Watch's home screen has two main types of component spaces, (1) a larger area in the form of a rectangle, or (2) multiple smaller circles. These components, also known as widgets or complications[1], are persistently displayed on the watch's main screen.

Through a series of brainstorming and iterative sketching, I created multiple visualization options falling under three main types: graphs representing one's own mood and goals, graphs representing multiple family members' mood and goals, and abstract representations (*e.g.*, flowers with petals for moods and leaves for goals). The sketches explored both personal and family data, as well as rectangular and circular widget components (*i.e.*, the types of Apple Watch widgets). As noted in the previous chapter, colors are a useful and intuitive way for children to represent moods, so for mood representations I chose to leverage the *Zones of Regulation* framework, a popular strategy used in schools to teach emotion regulation to children [111, 110]. Examples of sketches can bee seen in Figures 6.1 and 6.2.

I met with the research team to discuss sketches and iterate new designs. The co-design and iterative prototyping process led me to establish the following design principles for FamilyBloom's development:

[1] https://developer.apple.com/design/human-interface-guidelines/complications

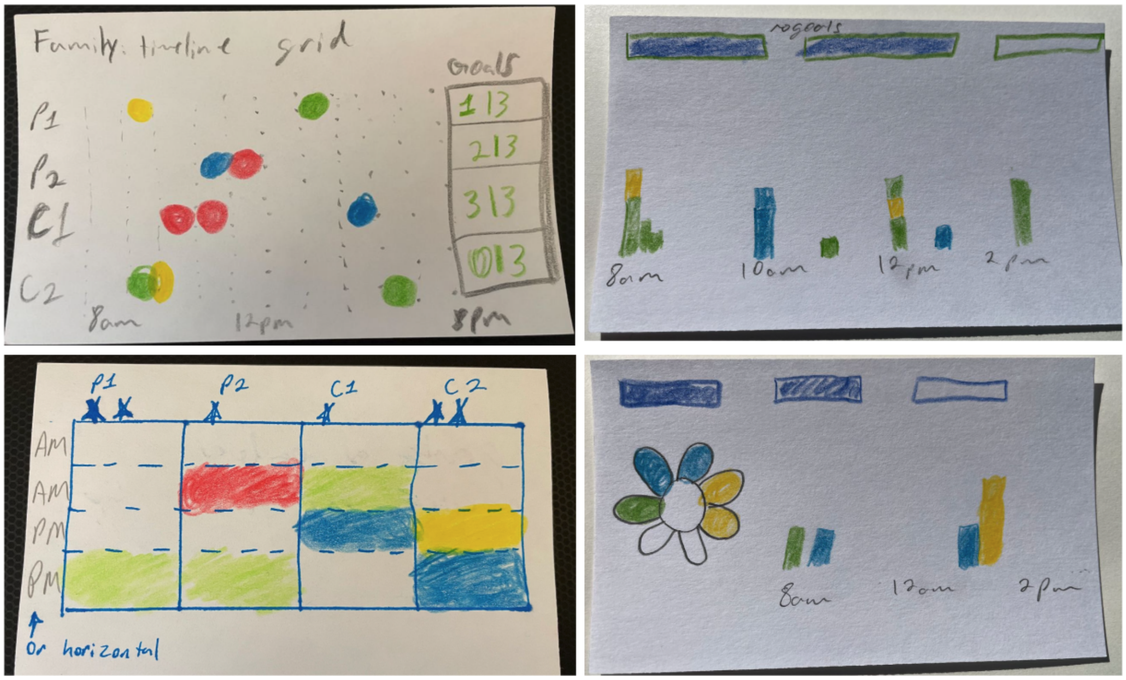


Figure 6.1: Example sketches for rectangle visualization that informed FamilyBloom. Some explored seeing data from every family member or personal data only. Representations varied from granular inputs per hour, aggregated in sequence or bar graphs, or abstract representations in shapes like flower petals.

Figure 6.2: Example sketches for circular visualizations that informed FamilyBloom. These sketches explored visualizations of a single person in granular, aggregated, or abstract forms. Abstract representations were using geometric and symmetric shapes, or involving characters.

1. **Avoid comparisons and center self-regulation:** To avoid comparisons and competition, visualization of family data should be granular per family member. For the smartwatch, the larger area of the home screen should center personal data for self-regulation and to encourage personal data engagement.

2. **Support both glanceable and detailed data visualizations:** The system should allow family members both a simplified and glanceable view of their data and the opportunity for more detailed granular data navigation, considering potential differences in data literacy and preferences.

3. **Depict progress of time:** Representations should convey a sequence of mood states by groups of time blocks, providing personal and family awareness beyond a momentary state at the time of visualization.

4. **Avoid nudging report of a preferred emotional state:** To minimize report bias, the system should not reward reports of an ideal emotional state. For example, if the visualization took the form of a character, the user might be tempted to input a "green" mood to make their character look happy.

5. **Avoid technical and social dependence for goal tracking:** The system should allow self-tracking to be independent of others' involvement to minimize workflow dependence on motivation and involvement of particular members.

Following these principles, I developed an initial version of higher-fidelity interface components. I further iterated on this version based on feedback from the research team, two ADHD adults, and a mother-daughter pair, with the daughter being in her late teens and also with ADHD. The ADHD adults are fellow students at UCI and the mother-daughter pair were volunteering assistance with the research team at the time.

The final mood tracking design follows a flower and clock analogy (Figure 6.3), with each petal representing a block of time and colored based on the last tracked mood. When no

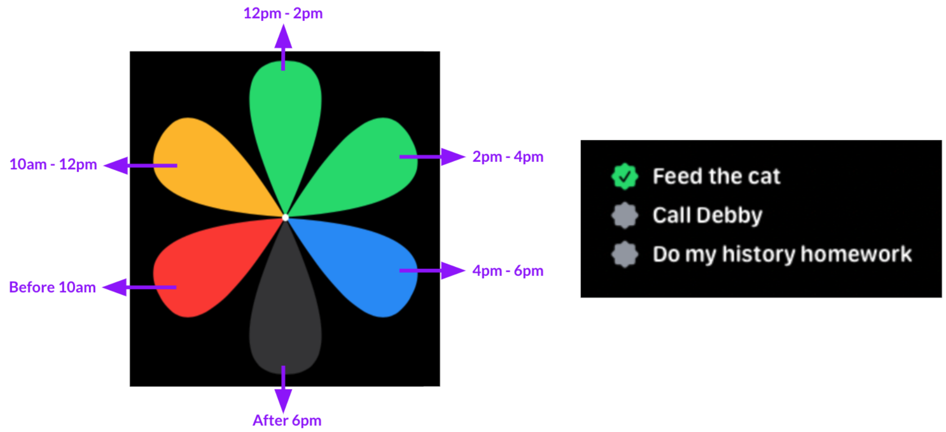


Figure 6.3: The final modality representation for visualizing moods and goals in FamilyBloom. Each petal in the flower representation takes the color of the last mood input in a time block. Most petals represent 2-hour blocks, with the exception of the first and last, that represent early morning and end of the day. Goals are simple text descriptions alongside icons representing the goal's state of "done" or "not done."

mood is tracked for a petal-time block, its color stays gray. By associating petals in sequence similar to an analog clock for a day's tracking, the design supports quick visualization without the need for granular navigation of all inputs while maintaining an associated *representation of progress of time* and *avoids nudging the report* of any specific state of emotion. Additional feedback suggested that some young boys might not like the flower analogy, so I designed an optional star representation that has similar components to petals.

The final goal tracking design is a daily three-item list of open-ended text with icons indicating goal completion status (green-checked for completed, blank gray for pending). This simple tracking aims to *reduce technical and social dependency* while still allowing for accountability through family sharing. Figure 6.3 showcases mood and goal data modality representations, specifying the time block for each petal.

Finally, I conducted a three-week pilot deployment with two children and their mother, and a 2-month deployment with my own family. These pilot deployments helped discover and resolve bugs (*e.g.*, synchronization errors), usability issues (*e.g.*, outlining the petal for the current time), and plan study procedures related to instructing participants and configuring their devices. I next detail the final design and main features of FamilyBloom per device.

6.2.2 FamilyBloom for the Smartwatch

The smartwatch app's main screen (*i.e.*, the *watch face*) highlights the user's mood flower and three goals (Figure 6.4a), *centering self-tracking*. Circular widgets represent other family members' data, displaying three letters from their names, their mood flower, and the number of their completed goals for the day.

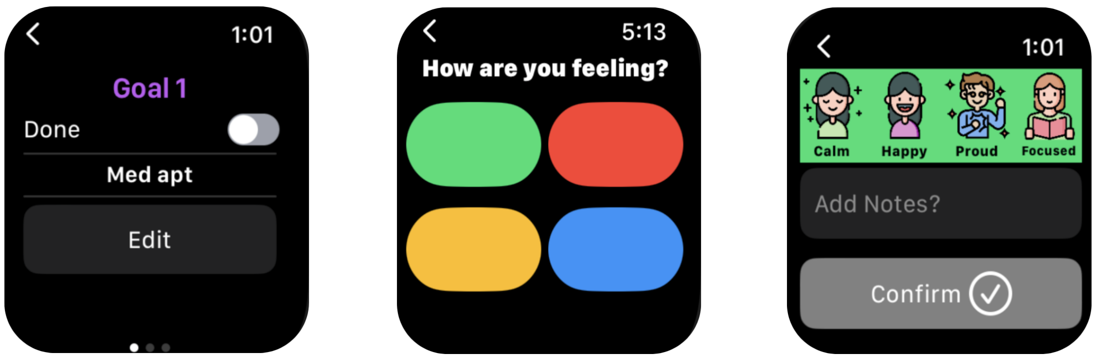
When users open the FamilyBloom app, they can navigate to screens for personal moods, goals, and viewing family members' data (Figure 6.4b). For goal management, users can edit the text for each of the three goals and mark them as "Done" when completed (Figure 6.4d). When making a mood input, users first select a corresponding color (Figure 6.4e) and then have the option to add notes before confirming (Figure 6.4f). The app also triggers one notification per petal between 9AM and 6PM asking how the user is feeling, and if they respond to this notification, the app opens to the screen in Figure 6.4e followed by Figure 6.4f for optional notes. Users could mute these notifications if they wished to.

To optimize smartwatch connectivity and battery life limitations, the app synchronizes when self-tracking data is input. Additionally, family widgets synchronize every fifteen minutes if no synchronization has occurred in the meantime. If connectivity is unavailable, data is saved only locally and synchronization is attempted again when connectivity is regained.

6.2.3 FamilyBloom for the Situated Home Display

FamilyBloom's design for the tablet is intended to provide glanceable and situated visualizations highlighting similar data as in the smartwatch app. The main screen (Figure 6.5-left) supports glanceable family visualization by displaying the abstract flower representation and

(a) Glanceable widgets. (b) Menu view. (c) Family view.



(d) Goal management. (e) Mood selection. (f) Adding notes.

Figure 6.4: FamilyBloom on the watch centers self-tracking on the watch face alongside smaller widgets for each family member's data (a). The app's initial screen (b) allows users to navigate to mood, goals, or family views. Users can manage three daily goals through text description and a 'done" or "not done" state. Users can select a mood (e), adding optional notes while seeing examples of moods associated with the selected color (f).

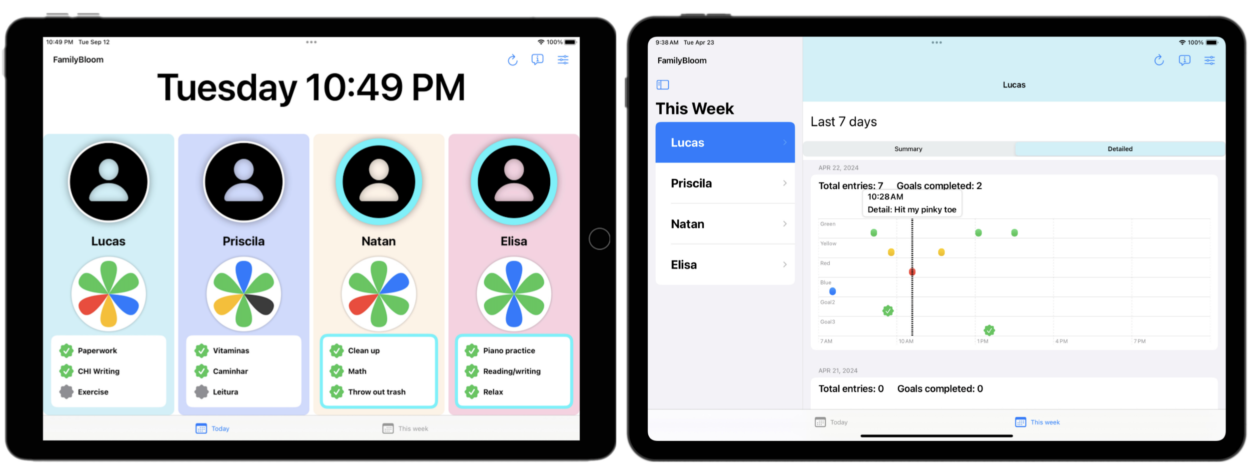


Figure 6.5: FamilyBloom on the tablet displays glanceable information about each family member, highlighting their flower mood abstraction and daily goals (left). Users can additionally see granular data for the last seven days per family member, clicking on data points to read notes or goal descriptions.

the list of daily goals for each family member. Users can customize each family member's background color and add a picture to make differentiation easier.

A secondary screen is available (Figure 6.5-right) for *granular data visualization* of each member's data for the last seven days. Users can click on a mood or goal data point to view the associated note or goal description. In all of these interfaces, family data are displayed individually to *avoid direct comparison and competition*.

Unlike the smartwatch app, FamilyBloom on the tablet is persistently connected data that has been synced, providing real time visualization. This app is persistently displayed on the tablet that is mounted in a commonly lived space in the home, like a kitchen counter or a living-room wall.

6.3 Methods

I conducted a deployment study of FamilyBloom between November 2023 and March 2024 with 12 families with ADHD children to understand perspectives of multi-device mediated personal and shared tracking in everyday life settings.

6.3.1 Participants

The FamilyBloom deployment was conducted with 12 families (44 individuals) (Table 6.1). Recruitment was in collaboration with a local school and through word-of-mouth. To enroll in the study, parents consented by signing a form and children consented verbally. Families had to have at least one child with ADHD between 8-14 years old, and siblings could participate if they were at least 6 years old. Overall, this study included a total of 14 ADHD children, 10 siblings, and 20 parent participants. F06 had two non-participating children that were

Table 6.1: Participating families in the FamilyBloom deployment study.

Family ID	ADHD Children's Gender, Age	Non-ADHD Children's Gender, Age	Caregiver Participants	Location of Situated Display
1	F, 10	M, 6	Father, Father	Dining/Living room
2	M, 10	F, 13;M, 13	Mother	Kitchen
3	F, 10	F, 7	Mother, Father	Entrance
4	M, 9; F, 8	-	Mother	Kitchen/Dinning room
5	M,12	F, 10	Mother, Father	Kitchen/Dinning room
6	F, 9	F, 7	Mother, Father	Dining/Living room
7	F, 10	-	Mother, Father	Living room
8	M, 11; F, 11	-	Mother, Father	Kitchen
9	M, 9	M, 6	Mother, Father	Entrance
10	M, 11	F, 14	Mother, Father	Kitchen/Dinning room
11	M, 12	F, 10	Mother	Kitchen/
12	M, 10	F, 9	Mother	Entrance

less than six years old, and the fathers in families F02, F04, and F11 did not enroll as participants. The parents of F08 and F09 disclosed being diagnosed with ADHD and it is likely that parents in other families have ADHD but are undiagnosed given the heritability of ADHD [77]. Table 3.2 summarizes details of participating families.

Participants were compensated individually in USD per activity: $10 for each week of using the study devices, $10 per survey, and $10 per interview. Compensation averaged $151 per participant. Alternatively to receiving the monetary compensation, participants could opt to keep the smartwatch. The iPad 9th generation used as a situated display during the study was given to families as bonus compensation when all members participated in all interviews. In this chapter, I use F# to refer to a specific family, C#[a-c] to reference a participating child ordered by appearance in Table 6.1 (*i.e.*, ADHD diagnosis and age), and P#[a-b] to reference a parent, also ordered by appearance in the table.

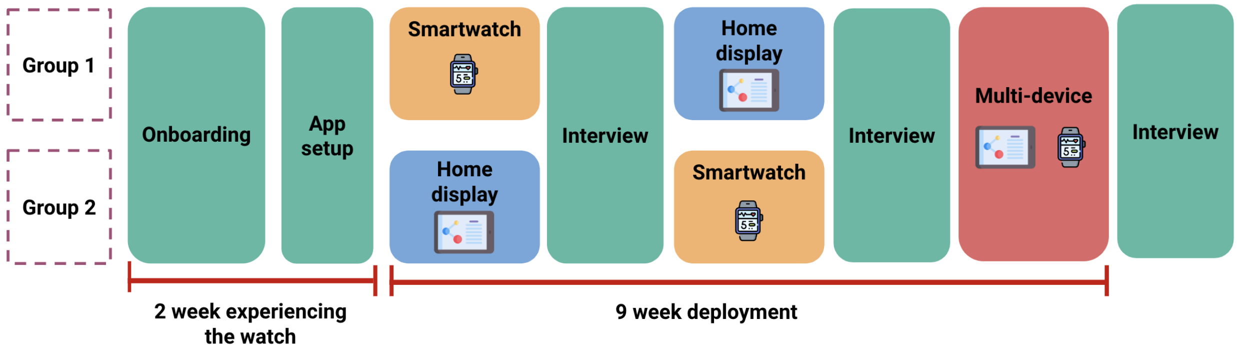


Figure 6.6: Visual representation of participant's involvement in the study. Participants first spent 2 weeks acclimating with the smartwatch after onboarding. Participants then were assigned between two groups that had incremental experiences over 3 phases for 9 weeks: first either with family data visible only on the watch or on the tablet, second with switching where family data was visible, before a final phase with having both family data on watch and home display. Overall, I met with families 5 times between onboarding, app and device configuration, and conducting interviews after each reconfiguration.

6.3.2 Study Procedures

Families first received and used smartwatches for two weeks to acclimate to the devices and then used FamilyBloom for nine weeks. To evaluate participants' perceptions of different device ecosystems for family tracking, families were randomly assigned to two groups that gradually experienced different FamilyBloom configurations. One group started with FamilyBloom on their watches, displaying family data on the watch face widgets, while the other group began with the tablet home display showing family data and watches without access to family data (but still supporting self-tracking). Families could choose where to place the home display and were encouraged to mount it on a wall or counter in an communal area that everyone frequented. Table 6.1 lists locations of where families decided to position their home display, with some locations being in-between and visible areas. After 3 weeks, the groups switched configurations. For the final three weeks, all participants had access to family data on both the smartwatch and home display.

In total, I met with families five times for planned activities, as depicted in Figure 6.6. In summary, the study phases were marked by the following activities and milestones:

1. **On-boarding and acclimating with smartwatches:** I first met families to loan and configure smartwatches, helping pair them with iPhones if available or providing a study phone if needed. Some parents (P03b, P04, P05b, P06a, P06b, P08b, P11) already owned an Apple Watch and preferred to use their own device in the study. This phase aimed to reduce the novelty effect of the smartwatch and allow children to learn how to navigate and interact with the device. I also explained the study objectives, procedures, and expectations. This phase lasted for two weeks.

2. **FamilyBloom setup:** I met with families to explain and configure the FamilyBloom apps on their devices based on their assigned group. If parents already owned phones and watches, I installed FamilyBloom on their own devices. We practiced using the app features together, and I answered any clarifying questions. Families then used FamilyBloom for 3 weeks.

3. **First interview:** After the three first weeks of using FamilyBloom, I met with families to discuss their experiences and perspectives on self and family tracking with their current app configuration. The interview focused on self and co-regulation practices, or lack of, with using FamilyBoom thus far. At the end of the interview, I prepared device and app reconfiguration, taking away or adding a tablet, and explaining the change. Families used the new configuration for three more weeks.

4. **Second interview:** After another three weeks, I met with families for another interview about new FamilyBloom configuration, differences with the previous experience, and any changes since my last visit. After the interview, I prepared devices and apps so that participants had access to family data across both the smartwatches and home display.

5. **Third interview and off-boarding:** After the final three weeks of using Family-

Bloom I met with families for the last interview. This interview was about participant's overall experience, comparing the multi-device availability for personal and family reflection, and perspectives about future opportunities, such as sharing data with others outside the family and leveraging sensed data modalities from the watch (*e.g.*, heart rate). Participants then returned devices and/or received compensation.

6.3.3 Data Analysis

My qualitative analysis of interviews with participants is inspired by the reflexive thematic analysis process [32, 31]. Two other research collaborators and I independently reviewed and open-coded two family interviews each. I then used the initial set of codes to create an initial thematic mapping on a digital whiteboard, which was used iteratively with the other researchers to review codes and elaborate themes. I then coded the remaining family interviews. The final codebook had 10 higher-level codes and 37 sub-codes. For example, a higher-level code was "Device boundaries for family sharing", that had sub-themes like "Involving non-participants", "Impact of routines", "Home navigation". I used the thematic mapping and coded data to structure the report of my findings around supporting reflection and family collaboration across devices. Themes were then refined during the writing process and in regular meetings with collaborators.

6.4 Findings

The deployment and evaluation of FamilyBloom with twelve families revealed varying perspectives on the utility, strengths, and weaknesses of the system's smartwatch and situated home display components. These perspectives were largely influenced by participants' daily routines and views on boundaries between personal and shared device and data use.

Families perceived viewing family data on the watch as generally useful for staying connected when apart and to increase awareness around each other's regulation needs. However, some participants rather occasionally changed or ignored the watch's family display in order to center the visualization around their own personal tracking needs and to be present about their tasks and activities while apart from others. FamilyBloom on the home display was reported as being useful as a situated reminder for tracking and reflecting, and a mediator of family discussion and collaboration during some joint family moments. Overall, both the home display and watch components of FamilyBloom were valued by families for opportunistic access to data, enabling family collaboration and reflection despite individual differences in routines and perspectives on shared health tracking.

Visualizing multimodal family data about moods and goals provided opportunities for family collaborative support, but could also lead to uncertainties and worries. This was in part due to the challenges in interpreting the mood representations and the motivation for goals. Additionally, families reported situations in which higher boundaries between personal and shared data is necessary to balance co-regulation opportunities with protecting others from heightened anxiety during prolonged struggles and life adversities, such as hospitalization or the loss of a loved one. Existing family strife or apathy additionally limited the utility of family tracking and sharing for mutual care.

In the following subsections, I detail the results of my analysis of families' perspectives on the strengths and limitations of FamilyBloom's multi-device aspect and their views on sharing multimodal family data about moods and goals.

6.4.1 Perspectives on tracking and reflecting with multiple devices

FamilyBloom's multi-device design provided families with multiple access points for personal and family health tracking data, accommodating self-reflection and collaboration under different contexts in everyday life. The smartwatch app component offered convenient and persistent visualization for personal tracking and family reflection, while the home display served as a centralized hub for individual reflection and mediating some joint family discussion. Despite the personal nature of the smartwatch, it occasionally took on a role similar to the display, supporting references to tracked data during social interactions between family members, in and outside the home.

The different devices for FamilyBloom also introduce challenges and tensions, such as the home display's utility depending on home navigation and routines per family member. There are also contextual factors and personal preferences that can lead to ignoring or removing family data on the watch face. In the following subsections, I present the results related to family perspectives regarding FamilyBloom's multi-device utility the smartwatch and home display components.

Benefits of glanceable tracking and reflecting with the watch face

The smartwatch component of FamilyBloom provided participants with convenient and persistent access to personal and family tracking data, serving as a glanceable reminder for quick self-tracking and reflection on others' data. Participants found the watch face particularly useful for staying connected with family members' moods and experiences throughout the day, even when they were not in the same location. For example, P06a appreciated the ability to check in on family members' moods through the watch face because:

> *"I'm constantly moving, so I liked being able to see everybody's moods on the watch, because when I do get a moment to sit down I'm seeing how things are going throughout the day for them, and I don't get a chance to see the tablet [home display] often."*

Families generally perceived that the glanceable nature of the watch face facilitated realization of other's need for support. C02b noted, *"It was really nice to check and see if anyone needed help."* C06a reported how the watch's body-mounted nature helped her to quickly and casually reflect on other member's needs:

> *"If you use the watch, you can feel it on you. I can look at other people's stuff on my watch, and then I go like, 'Oh, I wonder why this person put this in.' I think the watch reminded me more [about others]. All it takes is two seconds, a quick look and it's like 'Oh, my mom is sad.' So I can go talk to them and figure out why."*

These findings suggest that persistent visualization on the watch can be a valuable tool for family members to stay connected and aware of each other's wellbeing, even when they are not physically together, and reflect on opportunities to provide support later when together.

Avoiding family data on the watch face to center the moment and the self

External stressors and the demands of daily routines can lead participants to intentionally or unintentionally avoid family data on the watch face when apart from the family social context.

Parents, in particular, mentioned how stressful situations and the rush of routine activities could **unintentionally** cause them to ignore family data on the watch face even when looking at the device. For example, P12 explained that *"I was just stressed. Well, it's still ongoing. But this stressful situation, because of it I didn't even pay attention to their [children's] colors"* and instead viewed family data on the home display after coming back from work because *"its just there when I get home, its convenient. It kind of acts as a reminder for you to see everyone's data... its bigger."* Similarly, P03a said *"I am having* *to think about so many things throughout the day that I often don't look at their flowers;"* P06b noted *"when I get really busy with work [remotely], I still always look at my watch like for time, but then skip seeing their flowers;"* and P09b said *"sometimes my job is back to back to back meetings. Then I have no time, then I forget to go back to the watch and look at their flowers."* These examples illustrate how stressors and other demands on a person's cognition and attention can divert awareness from family data in everyday life, despite being quickly accessible through the glanceable watch face.

Participants also reported **intentionally** changing between watch faces to focus data and reflection on the self. People's perspectives on using family data for personal reflection shifted according to boundaries between personal and family environments, with intentions of collaborative support shifting to self-centric needs around tasks and information not related to the family. Participant's reports indicate that such shifts typically occurred when they left the social context of the family, such as for their routine work, even if working from home. Participants explained that certain information was especially important for them, such as C05a wanting to focus on *"my [exercise] rings during the day,"* P08b needing *"the GMT[2] a lot, because I work with [a company in] Japan,"* (Figure 6.7b) and P06b stating, *"the temperature, workout, and my schedule. Those are 3 things I check the most and I want it there [on the watch face] to not have to jump around other screens."* P03b explained his watch face preference (Figure 6.7a) during most of the day when away from the family:

> *"[I switch to] the watch face that had a lot more info. There's one [widget] that shows my heart rate. So I think about my heart rate when I see it. Why was it so high earlier? Why was it low? So there are other ones that like to use. And I switched from that one for the family. Maybe then just have the family thing inside the app. I can just open the app itself."*

[2]Greenwich Mean Time, meaning he used to track different time zones

These examples demonstrate how people might wish to adapt their watch face to track and reflect on other personally meaningful information tied to context-related priorities.

Others **intentionally** changed their watch face during certain moments or events to avoid distraction, opting for a simplified focus on time and hedonistic visualizations, like pictures and cartoons. C04b explained that *"at school, I did [mood] check-in"* but sometimes FamilyBloom could be *"distracting... so I changed [the watch face], I picked this [snoopy cartoon watch face], it was less distracting."* C06b sometimes changed to a picture of the family dogs (Figure 6.7c) because *"this one [watch face with dog pictures] reminds me of her whenever I look at it (...) I still miss her."* P08a similarly chose *"just a background picture and the time, just simple. Otherwise it's like too much for me."* Her husband explained that *"she has so many other things going on right now"* and she then added *"I can guarantee a lot of the moms probably feel the same. You don't have time to sit down, you never stop moving, you know."* P08a concluded that after the hectic day's activities, she would be able to view everyone's data *"a time at the end of the day, when you're more relaxed"* or if *"if you could instead talk to Siri [voice assistant] about your moods while doing activities, it would be better."* These examples illustrate how people may prefer to tailor their access and review of tracking according to cognitive state and other contexts. It also points to the strength of having a situated display as a dedicated and fixed data visualization location byond the personal device, wich is further detailed next.

Strengths of the situated home display for personal use

The home display provided several benefits for personal tracking and reflection, complementing the smartwatch component of FamilyBloom. Participants appreciated the larger size of the display and the ease of accessing data, which served as a persistent reminder that caught their attention when navigating the home. P11 noted *"I am sure we wouldn't even have remembered to track if not the tablet there, even with the watch. It's super noticeable seeing*

(a) P03b often changed his watch face to be dedicated to tracking data not related to his family for most of the day while he is away from home.

(b) P08a wished to monitor different time zones related to his work and his personal mood flower to take up a corner of the screen.

(c) C06b, like C04b and P08b, some times wished to see pictures of loved ones or pets on their watch and to diminish distraction.

Figure 6.7: Some participants viewed the watch face as a space dedicated to personally-related data when outside the family context. These participants generally wished that FamilyBloom's personal tracking features could be contained within a small widget alongside other non-family widgets (*e.g.*, weather, exercise, or work-related information). They reported that family-centered visualizations on the watch face could take away opportunities to display or track other personally relevant information when they were apart from the family's social context. To address this, they often switched between the FamilyBloom watch face and other watch faces throughout the day, adapting to their shifting contexts and personal needs.

the gray flowers there." P11's report illustrates how the display often influenced individuals to plan for self-tracking by reminding them about the availability of FamilyBloom and the objective of family sharing.

Families also reported how the display helped individual access to shared data while in the home for awareness and reflection about each other's wellbeing. P06b mentioned, *"Having the tablet there is like a quick, it's a very quick glance, I can check and see how, you know, where they're at with their check-ins, it's a reminder. Like, I am concentrating on something and I come in to grab something from the kitchen, a drink or snack, I'll see it on the tablet."* C06b added, *"It's like way bigger to see everything, and you can see their goals better."* Overall, the availability of the home display supported people with multiple opportunities to visualize and reflect on tracked data.

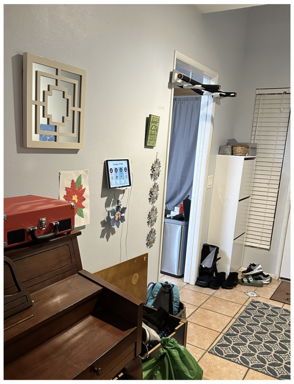
The home display also facilitated the involvement of family members who where not participants and did not wear smartwatches, or when some participants changed their watch face (*e.g.*, see previous subsection). In F04, the father did not participate in the study because *"he can't wear a watch because of his [non-disclosed] job"* (P04). The home display allowed him to engage with the family's tracking data:

> C04b: *"I like the tablet because dad can talk to us about it."*
>
> P04: *"Yeah, he didn't say anything before [when only with the watch], just looked at their watch just to see what it was. What I like about the iPad [now] is that other family members who aren't doing, having a watch, can still be involved and participate and be more connected with the family. Like, he would see [C04b]'s moods or mine and be like 'Oh, are you not feeling well today?' Like, he would see that she was mad at school halfway through the day, or whatever, and they would speak about it and find out what happened."*

Similarly, F02 expressed that the home display was a positive redundancy because *"it's* *different, I mean it's the same information, but it's bigger and [husband] wasn't part of the study, but he could see that. So, you know, he could participate even though he wasn't wearing the watch."* Many people might prefer to not self-track with a wearable, but still wish to be involved in family tracking. P07b self-tracked with the watch but explained that *"I typically don't wear watches, you know. There is a lot of people that don't want to use Apple Watches,"* with P07a adding, *"he doesn't like the actual feeling of things on his body, even having the wedding ring is difficult."* Similarly, P05a said *"honestly, I prefer tracking with this [smart ring], its simpler and smaller. It tells my sleep and my energy level."* By offering family data access even to those not actively engaged in self-tracking and wearing a watch, the home display provided opportunity for involvement and collaboration to the whole family.

The usefulness of FamilyBloom on the home display can depend on each family member's routines and physical movement within the home. Extended periods outside the home or not passing by the room where the display was situated limited access and, consequently, the opportunities to view and engage with data on the device. When asked about their preference for family data on one device or both, F10 discussed:

> P10a: *"So it's divided. For me and [C10a] we are home often so we see the iPad. [P10b] and [C10b] aren't here as much, so they use the watch to see the flowers. The option to have it both places, that would be good, so whoever it suits best gets it the way they wanted, you know."*
>
> P10b: *"Yeah, sometimes I am away for work for like three days, or will arrive home really late, so seeing on the watch is better for me."*
>
> C10a: *"For me, I get home late from practice and maybe go in the kitchen really quick, so I don't really see it [the display]."*
>
> C10b: *"I like both, it's better. You can see it [data] everywhere no matter what."*



(a) F03 positioned their display in the living room close to the home entrance.

(b) F01 had their home display next to the dinning area and used it for discussions during meals.

(c) F09 moved their display from the kitchen to the living room to be closer to the front door and where they stayed most often.

Figure 6.8: Families typically positioned the situated display in their kitchen, living room, or in-between, such as a wall in a corridor or close to the front door. Families reported that opportunistically seeing the display in the home as they were going about the day reminded them to track and see how others were doing. During some joint moments, like dinner, it was also a useful reflection and discussion tool.

Some people might not frequent the space with the home display often, even when at home. For example, C05b said *"I am never down here [in the kitchen]. I stay in my room [upstairs]."* P07b said *"I just don't walk over there all that often. Maybe if it was by the refrigerator, or something, where I might see it more often rather than having to go search for it."* Smaller homes or when positioning the display in a corridor or access are (*e.g.*, Figures 6.8a and 6.8c) can additionally influence how members interact with the display. Overall, individual's routines and where the display is positioned can inform how frequent one has opportunity to view the situated home display.

These examples demonstrate how FamilyBloom's multi-device approach can help account for different preferences in families. By providing both the smartwatch and home display components, FamilyBloom was reported to accommodate some of the varying routines and needs of individual family members. While some participants benefited from the additional access to data with the home display, others relied on the smartwatch for access to family data.

The ability to choose between or combine these devices based on personal circumstances can enhance overall reflection about other members in the family when apart.

Supporting diverse joint family uses

FamilyBloom's multi-device approach supported various moments of joint use. Both the situated display and wearable access to family data facilitated collaborative discussion and reflection during some moments when family members where together, most often in the home and sometimes outside.

Family's reports indicate that the tablet's situatedness in the home was often utilized during morning and end-of-day communal moments, such as getting ready for school and during dinner. When families were getting ready for the day, the tablet could serve as a reminder to put the watch on and prepare family members to become mindful of self-tracking for the day. P03b (Figure 6.8a) explained *"it's a reminder. With just the watch, sometimes they [children] would forget to put it on, it stays on the charger [...] [With the home display present] when we are getting ready for school, it's right by the front door, so we then see and remember, like, 'girls, go get your watches".'* The display also served some families to stimulate joint reflection during mealtimes (*e.g.*, Figure 6.8b), with F01 noting, *"It's just there during dinner, so it is like a reminder to go over the day and discuss. It becomes a topic of conversation."* Similarly, P02 said *"I would notice that they [children] would comment on everybody else's mood when we were in the kitchen, because that's where the iPad was. So I think having it be in a central area, creates conversation about it."* Overall, FamilyBloom on the home display helped some families jointly coordinate and discuss their data during routine communal interactions.

FamilyBloom on the watch also played a role in joint use during some moments throughout the day. P07a explained how they jointly used the device during commute to school for goal setting: *"In the morning on the way to school, we will speak her goals into the watch and we'll talk about, like, the things that she needs to work on. For example, sportsmanship because she plays volleyball so she gets upset at her teammates [...] It's a time we have together."* F06 established a routine of coordinating their morning routine alongside collaboration with using FamilyBloom on their watches. P06b explained that *"it's like a morning ritual;"* C06b: *"we do it [track mood] in the morning before school;"* P06a: *"there's no specific rules or set time about when it happens, it's done casually with the watch as we get ready. So we'll remind each other to check-in [moods and goal]."* P06a also described how the watch complemented the tablet during joint dinner discussions: *"we eat dinner very close to where the tablet is, so we're able to very easily look over and kind of get a good sense, but I'm just like okay I'm sitting here with the watch, I always have it on, so we just use that."* As families navigated different joint activities throughout the day, having the watch available during social interactions was useful for some to collaborate around mood and goal regulation.

6.4.2 Benefits and tensions with mood and goal sharing

In addition to perspectives on device uses for tracking and reflecting, participants reported on the utility of tracking and sharing moods and goals within families. Perspectives around relationships and modality of data representations informed sensemaking practices and challenges, while social dynamics around accountability influenced the completion of goals involving multiple members but often insufficient for personal goals.

Providing data-mediated empathy, connection, and social interactions

Sharing data about each other's emotional experiences can lead to insights and better understanding of self-regulation struggles and needs. Most families reported that FamilyBloom helped communication and connection with children's needs. P08b explained *"I think it* *has been helpful knowing her [C08b] extreme emotional swings. Being ADHD, adolescent, pre-teen girl, there's kind of been a lot of ups and downs and extreme ends of emotional reactions."* P12 perceived an increased personal interest on her children's emotional states, saying *"I'm definitely asking the kids more often about their feelings."* P07a detailed how reflecting on her daughter's mood data led her to have empathy and seek how to be more supportive:

> *"It's a visual map of really how she's feeling throughout the day. Because a lot of her ADHD symptoms caused her to have low mood, I think the fact that she is like documenting it makes me realize 'Oh, she's in a low mood and tired.' I really understand more. It makes me sad because I don't want her to feel tired, I don't want her to have a low mood, I want her to be happy and energized... So I am like, how can I have a positive impact on her mood?"*

FamilyBloom also helped children learn more about their parents' needs, even though parents tend to be more self-regulated than children. The parents of F06 reported how sharing their own moods was important for their children to be more mindful of the parent's own moods and struggles:

> P06a: *"[C06b] was like 'why were you blue today mom?', and I'm like then explaining 'I'm tired, I've had a long day'."*
>
> P06b: *"Yeah, I've enjoyed the flower because it is beneficial for them to see, like, how we felt during the day, it starts up conversations."*
>
> P06a: *"I like it because we tell them we're people too, we have feelings as well and I don't think that they always really think about that as kids, they think about themselves and what's going on in their lives, in their days. I don't think they always have an idea of what's going on with their parents when we're not all*

together, and even sometimes when we are together. So, I like that they have a little bit of insight into how we're doing throughout the day."

By highlighting parent's moods, systems like FamilyBloom can facilitate mutual understanding of each other's emotions and help build stronger family bonds and empathy.

Seeing family data when apart can help prepare for interactions and provide support when families converge. Some parents mentioned checking family data on their way home to plan how they would behave. P09b explained, *"Before I come home, I'm checking on the watch what's going on. Like, did they have a rough day, a bunch of reds? And if I see that, I'll adjust. Like, you know, I won't be intense, making my bad jokes, or upset them, you know."* Similarly, P07b said, *"I'll check the flower and see how they are, like if in a bad mood and, you know, be more quiet [laughs]."* Having access to family members' emotional states before reuniting allowed some parents to adapt their behavior and plan supportive activities, demonstrating the potential of shared mood tracking to facilitate preparations for co-regulation strategies ahead of time.

Helping identify risks to children and involve external support

By reviewing family data over time, FamilyBloom enabled reflection beyond momentary states related to wellbeing and lead some families to identify trends of health risks. Such data-driven insights lead families to consider sharing ADHD children's data with their extended care team. While sharing with clinicians was seen as a normal part of care, perspectives around potentially sharing with teachers largely depended on existing student-teacher relationships.

Sharing mood data during clinical visits was seen as a way to improve clinicians' understanding of children's regulation and inform care. F02 detailed how FamilyBloom helped identify depressive periods for C02a and inform the collaboration with their new medical provider, ultimately leading to a change in treatment and medication prescription. P02 explained:

> *"He was blue [flowers] a lot, over and over blue all the time. I don't think we would have been aware about how often he was blue if it not for the app. So we took it to his new doctor and, you know, with the anxiety and the problems, they ended up changing his medication. From all of this, our big great thing is that he got his medication changed and, since then, he's a lot happier and started getting all these greens."*

When it comes to sharing data with teachers, children's willingness depends on their relationship with the teacher. C04b mentioned, *"[my teacher] she asks me how I am feeling and she helps me."* but her brother, C04a, stated, *"It's private... I wouldn't share ever [with my teacher]."* C09a also expressed discomfort with sharing data with a specific teacher:

> C09a: *"I don't like him [teacher]. Because, like, he doesn't care and just tells me to focus on my work. I don't want him to see my [mood] stuff."*
>
> P09a: *"Well, the red petals [at school] is usually because you are upset with him [the teacher], right, with something he said or did. What if he seeing your red petals prompted him to change how he interacts with you?"*
>
> C09a: *"Mom, that doesn't make a difference!"*
>
> P09b: *"But if he sees you are sad, then maybe he will see he is upsetting you and make him change his behavior. What do you think?"*
>
> C09a: *"Still no."*
>
> P09: *"And what if it was Mr. [previous teacher]?"*
>
> C09a: *"Oh, yeah, sure, he is understanding. He is super nice, he is one of my favorite teachers."*

Parents can have concerns with teacher's interpretation of children's moods with limited contextual information. For example P06a mentioned,

> *"Sometimes kids can get upset for the littlest things, it could be for various reasons. Then the teachers are seeing like just a bunch of whatever, reds. So, you know, it could definitely be taken out of context... The teacher's insight is restricted."*

This perspective highlights the need for careful consideration of how mood tracking data is shared and interpreted by individuals outside the family as the data may lack nuance and depth of context, potentially leading to misinterpretations and misunderstandings.

Some conflicts and apathy became more apparent

While FamilyBloom generally facilitated empathy and connection, for some families the experience with the system highlighted apathy and distances in specific relationships. For example, C12a explained, *"To be honest... like, I don't really care [for seeing mom's emotions]. Not to be rude, it's hard to explain. I don't know. I am curious about what new thing she put in, but other than that, I don't really care."* Overall, some participants expressed a lack of interest or concern about how others felt beyond just being curious about their data, shedding light on challenges with affective expression and involvement families might be facing.

Family strife and apathy could diminish interest on reflecting about each other's emotions. For example, in F07, the relationship between daughter and father was tumultuous while the relationship between daughter and mother was less so. In the first interview, P07b explained *"Honestly, she [C07] doesn't give a shit about my feelings,"* while the mother explained *"she did ask me about my color, how I was feeling."* However, over time, the system seemed to foster some empathy and discussions. In a later interview, the mother P07a explained an evolution: *"It was really helpful with giving her [C07] the opportunity to express herself and for her emotional state ... I felt like [P07b] was more involved this time. And sort of recognizing how she's feeling! Like, 'Oh, you're upset, like, why red?"'* In another example, P08b explained that *"C08a can be a bit mean when he is bored... There was one time he teased his sister because she was upset or something and had a red petal. They had a little argument, so you know, we stepped in."* Overall, improving family awareness about each other's feelings does not necessarily eliminate conflict but can help mediate some discussions that might lead to resolutions.

Families' experiences indicate that awareness and sharing practices, while it can promote some reflection, can still be limited by challenges in family functioning and affective attitudes between some members. Systems like FamilyBloom have the potential to facilitate empathy and connection while practical use is influenced by relationships within the family.

Practices and limitations around accountability driving goals

FamilyBloom's glanceability provided participants with persistent visualization of goals, but accountability for goal execution via sharing in the family was typically limited to goals involving multiple family members or related to the home environment.

Seeing personal goals consistently served as a useful reminder for participants about their to-dos. However, motivation towards achieving personal goals depended primarily on intrinsic motivation and circumstances rather than system mediating co-regulation from others. For example, C04a expressed her intrinsic motivation alongside being reminded when she said, *"It helped me with my list [of goals] and to do them. I can check them off on my watch whenever I go anywhere."* P04 expressed similar appreciation, but realizing the challenges with completing goals: *"I see them on the watch and it reminded me that I needed to do* *these things, but I have so many things going on. Maybe I need to change them [goals] to just be a bit kinder to myself."* P01a also appreciated that FamilyBloom helped keep goals in mind throughout the day, saying, *"I like how it reminds me of my goals. It has kept me like, I wanna do it, its something for me to keep in mind, even if I have meetings back to back all day and won't be able to complete it."* These experiences highlight the value of persistent goal reminders in supporting individuals, even if goal completion is not always achieved.

While participants praised the self-tracking aspect and glanceability of devices, parents did not particularly see benefits with others seeing their goals. P03b said, *"it's nice to see the goals but I don't know if it really matters for them [family] to see them."* Children noticed when parents did not complete or tracked personal goals (*e.g.*, *"They weren't doing it! I was the only one!"*, C11b). These personal fluctuations and preferences for goal tracking might have led to families not holding each other accountable for checking goals as "done" in the system. This is exemplified by P04's concluding thoughts: *"I think the goals are good for them individually, for them to remember, but then, I forget or am super busy, or sick... So yeah, the goals kind of fell off to the wayside."* Overall, the shared nature of tracking goals with the system led some to reflect on the challenges of completing them and how others in the family can have a similar experience.

For children, especially those with ADHD, intrinsic motivation may be less prevalent, and some families expressed a desire for features with extrinsic structures to support goal achievement, such as rewards. Families often compared the mood and goal tracking interaction modalities, wishing that goal tracking could provide a similar sense of satisfaction as *"completing all the petals in my flower"* (C06a) over the day. They suggested incorporating *"gamification, reward system"* (P08b) elements or even simple visual reinforcements like *"sparks, fireworks [animation] when I finish my goals"* (C08a) or *"a rainbow!"* (C08b). Ultimately, when asked about tracking and sharing goals, families often reported a general sense that FamilyBloom's goal features were missing elements that could make it more engaging and rewarding, similar to the CoolTaco system described in Chapter 5, as opposed to the current simplicity of a shared list. These findings suggest that future designs for family goal tracking systems should consider incorporating more interactive and motivating elements, particularly for children with ADHD who may benefit from additional extrinsic reinforcement.

Some parents considered that personal goal management can be complex, requiring more capable tools and may not necessarily need to be shared with the rest of the family. P01b explained, *"my goals are bigger and there are several, not just a daily thing, they take more time and preparing. I am not going to put 'write proposal' there as my day's goal. So, I haven't been using the goals [in FamilyBloom], it hasn't been really useful."* P08b also preferred using other tools for managing personal goals, stating, *"Honestly, if it's a personal goal it is probably on my computer, like on a list in Outlook. If the watch was integrated with that, I could track them, but as it is, it is one more thing for me."* While goals on the watch face can help with remembering, it may not always be the most effective tool for managing complex personal goals, which can range from personal and work, varying in number, and more.

Families reported accountability practices specifically for goals related to the family environment, such as home-related activities, contrasting with their approach to most other goal types. In F08, the accountability of goals focused on chores, which they currently managed using a wall chart (Figure 6.9). F08's parents explained:

> P08a: *"So we have a chore chart, it is for [P08b] and I to have our daily things, and also getting the kids more involved. It has goals for everyone in the family for different days, so it is helping teaching accountability because we all live here and need to do our part. It usually falls on me to do a lot of chores, but in this way everyone can see that the others, even their dad [P08b], is doing it."*

> P08b: *"Now, if you wanted to really get into this, maybe the watch and the tablet [with FamilyBloom] could be tied to something like this, home skills, where anyone can tap on the screen for goals like this. And for other goals, like if [C08a] achieved his goal of 'sharing' or 'kindness,' then either we could tap he did it, showing that we appreciated it. Because often he says we don't appreciate him. That is something that would integrate well."*

Accountability was also present for goals related to quality family time, which could otherwise be overlooked due to busy schedules without system support. P05b said, *"well, the most efficient [goal] ones for me was the 'connect with [C05a] and [C05b] for 15 minutes,' every day. They made sure to remind me to do that one, like 'we still haven't done it!', so yeah, they made sure I didn't forget to do that one."* Similarly, P02 shared, *"I wasn't too good at doing my goals. Except the one about [C02a]. He would say 'Mom, when are we gonna play together? You haven't met your goal yet so you can't check it off.' So that goal helps me to make sure I do that, and he knows that's my goal. So he holds me accountable, he makes sure that I do it."* These examples demonstrate the potential for systems to leverage accountability for shared family goals related to joint activity.

While co-regulation can be beneficial in helping children focus and engage with goals, my research indicates that accountability might not be present or enough when families have shared goal-tracking. Adults might wish for more complex management of their personal goals and might be more understanding of children's goal-directed challenges when considering their own fluctuations in achieving routine goal.

Tensions with sensemaking of shared mood data

Making sense of each other's moods through FamilyBloom raised tensions related to the modality of mood representation and the effort required for self-reporting notes for context.

Figure 6.9: F08 explained that shared goals in FamilyBloom would have been better if focused on shared tasks related to the family context, like chores and responsibilities in the home. The parents explained that by situating these tasks and demonstrating that everyone had equal responsibilities over the week, it would provide a sense of justice with equal distributed effort. They explained how this would improve their current strategy of using a whiteboard in the kitchen by integrating with personal watches.

Families viewed the color and flower modalities as useful representations for a general awareness of emotional states but wished to understand the underlying reasons and details. Higher-level sharing can lead to eventual conversations for clarification (*e.g.*, *"if it's red I asked them 'Why?',"* C01a), but potentially also lead to confusion or uncertainty before such opportunities arise. Families shared that the colors were *"a little bit tricky... it can loose their meaning"* (P02) for interpretation, or *"sometimes I don't understand what the colors mean. Like how bad is that blue or red, or if it is a good thing, like excited,"* (P07b). This potential ambiguity of the modality could stimulate people to be reluctant with how they tracked, such as C04a who said, *"I get nervous that they will get really scared when I put red or blue."*

Abstraction of mood representations can also lack insights into intensity of mood states, which also can lead to worry or uncertainty on how family members can intervene. F05 had an extensive discussion around such uncertainty:

P05a: *"This doesn't happen with green [mood], everything is fine, balanced, happy. [But,] I'm worried that if I put blue, I kind of felt sensitive to, like, them misinterpreting tired or sick with something bad, you know."*

C05b: *"Also, it is sometimes hard to pick just one color, I can have more than one emotion at the same time."*

P05b: *"I'll echo what [P05a] said, like there are a wide spectrum, so is it like panic or scared? Is it angry or frustrated? So that impacts the conversation, I am thinking if there is a need for intervention and assistance, or more like just circling back about the mood."*

The opportunity of adding notes to mood inputs was leveraged by some to add context of cause or depth, such as for P06b, that expressed their appreciation for the feature: *"I've enjoyed it because I can kind of see how they are. But we wanted to know more about 'why' the girls' colors were like, red or blue. Later, with the tablet we were able to check the notes for their moods and that was interesting... Sometimes I could actually hear them in their rooms talking to the watch about their feeling [adding notes to moods]."*

However, adding notes could require more effort both for input and intentional review. For example, F05 continued to discuss the tension between specificity and effort:

P05a: *"You can add notes, but that's more work and we haven't been using those."*

C05a: *"Or a number, like one to ten for how much. Or maybe select the mood [icon] in the color."* (*i.e.*, example icons in Figure 6.4f)

P05b: *"But then, the conflict is I really like how quick it is right now. It's like 3 clicks and done."*

By proposing a range of modalities for intensity or specificity of emotions, F05 considered different solutions, but with the need to consider the balance for quickness of self-report and detail for family sensemaking.

Moods and emotions can be seen as abstract or hard to represent and understand. While people may know the 'why' of a personal mood state and the nuances of related circumstances, for the sensemaking of others reflecting on shared data the ambiguity or lack of detailed depth and context can stimulate uncertainty and worry. The tensions between the effort required for more detailed mood tracking and the desire for quick and easy tracking highlight the challenges in designing for balancing effort of self-reporting mood and providing details for family reflection.

A need for boundaries of self-tracking and family sharing

Despite a general positive perception of FamilyBloom's default sharing of self-tracking data to the family, participant's reports indicate a need for supporting boundaries related to access and representation of personal data.

FamilyBloom's participants described situations of purposefully avoiding self-tracking for family sharing to shield others. For example, P08a said *"We lost my dad last year, and my best friend died of cancer all within like months of each other. I don't necessarily want my kids to see over and over 'mom was sad again'."* P05a explained how several events led them to refrain from tracking and sharing: *"It was a crazy month. My mom got hospitalized for a week, then we got sick for a week, then we lost our car and had to figure out buying a new car."* and P05 added *"It was freaking chaos... and then, it was almost kinda of like I was trying to shield the kids, because her mother was at the hospital and it was pretty worrisome and we were saying 'its going to be OK.' But at the same time, you know, they would have been seeing red or blue for us."* These findings indicate how some family members perceive that sharing of data representing extreme stressful situations could be detrimental instead of building co-regulation, preferring to address such situations through other more sensitive social interactions instead of through technology.

Avoiding shared tracking can be with the intention to avoid family discussion altogether. In the first interview, P01a and P01b explained that they had gotten into a serious disagreement, so *"for those days I was really mad. I didn't put anything [moods] for two days because I didn't want all red flowers, twenty-four hours of red for them to discuss. I really didn't want them to engage about it."* P07a wished to keep a higher boundary between her moods at a stressful workplace from her home environment, saying *"if I had a bad day, I think I try to not bring my work home, or like the behaviors I have at work. I don't want to bring them home."* Children also expressed a desire for control over their data sharing. C05a noted, *"sometimes people want to share, sometimes they don't... When I didn't [want to share], I just put a green [mood] or nothing."* C02b said, *I erased my goals.... I don't want them telling me what to do."* P01 responded jokingly, *"Its fine, he is only 6, his goal is to survive [laughs]."* Overall, when participants wished to refrain family engagement about certain parts of their lives or discuss certain events, they opted to not track these moments at all.

Family and personal boundaries for sensemaking can encompass both the representation of data for personal reflection and the boundaries of sharing specific data itself. Some participants in the study articulated personal preferences regarding the mood data modality for personal sensemaking versus when shared. For example, F07 discussed these distinctions by reflecting on two "layers" (P07b):

> P07a: *"I think it needs to allow personal customization, like for different shapes and colors. Like, for me, blue is calming, centered. I am gonna choose the colors that are meaningful to me, like I love pink instead of the green. So that it is more personal."*
>
> P07b: *"You know, like everyone has different personal concepts for that. So it is up to the individual to select a color for themselves."*

Interviewer: “But how does it look like when shared?”

P07a: *“Maybe its numbers one to five, for low and positive mood”*

P07b: *“Or the current colors”*

C07: *“Honestly, since I’ve been going to the school for one and a half years, they have been teaching me the colors, so its pretty easy for me.”*

While default sharing of family data offers much opportunity for collaboration, reports such as of F07 indicate that some families wish for higher boundary-setting flexibility around personal data representation and a opportunity to delimit sharing under particular situations deemed not be desirable for the family environment.

6.5 Discussion

My analysis of the FamilyBloom deployment has provided insights into how multi-device systems can facilitate self-tracking and collaborative reflection across devices (RQ4). While existing research in family informatics has predominantly focused on supporting reflection through single devices, such as parent-controlled mobile apps (*e.g.*, [40, 202]) or a family dashboard (*e.g.*, [175]), the multi-device and multimodal nature of FamilyBloom enabled diverse forms of engagement with tracking data for when family members were apart and together. This approach allowed participants to track and reflect on data according to their individual routines while also fostering new opportunities for joint reflection and problem-solving when used collectively during family time.

My findings indicate FamilyBloom’s was useful in promoting family connection and collaboration around health and wellbeing. By offering glanceable views of family members’ mood and goal data across devices, the system facilitated convenient interaction for insight into each other’s emotional states and challenges. This sometimes fostered empathy and mutual understanding among family members and provided a platform to mediate discussions, even for those not actively self-tracking. This finding builds upon prior research highlighting the potential for family informatics to enhance family connection and awareness [175, 176, 229], and indicates how multi-device multimodal systems can extend these benefits through multiple access points and data representations for shared reflection.

However, findings revealed important tensions and challenges that arise when designing family-centered tracking that targets collaborative reflection. For shared moods, these tensions can be around modality trade-offs between representation for simplicity versus nuanced expression and contextual details. People might also need more control over boundaries of default sharing of moods to have the power of avoiding undesired family discussion or to shield others from heightening stressful life struggles they might already be involved with or aware of. For goal tracking, there is a similar tension, with limited accountability practices depending on scope of goals and some wishing for more complex, person-centric goal management. Addressing these tensions is important for systems to satisfy needs for both the self and family layers of health management.

6.5.1 Glanceability Across Devices for Supporting Reflection Amidst Family Routines and Preferences

The multi-device design of FamilyBloom facilitated reflection among families in various personal and family circumstances, spanning from planned discussion moments, like mealtime, to more spontaneous moments like getting ready for the day or during commute in the family car. Participants reported using both the display and smartwatch components individually and jointly. While it was expected that the display take on such uses (see Chapter 5), smartwatches are typically a personal device but still mediated joint discussion around data. By providing access to shared data across devices, families took advantage of both planned and spontaneous opportunities to check in on each other's wellbeing and discuss how to provide support. This finding aligns with prior work highlighting the potential for ubiquitous technologies to facilitate family communication and coordination around health (*e.g.*, [176, 88]). Findings also extends recent research on the use of situated displays [222, 104] and smartwatches [27, 87] to support collaborative reflection within families.

Despite these advantages, some families had members that were not self-tracking or with personal preferences around what device to use for reflection on family data. As reported by participants, some people might have tactile sensitivity and prefer not to use a body-mounted device, or have other preferences on how and where to track, such as with a smart-ring, phone, or on a home display. Results from my study indicate that people might wish to shift from family-centered tracking to personal information needs when their own contexts shift away from the family's social contexts, like during work. Others might prefer to not self-track at all, but still desire to make use of family data as a mediator for their own supportive actions. These findings showcased some limitation of smartwatches for family informatics, but indicate that expanding family informatics to support more devices and different ways of engaging with data can be inclusive of idiosyncrasies of personal and group preferences.

Future family informatics systems could be more inclusive of individual preferences by incorporating a range of personal devices and interactions that best satisfy personal experiences, affinities, and circumstances in respect to using family data. This expands on my initial study, described in Chapter 3, around multiple devices for data collection [220], by indicating that glanceable visualization for reflection can also benefit from being in multiple devices. Future systems could also tailor family joint use according to shared routines and circumstance. For example, while the watch was used outside the home for joint goal-setting and discussion, such as on the way to school, there might be better interactions that account for turn-taking in leading data input, the adult's multitasking while driving, and more. Similarly, systems could adapt visualizations and interactions to the family's context and activities, such as while getting ready in the morning or reflections at the end of the day during dinner time. Future work could explore how joint family engagement can be supported under different circumstances and with different interaction modalities. A challenge remains in providing integration across different platforms and individuals for such diverse family uses. It can also be challenging to maintain more devices, although this might be diminished if accommodating the devices individuals are already attuned to when incorporating their preferred technologies for family informatics systems.

6.5.2 Designing Family Tracking Towards Empathy and Family Connection

For many participating families, access to shared mood and goal data through FamilyBloom fostered awareness about everyone's struggles. Discussing each other's emotional states and challenges led some to understand individual needs and opportunities for support. While family informatics that emphasize token or social rewards for achieving goals can improve regulation [200, 220], highlighting dysregulation in moods or unfinished goals can unintentionally reinforce negative wellbeing states. By emphasizing tracking equally for both parents and children, some families reported how FamilyBloom helped normalize that everyone faces self-regulation challenges. Such realization was reported to promote some empathy, encourage family members to be kinder to each other, and help attune expectations.

However, my findings also revealed that for some families, pre-existing patterns of conflict or relational strain may have limited the positive impact of shared tracking. This finding illustrates how affection expression and involvement in the family's functioning is relevant to how families might or might not use shared tracking data. It reinforces findings from Chapter 5 indicating the need for multi-device tracking systems to incorporate additional scaffolding and guidance to help families navigate their relational and communication challenges towards using shared health data for improving wellbeing. For example, this could take the form of prompts for structured reflection and dialogue, suggestions for supportive actions, or integration with coaching or therapy services. Still, these findings showcase the limitations of family informatics systems in the face of family strife and attitudes affecting motivation for collaboration.

While most families reported often using shared data to inform care, practices around avoiding sharing of data can be a practice of care as well. Prior work has called for *"caring-through-data"* [114] as a health tracking lens opposed to *"data-as-care,"* acknowledging that datafication is not the final solution to health problems in itself. In this study, intentionally avoiding tracking mood data under specific situations or having leniency with other's unfinished goals was a way of caring through absence of data. Some families reported avoiding tracking data as a way to shield stressors from the family, even if everyone was aware, such as during life catastrophes like sickness and hospitalization. Families also considered the complexity around motivation and effort for goal completion, considering that the system was generally a useful reminder but everyday circumstances and intrinsic motivation drive actual goal completion.

It is still important to design systems to help families to gain balanced states of emotion or set and achieve goals but it is beneficial to help families equally emphasize praise and building self-efficacy. The FamilyBloom evaluation highlights the potential for multimodal tracking systems to not only facilitate the exchange of informational content but also augment relational connection within families. To amplify these benefits, the design of future family informatics systems could explore ways of translating individual tracking data into cues and prompts that stimulate perspective-taking, empathetic and encouraging communication, and supportive action among family members, extending existing approaches to co-regulation via directing attention and effort.

6.5.3 Considering Boundaries of Data Sharing and Representations for Sensemaking

The deployment of FamilyBloom surfaced tensions between self and family tracking that would benefit from higher controls over boundaries of sharing and data representation modalities. Participants described situations in which they wanted to limit or adjust information before being shared with other family members, such as work related goals or to prevent discussion about specific events. Different from personal informatics with sharing possibilities, boundary-related wishes in a family-centered system relate to perspectives around two layers of default sharing. One layer pertains to supporting self-tracking and sensemaking while a secondary layer relates to how such data is filtered to others in in personal or shared devices. To account for these perspectives, future tracking systems could support the co-existence of personalized tracking interfaces and consistent, mutually intelligible shared data representations.

Some participants expressed interest in customizing the mood colors and representations in their individual tracking interface in ways that differed from the shared family view. Enabling this type of customization while maintaining a standardized format for shared data could help preserve individual autonomy and preferences while still facilitating collective sensemaking. Future family informatics systems could implement two levels of mood data representations to accommodate the personal and shared layers of reflection. The personal layer would allow individuals to customize their tracking interface and data representations according to their own preferences and needs, such as selecting personally meaningful mood colors. This personal layer could support self-reflection and provide a sense of control over one's data. The shared layer, on the other hand, could present a standardized, mutually agreed-upon representation of data for collaborative sensemaking within the family to ensure that it meets everyone's needs and preferences for joint reflection. A tension still remains about the desire for quick, low-effort mood tracking more specific, contextually-rich data. This tension transfers over to family sensemaking in that members may wish for granular and contextual tracking to lower uncertainty and worry with interpreting mood states and needs.

Goal tracking and sharing in the family had similar boundary tensions within families. Simple sharing of goal descriptions had limited use for people's accountability except for goals that involved multiple members, like family activities. Adults in particular compared FamilyBloom with their more robust personal productivity tools for goals or expressed that often there was something missing, like extrinsic rewards, to promote additional motivation. Considering these findings, there is similar opportunity here for supporting different but integrated layers of goal tracking and sharing individually and to the family.

A multi-layered approach to designing for both personal and shared data representations in family informatics systems is distinct from the typical sharing features found in personal informatics tools. Rather than simply enabling users to export their individual tracking data with others, this multi-layered approach would support the continuous integration of different tracking modalities and motivational structures within the family context. For example, the system could differentiate between personal and family-oriented goals, allowing individuals to manage and share goals according to their specific needs and preferences. Adults might have a wide range of personal goals corresponding to different aspects of their lives, which they may prefer to manage using more complex and powerful tools individually. However, such tools could be integrated with family informatics tools to share a subset of goals adults might be willing to share. These shared goals could serve purposes such as accountability, role modeling, empathy building, or ones related to the family environment, such as household chores or activities involving multiple family members.

For children, the system could provide a token economy as an extrinsic motivation mechanism to support their goal tracking and achievement, potentially incorporating co-regulation features similar to those suggested in Chapter 4 considering progressive independence alongside family support. By tailoring goal management features to the diverse needs of family members, family informatics system for goal-representation modalities could promote transparency and collaboration while still respecting individual differences and preferences.

6.6 Summary and Conclusion

In this chapter I have reported on ADHD families' evaluation of the FamilyBloom deployment. The findings from my analysis demonstrate he potential of multi-device ecosystems for personal and family health tracking to support both individual and collaborative needs, directly addressing the research question on how systems can facilitate self and collaborative tracking and reflection across devices (RQ4) and contributing to my central thesis.

In support of my thesis claim T1, findings highlight how the glanceable views of mood and goal data on smartwatches, combined with situated home display, enabled participants to remember to self-track and engage with data casually throughout the day. However, the study also surfaced tensions between the desire for simplicity in tracking and the need for detailed, contextualized data to support reflection, as well as between the simplified goal tracking targeted at fitting the watch screen and for family sharing versus more features with extrinsic reward strategies or robust goal management tools adults might prefer for their own productivity.

Regarding my second thesis claim T2, the deployment of FamilyBloom demonstrates the potential for multi-device systems to facilitate family collaboration and communication around health and wellbeing. The system's design, which inherently provided shared access to self-tracking data, enabled reflection on family data and problem-solving through discussions involving the situated display and opportunistic uses of the smartwatch. The findings indicate that such family shared tracking can be useful for identifying support needs and health risks, mediating collaborative efforts. However, the study also revealed tensions in shared sensemaking, particularly around the balance between data abstraction and specificity, which could lead to worry when family members are unsure about the intensity of moods. I have discussed how future family informatics systems might balance boundaries of data sharing and provide different layers of features and modality representations that account for individual preferences and shared understanding while integrating data sharing within the family.

The FamilyBloom study demonstrated the value and potential of leveraging multiple devices and modalities to support a range of individual and collaborative reflection practices among family members. As health tracking tools become increasingly embedded in the lives of families, it is crucial to design future systems that can adapt to the complex and dynamic routines and relationships within families. While the study surfaced important tensions and challenges around device and data representation preferences that require further investigation, it provides empirical insights about the potential of multi-device and multimodal approaches to support both individual and collaborative needs for health and wellbeing management.

Building upon the insights gathered throughout this dissertation, the FamilyBloom deployment serves as a culminating investigation in my dissertation, bringing together the key themes and insights from the previous chapters to demonstrate the potential of multi-device ecosystems for health tracking. The study's findings reinforce the central arguments of my thesis, highlighting the benefits and challenges of leveraging multiple devices and data modalities to facilitate self-tracking and family collaboration around health and wellbeing. As I move into the final chapter, I will further demonstrate how the findings from this chapter align with the previous studies in providing a holistic perspective on the design of multi-device personal and family informatics systems.

Chapter 7

Discussion and Conclusion

This dissertation demonstrates the potential of leveraging multiple devices and data modalities to make health tracking convenient and collaborative. Chapter 3 demonstrates how such ecosystems can help people collect data under different situational constraints and in support of their health goals related with food intake. Chapter 4 describes how multi-device systems can mediate children's self-tracking supported remotely by family members. Chapter 5 explores integration data from family member's personal tracking to promote joint reflection and collaboration. And finally, Chapter 6 have demonstrates how personal and shared devices can connect self and shared tracking to bridge the personal and family needs for awareness, connection, and mutual support around health.

The research of this dissertation encompasses two complex and challenging domains for health behavior management and data tracking. First, food journaling is notoriously burdensome, especially in the data collection stage [54, 55]. Secondly, ADHD families have heightened challenges with wellbeing and need for collaboration [229, 66, 259]. These are contexts in which health tracking has much potential to help improve health and wellbeing. Similar to Figueiredo [56] and Pine & Liboiron [177], I have used these studies as *"extreme* *and overt cases"* to additionally demonstrate opportunities for multi-device and multimodal health tracking towards more common and less extreme everyday life situations.

In this chapter, I synthesize the findings from these studies in light of my thesis claims and discuss their implications for the design of multi-device personal and family informatics systems. I begin by examining how the insights from my studies contribute to facilitating convenient data collection and reflection across contexts, first for individual self-tracking and then for family collaboration. I then discuss the challenges associated with developing and maintaining multi-device infrastructures for health tracking, drawing on the experiences from the ModEat, CoolTaco, and FamilyBloom deployment studies. These challenges highlight the complexity of creating interconnected systems that rely on data synchronization between devices and multiple users, and are relevant not only to research contexts but possibly to the broader landscape of users engaging with health tracking in their device ecologies even if provided by commercial or health care providers.

7.1 Multimodal and Multi-Device Systems Facilitating Self-Tracking (T1)

The findings from my studies demonstrate how systems that support multimodal and multi-device health tracking can help people be able to track and reflect as they shift between contexts and environments. By leveraging different device capabilities and features, people can continue to track considering the multiple opportunities of data collection and self-reflection rather than with single mode of tracking. I now discuss key insights from these studies in support of the first thesis claim, focused on needs related to the individual.

7.1.1 Making Self-Tracking Available Across Contexts and Situational Constraints

People often wish to monitor various aspects of their health and behaviors throughout the day. However, they must navigate diverse contexts characterized by unique environmental characteristics and constraints that impact self-tracking efforts. Perceived social norms, ongoing tasks in-the-moment, and physical location are common factors people consider as they pause to self-track. **Multimodal multi-device systems can help individuals continue to self-track under different and often complex environments.**

Convenience and availability of interaction options play an important role in facilitating self-tracking. When self-tracking is too difficult or impossible given device unavailability, people can skip self-tracking [55], which in turn can lead to abandoning the practice before gaining any personal health benefits [51, 127, 74, 55]. My findings demonstrated that by providing users with the possibility of choosing between multiple ways for data input (e.g., item selection, text, voice, photos), across devices like smartphones, computers, and voice assistants, people can adapt their tracking practices to their changing needs and circumstances. This flexibility indicates how users can maintain consistency in their tracking even when faced with situational constraints or challenges, such as time constraints or the availability of specific devices.

When navigating social situations, which typically can deter people from tracking in-the-moment [55], individuals can opt for less intrusive input modalities to minimize disruption. For example, they may take a quick picture or select items on a smartwatch discreetly. Having multiple options allows users to continue self-tracking without completely disrupting ongoing social interactions or activities while not missing out on collecting data for reflection.

Beyond circumventing situational constraints, multimodal systems can enable people to capture data in different ways to support diverse and evolving goals. Combining different data types can build nuanced tracking and capture some contextual information that people value and possibly use for recall and self-understanding later. Throughout my findings, people often wished to included contextual information in their data, such as experiences with meals (Chapter 3) or notes about self-regulation states (Chapters 5 and 6). Prior work has indicated the ambivalence people might face with datafication of their health, facing uncertainties about ambiguous, uncontextualized data [134] and the practice of creating multiple narratives around ones data [114]. My work indicates that by leveraging the strengths of different data modalities, systems can enable nuanced journaling, potentially reducing ambiguity and empowering people to shape their self-tracking practices to better satisfy their reflection needs. This, in turn, allows individuals to construct personal narratives that align with their goals and experiences, providing a more meaningful and contextualized understanding of their wellbeing.

Personal preferences and aversions are key factors in self-tracking using ubiquitous systems. These preferences can be influenced by various factors, including prior experiences, personal affinities, or even momentary cognitive states, such as being more focused or distracted, tired or energized, and so forth. Additionally, individuals may harbor aversions towards specific modalities or devices due to unfamiliarity with new interactions or a perceived lack of alignment with their health goals. Aversion can also be linked to sensory sensitivities. For example, some individuals may prefer not to wear a watch or carry a phone in their pocket, preferring interacting with a home display or voice assistant instead. Multimodal multi-device systems offer a solution to accommodate these diverse preferences and aversions, allowing individuals to choose how and with what they track more comfortably, based on their mental model, or current state of mind.

In summary, my work demonstrates that multi-device systems can tap into the strengths of each device platform to support self-tracking across diverse contexts. By providing multiple interaction options, individuals can engage in self-tracking under varying physical and mental conditions. **My findings collectively indicate that multimodal and multi-device approaches can make self-tracking more available and adaptable to people's diverse needs, preferences, and environmental constraints**.

7.1.2 Supporting Self-Reflection in Spontaneous and Planned Moments

Multimodal and multi-device systems can offer more opportunities for self-reflection under different situations. **The multiplicity of how people access tracking data can facilitate both intentional and planned reflection, as well as spontaneous and opportunistic reflection practices that align with individual routines**.

Making multimodal data readily available in multi-device systems can help people remember to track and consider their health data in the moment throughout the day. Forgetfulness is a common barrier to consistent health tracking and habit formation, as documented in previous research [51, 127, 74, 55]. Therefore, offering convenient access to tracking tools and insights throughout the day can foster more regular engagement with self-tracking practices and encourage thoughtful reflection on one's behaviors and their impact on overall wellbeing. For instance, my findings indicate people often plan dedicated time with a preferred device to engage in deep reflection using their data, focusing on nuanced contexts, behavior patterns, and progress towards health goals. Such intentional reflection was observed across various domains, including goal-setting, dietary choices, and more. In addition to planned reflection, individuals also engage in casual reflective practices throughout the day, such as glancing at their smartwatch for immediate insights or interacting with a situated display as they naturally navigate their home environment. These spontaneous moments of reflection enable individuals to make timely adjustments to their behaviors and engage in self-regulation as part of their daily routine.

In conclusion, my research highlights the potential of multi-device systems to support diverse self-reflection opportunities. By facilitating consistent and opportunistic reviews of personal data, such systems can enable individuals to engage in reflective activities throughout the day and adjust behaviors for wellbeing, including self-regulation.

7.2 Facilitating Family Collaboration around Health and Wellbeing (T2)

My dissertation demonstrates how device ecologies can be designed to support better connection and collaboration for collective health and wellbeing within families, both during personal time and across locations, as well as during dedicated family time. I next revisit insights of my studies backing my thesis claim T2 on multimodal multi-device systems supporting collaboration needs within families.

7.2.1 Supporting Individual Reflection on Family Data Across Routines

My dissertation demonstrates that supporting different modalities and devices for family health tracking **can make systems more suitable to accommodate the variation and individuality of each member's routines and attitudes around collaboration**. Family members have unique preferences around engaging with family data that can be shaped by personal routines, data interpretation skills, affective attitudes, or views about roles and responsibilities of caregiving. By allowing family members to have multiple interaction modalities for engaging with family data and with different devices, systems can support members' connection and collaboration with others while aligning with such variations.

While ubiquitous systems can facilitate co-regulation through reflection, particularly when families are physically apart, it's essential to find a balance between fostering connection and providing access to shared data without creating excessive technical and social dependencies. Excessive dependency, particularly between children and parents, may undermine the benefits of autonomy in tracking and reflecting. Individual family members may have varying attitudes towards their roles, control, and overall involvement in family collaboration [231]. By facilitating sharing between family members without imposing complete dependency, individuals can track more independently and reflect on how their reflection integrates with others' needs. This approach not only promotes individual autonomy but can also foster collaboration and shared responsibility within the family. Thus, multi-device systems can encourage reflecting on each other's data as a means to facilitate co-regulation and mutual support within the family unit, but not as a requirement for individual self-regulation features to work.

When reflecting on others' data individually, people can gain awareness of their health state and wellbeing needs, but interpreting and using family data practically can depend on data literacy skills and role in the family. For example, children might have trouble understanding some data modality representations and figuring out how they can support others, while parents may have different expectations and capabilities in terms of making sense of and acting upon family health data. Offering reflection support in the face of such levels of individual differences remains a challenge when designing family informatics systems but important to support families given the heterogeneous presence of preferences and characteristics of individual members.

Making sense of others' data when reflecting alone can be impacted by modality choices and corresponding level of specificity and representation. My work resonates with others that indicate that while health data may lead to assurance and peace of mind about health, it can also lead to frustration and stress when people can't make sense of it [114, 110, 134]. Certain modality might be easier and quicker to track with, but might lack nuanced and contextual meaning. This can lead to uncertainty and worry when there is ambiguity. Offering multi-modality may diminish ambiguity by allowing people to track more contextual information that help others make sense when reflecting individually, such as text or voice notes alongside other health data. However, this comes at a trade-off with additional self-tracking effort. Despite these issues, uncertainty around tracked information can have positive impacts on reflection, such as instigating exploration and family discussion when eventually people come together.

Individuals' opportunities to reflect and participate in family co-regulation can vary greatly depending on their routines and attitudes around involvement. By offering increased access and reflection on family data, ubiquitous systems can help family members see other's health needs and struggles, stimulating empathy. However, not all people will make such leaps in face of concerning data (*e.g.*, negative moods over time), indicating that personal indifference's and low family functioning can persist even when system highlight needs for support. Family informatics systems might have a limited role in supporting families in severe conflict, but have the potential of promoting connection between members and offer guidance on improving supportive attitudes towards family's wellbeing.

In summary, my dissertation demonstrates the importance of designing multi-device systems that accommodate the diverse needs, preferences, and roles of individual family members in reflecting on shared health data. By providing multiple ways for individuals to access and reflect on family data, these systems can support more empathetic and co-regulation opportunities. However, there is still a need for carefully navigation of challenges around balancing independence and collaboration, ensuring data clarity and interpretability, and accounting for the varied affective attitudes of some family members.

7.2.2 Supporting Family Co-Located Use of Shared Data for Co-Regulation

While most tracking is typically done individually, there are opportunities for **involving multiple people in jointly co-constructing data**. Although primarily designed with self-tracking in mind, even personal informatics tools can influence behavior or attitudes from others in a family, friend, or work environment. Conversational inputs might be particularly adaptable to collaborative tracking, with children and parents helping each other describe data in the context of shared meals, activities, and goals. This finding resonates with prior work suggesting that conversational agents are often engaged by multiple users in the home simultaneously [171, 180]. Multi-device ecosystems can facilitate co-located family engagement to track data together. For example, families might collaborate during family time to set collective goals or discuss individual goals related to self-regulation and wellbeing. Families can also leverage different modalities to co-construct entries, such as turn-taking with voice description, another person adding a picture, and so forth. Such collaborative approaches could not only distribute the burden of tracking across family members but also foster a sense of shared ownership and connection in the data collection process.

In addition, having multiple devices for family data visualizations can **help families discuss and address daily wellbeing during moments together**. Such systems can satisfy joint data use during different types of family gatherings. Opportunistic use of data situated in a display in the home can facilitate discussions and problem-solving during meals and other moments next to the display. People might also leverage their individual devices during shared moments to reference synced data between each other, such as using the smartwatch while commuting together to drop off kids at school.

This multi-device approach also opens up new opportunities for boosting family joint use of shared data by integrating support from key stakeholders in children's lives, such as teachers and healthcare providers. Sharing multimodal family data can facilitate collaborative communication with clinicians with the objective of identifying and addressing emerging health concerns for families to review together. Similarly, families can wish for tracking systems to bridge the gap between home and school environments, enabling teachers to contribute valuable insights about children's needs and support the family's understanding of their child's behavioral patterns and regulation, stimulating discussion and problem-solving together. Teachers, like clinicians, might also benefit from awareness of children's regulation challenges outside of school to inform their co-regulation during class. This aligns with recent calls in the HCI for designing health technologies that account for the complex care ecosystems in which health behaviors and outcomes are embedded [230, 229]. However, families can be apprehensive about teachers accessing and interpreting personal data, especially if the student-teacher relationship is strained. There are also concerns about how teachers might make sense of shared data without sufficient context, potentially leading to misinterpretations.

Overall, my work suggests that the combination of individual and shared interfaces can help both independent and collaborative practices coexist within the family. By providing multiple touch-points and modalities for engaging with family data, multi-device systems can support diverse co-regulation needs and practices, from casual and opportunistic reflection during daily routines to more structured and purposeful discussions during joint moments of dedicated family time.

7.3 Challenges with Creating, Maintaining, and Using Multi-Device Systems for Health Tracking

Despite opportunities for facilitating health tracking, all multi-device deployment studies I conducted reported in this dissertation surfaced practical challenges related to the development and maintenance of interconnected health tracking systems, both for participants as users as well as for myself in the role of system provider [219]. These challenges highlight the complexity of creating and deploying pervasive technologies that provide synchronization between devices, data modalities, and involving multiple people. They emerge from both user and researcher perspectives, encompassing issues related to device management, infrastructure maintenance, cross-platform development, and data management.

From a user perspective, ensuring that all devices in the ecosystem remain updated, charged, and functional can be a significant challenge. Participants often contacted me about troubleshooting smart speakers or connectivity problems among their devices. In deployments involving families, updating and charging the smartwatches was a routine challenge on top of remembering to wear the device. Several family members additionally lost their watches or had challenges with maintaining Wi-Fi connection, leading both children and adults to have gaps in tracking and with potential disruptions to the family co-regulation process. This challenge is especially heightened in families with children with ADHD, as the task of managing and regulating the use of these technologies requires additional attention and self-regulation skills.

From a provider perspective, maintaining a seamless user experience requires robust back-end infrastructure that can handle device disconnections and data synchronization issues. Developing and maintaining apps across different platforms and standards also poses a substantial challenge. While leveraging commercially available consumer devices taps into people's existing device ecosystems, it also introduces the risk of platform lock-in. For instance, Apple

Watches cannot be directly connected to Android phones, limiting the flexibility and inclusivity of the study. As these platforms and development frameworks continue to change over time, it is challenging to maintain compatibility across devices and optimal performance (e.g., smartwatch's battery life).

These challenges are not limited to study contexts and will continue to be a concern for multi-device personal and family health informatics as a whole. While the experiences I reported in this dissertation are situated in research deployments, much responsibility falls onto users to care for the tracking ecosystem on their end, which might also happen as commercial or healthcare providers increase device and data modality availability in health tracking. Thus, future systems and studies must grapple with the dilemma of balancing the benefits of leveraging familiar, commercially available devices with the challenges of maintaining a cohesive and reliable multi-device ecosystem during real-world uses.

7.4 Future Work

I aim to continue to investigate multi-device and multimodal system designs to better support individuals and families to manage health and wellbeing. As mentioned above, there are many technical challenges, as well as needs for these systems to better support data integration and use towards actions for improving people's lives and considering their diverse social and living dynamics. In particular, future work I am interested in pursuing are:

Considering diverse family makeups and their available technologies: Families can be in all sizes and shapes, with cultural, economic status, and idiosyncratic dynamics influencing relationships and attitudes around health collaboration. Moving forward, I plan to investigate the design of systems that take these factors into consideration towards better supporting health management.

Integrating people's extended social supports: Beyond family collaboration, there are others with important roles in people's wellbeing. When considering children in particular, teachers and clinicians, for example, play a crucial role in helping with their development. By integrating data-driven support in their collaborative roles, multimodal and multi-device systems could connect the larger care ecosystems while leveraging technology mediation.

Exploring opportunities for semi-automated tracking: My studies highlight opportunities for semi-automating tracking by combining manual modalities alongside leveraging automated sensing or interpretation to reduce the burden of self-tracking. Prior work suggests that semi-automated tracking can strike a balance between lowering data capture burden and maintaining awareness and reflection involved in manual tracking. Exploring further, I plan to investigate how automation, such as utilizing automated analysis of voice and text descriptions or leveraging smartwatch sensors to fill gaps from missed self-reports, can enhance tracking convenience while preserving user control over their data and its sharing with other family members.

Facilitating self and joint reflection towards action: There is a need to aggregate and simplify heterogeneous data to help people's sensemaking and decisions. Beyond integrating multimodal data across devices and individuals, there is much needed guidance for people to take data-driven action to improve their wellbeing. I believe that creating smart systems that output insights, suggestions, and evidenced-based interventions based on people's information is an opportunity to help non-experts in managing themselves and understand how they can better support others while caregiving.

Investigating conversational tracking and reflection across devices: As voice assistants are increasingly pervasive across device platforms and locations, it is an interesting opportunity for engaging with data with natural language. I have started to investigate this space since the ModEat deployment and will explore VAs for family informatics, especially to facilitate children's understanding and engagement with family data given how voice might have less barriers than data visualizations.

7.5 Conclusion

In this dissertation, I have investigated how multi-device ecosystems can support personal and collaborative health tracking in everyday life contexts. People's interaction with technology has substantially increased, facilitated by the widespread adoption of smartphones, wearables, smart home devices, and other interactive technologies. This proliferation has not only enhanced communication, entertainment, and support for everyday tasks but has also opened up new opportunities for individuals and families to collect and interact with health data. However, despite the growing adoption of diverse technologies, current personal and family informatics systems fail to fully leverage the affordances and interaction modalities inherent in people's device ecosystems, which impedes the realization of more flexible, contextually-appropriate, and collaborative forms of tracking and reflection.

Through my analysis of a series of studies, I have demonstrated the potential of multimodal and multi-device approaches to facilitate convenient data collection and reflection for both individuals and families. The ModEat study (Chapter 3) showed how multiple tracking options across devices can support data collection more readily available under different daily contexts and constraints. The CoolTaco study (Chapter 4) explored how multiple devices can mediate caregiving when apart, supporting co-regulation between parents and children with ADHD. The co-design study (Chapter 5) revealed opportunities for situated displays to guide family time with joint reflection on shared data. And the findings from the FamilyBloom deployment (Chapter 6) demonstrated how integrating tracking and reflection across personal and shared devices can support a more comprehensive collaborative experience between family members, accommodating the individual routines and preferences.

Collectively, my research has shed light on key design considerations and challenges for developing effective multi-device personal and family informatics systems. These include balancing flexibility and specificity in data capture methods, supporting both independent and collaborative tracking and reflecting practices for behavior regulation, accommodating diverse user preferences and contexts, and carefully navigating the social and emotional complexities of modality representations for sharing health data in the family. By providing empirical insights, my dissertation advances our understanding of how to create more available, adaptable, and useful tools for personal and collaborative health tracking.

As interactive technologies continue to evolve and permeate people's lives, it is crucial that personal and family informatics systems keep pace with these changes to better support people's health and wellbeing needs. My dissertation lays the groundwork for a new generation of multi-device ecosystems that can make health tracking and management more ubiquitous, engaging, and connected for individuals and families. However, realizing this vision will require ongoing research to address the socio-technical challenges of designing for everyday life contexts and lowering burden of manual self-tracking. Additionally, it's crucial to ensure that these systems are inclusive of various family structures and dynamics, while also being mindful of the diverse attitudes towards collaboration and technology preferences among family members.

I believe the insights and design implications from my work can inform not only the development of future tracking tools but also broader conversations around the role of technology in supporting health and wellbeing. As we move towards an increasingly data-driven and technological world, it is essential that we design systems that foster people's self-understanding and family's meaningful collaboration and social support. Ultimately, we need systems that empower people to lead healthier, happier lives on their own terms. By embracing a human-centered, multi-device approach to personal and family informatics, we can create technologies that truly meet people where they are and help them manage their wellbeing.

This means designing systems that are sensitive to the complexities and challenges of everyday life, and that respect people's autonomy alongside collaborative support. As the field continues to evolve, I hope that my work can contribute to a more holistic, inclusive, and empowering vision of how ubiquitous technology can support care networks for the wellbeing of individuals and families.

Bibliography

[1] Ate - the Mindful Food Journal.

[2] E-health application categories used by U.S. adults 2017 — Statista.

[3] How the MyFitnessPal App got 165 Million Users — LinkedIn.

[4] MyFitnessPal: Calorie Counter, Diet & Exercise Journal.

[5] Nutrition Data System for Research (NSDR).

[6] Google's 'smart' food diary is actually kind of dumb. *website*, 364(25):2392–2404, jun 2011.

[7] E-health application categories used by U.S. adults 2017 — Statista, 12 2019.

[8] Tracking for Health — Pew Research Center, 8 2020.

[9] E. A. Ankrah, A. Bhattacharya, L. Donjuan, F. L. Cibrian, L. Torno, A. Ritt Olson, J. Milam, and G. Hayes. When worlds collide: Boundary management of adolescent and young adult childhood cancer survivors and caregivers. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, CHI '22, New York, NY, USA, 2022. Association for Computing Machinery.

[10] P. Abtahi, V. Ding, A. C. Yang, T. Bruzzese, A. B. Romanos, E. L. Murnane, S. Follmer, and J. A. Landay. Understanding Physical Practices and the Role of Technology in Manual Self-Tracking. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT 2020)*, 4(4):1–24, dec 2020.

[11] F. Amini, K. Hasan, A. Bunt, and P. Irani. Data representations for in-situ exploration of health and fitness data. In *Proceedings of the International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth 2017)*, pages 163–172, New York, NY, USA, may 2017. ACM.

[12] T. Ammari, J. Kaye, J. Y. Tsai, and F. Bentley. Music, Search, and IoT. *ACM Transactions on Computer-Human Interaction*, 26(3):1–28, jun 2019.

[13] S. Ananthanarayan, K. Siek, and M. Eisenberg. A craft approach to health awareness in children. In *DIS 2016 - Proceedings of the 2016 ACM Conference on Designing Interactive Systems: Fuse*, pages 724–735, 2016.

[14] A. H. Andrew, G. Borriello, and J. Fogarty. Simplifying Mobile Phone Diaries: Design and Evaluation of a Food Index-Based Nutrition Diary. In *Proceedings of the International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth 2013)*, pages 260–263, 2013.

[15] E. A. Ankrah, F. L. Cibrian, L. M. Silva, A. Tavakoulnia, J. A. Beltran, S. E. Schuck, K. D. Lakes, and G. R. Hayes. Me, my health, and my watch: How children with adhd understand smartwatch health data. *ACM Trans. Comput.-Hum. Interact.*, 30(4), sep 2023.

[16] A. P. Association. *Diagnostic and statistical manual of mental disorders: DSM-5™, 5th ed.* American Psychiatric Publishing, Inc., Arlington, VA, US, 2013.

[17] A. Ayobi, P. Marshall, and A. L. Cox. Trackly: A Customisable and Pictorial Self-Tracking App to Support Agency in Multiple Sclerosis Self-Care. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2020)*, pages 1–15, New York, NY, USA, apr 2020. ACM.

[18] A. Ayobi, T. Sonne, P. Marshall, and A. L. Cox. Flexible and Mindful Self-Tracking: Design Implications from Paper Bullet Journals. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2018)*, volume 2018-April, pages 1–14, New York, NY, USA, apr 2018. ACM.

[19] E. Barrett-Connor. Nutrition epidemiology: How do we know what they ate? In *American Journal of Clinical Nutrition*, volume 54, pages 182–189, 1991.

[20] E. P. Baumer, S. J. Katz, J. E. Freeman, P. Adams, A. L. Gonzales, J. Pollak, D. Retelny, J. Niederdeppe, C. M. Olson, and G. K. Gay. Prescriptive persuasion and open-ended social awareness: Expanding the design space of mobile health. In *Proceedings of the ACM Conference on Computer Supported Cooperative Work (CSCW 2012)*, pages 475–484, 2012.

[21] G. E. Baykal, M. Van Mechelen, and E. Eriksson. Collaborative Technologies for Children with Special Needs: A Systematic Literature Review. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2020)*, pages 1–13, New York, NY, USA, apr 2020. ACM.

[22] A. Bedri, D. Li, R. Khurana, K. Bhuwalka, and M. Goel. FitByte: Automatic Diet Monitoring in Unconstrained Situations Using Multimodal Sensing on Eyeglasses. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2020)*, volume 20, pages 1–12, New York, NY, USA, apr 2020. ACM.

[23] A. Bedri, R. Li, M. Haynes, R. P. Kosaraju, I. Grover, T. Prioleau, M. Y. Beh, M. Goel, T. Starner, and G. Abowd. EarBit. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT 2017)*, 1(3):1–20, sep 2017.

[24] E. Beneteau, A. Boone, Y. Wu, J. A. Kientz, J. Yip, and A. Hiniker. Parenting with Alexa: Exploring the Introduction of Smart Speakers on Family Dynamics. In

Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2020), pages 1–13, New York, NY, USA, apr 2020. ACM.

[25] E. Beneteau, O. K. Richards, M. Zhang, J. A. Kientz, J. Yip, and A. Hiniker. Communication Breakdowns Between Families and Alexa. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2019) - CHI '19*, pages 1–13, New York, New York, USA, 2019. ACM Press.

[26] J.-I. Biel, N. Martin, D. Labbe, and D. Gatica-Perez. Bites'n'Bits. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT 2018)*, 1(4):1–33, jan 2018.

[27] T. Blascheck, L. Besançon, A. Bezerianos, B. Lee, and P. Isenberg. Glanceable visualization: Studies of data comparison performance on smartwatches. *IEEE Transactions on Visualization and Computer Graphics*, 25(1):630–640, 2019.

[28] I. Blau and M. Hameiri. Teacher–families online interactions and gender differences in parental involvement through school data system: Do mothers want to know more than fathers about their children? *Computers and Education*, 59(2):701–709, 2012.

[29] I. Blau and M. Hameiri. Ubiquitous mobile educational data management by teachers, students and parents: Does technology change school-family communication and parental involvement? *Education and Information Technologies*, 22(3):1231–1247, 2017.

[30] B. Bloom, R. A. Cohen, and G. Freeman. Summary health statistics for U.S. children: National health interview survey, 2010. *Vital and Health Statistics, Series 10: Data from the National Health Survey*, 10(250):1–8, 2011.

[31] V. Braun and V. Clarke. Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2):77–101, 2006.

[32] V. Braun and V. Clarke. Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health*, 11(4):589–597, aug 2019.

[33] N. Bressa, J. Vermeulen, and W. Willett. Data Every Day: Designing and Living with Personal Situated Visualizations. In *CHI Conference on Human Factors in Computing Systems*, pages 1–18, New York, NY, USA, apr 2022. ACM.

[34] M. B. Bronson. *Self-regulation in early childhood: Nature and nurture.* Guilford Press, New York, NY, US, 2000.

[35] B. Brown, A. S. Taylor, S. Izadi, A. Sellen, J. J. Kaye, and R. Eardley. Locating Family Values: A Field Trial of the Whereabouts Clock. volume 4717 LNCS, pages 354–371. 2007.

[36] K. C. Bul, P. M. Kato, S. Van der Oord, M. Danckaerts, L. J. Vreeke, A. Willems, H. J. van Oers, R. Van Den Heuvel, D. Birnie, T. A. Van Amelsvoort, I. H. Franken, and A. Maras. Behavioral outcome effects of serious gaming as an adjunct to treatment for

children with attention-deficit/hyperactivity disorder: A randomized controlled trial. *J Med Internet Res*, 18(2):e26, Feb 2016.

[37] N. Bunford, S. W. Evans, and J. M. Langberg. Emotion dysregulation is associated with social impairment among young adolescents with adhd. *Journal of Attention Disorders*, 22(1):66–82, 2018.

[38] L. E. Burke, M. B. Conroy, S. M. Sereika, O. U. Elci, M. A. Styn, S. D. Acharya, M. A. Sevick, L. J. Ewing, and K. Glanz. The effect of electronic self-monitoring on weight loss and dietary intake: A randomized behavioral weight loss trial. *Obesity*, 19(2):338–344, feb 2011.

[39] M. E. Cecchinato, A. L. Cox, and J. Bird. Always on(line)? user experience of smartwatches and their role within multi-device ecologies. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, CHI '17, page 3557–3568, New York, NY, USA, 2017. Association for Computing Machinery.

[40] M.-Y. Chan, Y.-H. Lin, L.-F. Lin, T.-W. Lin, W.-C. Hsu, C.-y. Chang, R. Liu, K.-Y. Chang, M.-h. Lin, and J. Y.-j. Hsu. Wakey: Assisting parent-child communication for better morning routines. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing*, CSCW '17, page 2287–2299, New York, NY, USA, 2017. Association for Computing Machinery.

[41] Y.-S. Chan, J.-T. Jang, and C.-S. Ho. Effects of physical exercise on children with attention deficit hyperactivity disorder. *Biomedical Journal*, 45(2):265–270, 2022.

[42] P.-Y. P. Chi and Y. Li. Weave. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2015)*, volume 2015-April, pages 3923–3932, New York, NY, USA, apr 2015. ACM.

[43] E. K. Choe, S. Abdullah, M. Rabbi, E. Thomaz, D. A. Epstein, F. Cordeiro, M. Kay, G. D. Abowd, T. Choudhury, J. Fogarty, B. Lee, M. Matthews, and J. A. Kientz. Semi-Automated Tracking: A Balanced Approach for Self-Monitoring Applications. *IEEE Pervasive Computing*, 16(1):74–84, jan 2017.

[44] E. K. Choe, N. B. Lee, B. Lee, W. Pratt, and J. A. Kientz. Understanding quantified-selfers' practices in collecting and exploring personal data. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1143–1152, New York, NY, USA, apr 2014. ACM.

[45] K. S. Chun, S. Bhattacharya, and E. Thomaz. Detecting Eating Episodes by Tracking Jawbone Movements with a Non-Contact Wearable Sensor. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT 2018)*, 2(1):1–21, 2018.

[46] C.-F. Chung, Q. Wang, J. Schroeder, A. Cole, J. Zia, J. Fogarty, and S. A. Munson. Identifying and Planning for Individualized Change. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT 2019)*, 3(1):1–27, 2019.

[47] F. L. Cibrian, K. D. Lakes, S. E. Schuck, and G. R. Hayes. The potential for emerging technologies to support self-regulation in children with adhd: A literature review. *International Journal of Child-Computer Interaction*, 31:100421, 2022.

[48] F. L. Cibrian, K. D. Lakes, A. Tavakoulnia, K. Guzman, S. Schuck, and G. R. Hayes. Supporting Self-Regulation of Children with ADHD Using Wearables: Tensions and Design Challenges. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2020)*, pages 1–13, New York, NY, USA, apr 2020. ACM.

[49] F. L. Cibrian, E. Monteiro, E. Ankrah, J. A. Beltran, A. Tavakoulnia, S. E. Schuck, G. R. Hayes, and K. D. Lakes. Parents' perspectives on a smartwatch intervention for children with ADHD: Rapid deployment and feasibility evaluation of a pilot intervention to support distance learning during COVID-19. *PloS one*, 16(10), oct 2021.

[50] P. Classi, D. Milton, S. Ward, K. Sarsour, and J. Johnston. Social and emotional difficulties in children with ADHD and the impact on school attendance and healthcare utilization. *Child and Adolescent Psychiatry and Mental Health*, 6(1):33, 2012.

[51] J. Clawson, J. A. Pater, A. D. Miller, E. D. Mynatt, and L. Mamykina. No longer wearing. In *Proceedings of the ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp 2015)*, pages 647–658, New York, New York, USA, 2015. ACM Press.

[52] S. R. Cobb and C. H. Davies. Neurodevelopmental disorders. *Neuropharmacology*, 68:1, may 2013.

[53] N. Colineau and C. Paris. Motivating reflection about health within the family: The use of goal setting and tailored feedback. *User Modeling and User-Adapted Interaction*, 21(4-5):341–376, 2011.

[54] F. Cordeiro, E. Bales, E. Cherry, and J. Fogarty. Rethinking the Mobile Food Journal. In *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI 2015)*, volume 2015-April, pages 3207–3216, New York, NY, USA, apr 2015. ACM.

[55] F. Cordeiro, D. A. Epstein, E. Thomaz, E. Bales, A. K. Jagannathan, G. D. Abowd, and J. Fogarty. Barriers and Negative Nudges: Exploring Challenges in Food Journaling. In *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI 2015)*, volume 2015-April, pages 1159–1162, New York, NY, USA, apr 2015. ACM.

[56] M. Costa Figueiredo. *Data Work and Data Tracking Technologies in Fertility Care: A Holistic Approach.* PhD thesis, 2021. Copyright - Database copyright ProQuest LLC; ProQuest does not claim copyright in the individual underlying works; Last updated - 2023-06-22.

[57] M. Costa Figueiredo, C. Caldeira, T. L. Reynolds, S. Victory, K. Zheng, and Y. Chen. Self-tracking for fertility care: Collaborative support for a highly personalized problem. *Proc. ACM Hum.-Comput. Interact.*, 1(CSCW), dec 2017.

[58] M. R. Craig, A. R. Kristal, C. L. Cheney, and A. L. Shattuck. The prevalence and impact of 'atypical' days in 4-day food records. *Journal of the American Dietetic Association*, 100(4):421–427, apr 2000.

[59] M. L. Danielson, R. H. Bitsko, R. M. Ghandour, J. R. Holbrook, M. D. Kogan, and S. J. Blumberg. Prevalence of parent-reported adhd diagnosis and associated treatment among u.s. children and adolescents, 2016. *Journal of Clinical Child & Adolescent Psychology*, 47(2):199–212, 2018. PMID: 29363986.

[60] A. Darby, M. W. Strum, E. Holmes, and J. Gatwood. A Review of Nutritional Tracking Mobile Applications for Diabetes Patient Use. *Diabetes Technology & Therapeutics*, 18(3):200–212, mar 2016.

[61] N. Daskalova, K. Desingh, A. Papoutsaki, D. Schulze, H. Sha, and J. Huang. Lessons Learned from Two Cohorts of Personal Informatics Self-Experiments. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT 2015)*, 1(3):1–22, 2017.

[62] Dataintelo, D. Patel, and Dataintelo. Kids Smartwatch Market Research Report 2024-2032, 2 2024.

[63] L. Di Geronimo, M. Husmann, and M. C. Norrie. Surveying personal device ecosystems with cross-device applications in mind. In *PerDis 2016 - Proceedings of the 5th ACM International Symposium on Pervasive Displays*, pages 220–227, 2016.

[64] T. Dong, E. F. Churchill, and J. Nichols. Understanding the Challenges of Designing and Developing Multi-Device Experiences. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, pages 62–72, New York, NY, USA, jun 2016. ACM.

[65] R. A. Dore and L. Zimmermann. Coviewing, Scaffolding, and Children's Media Comprehension. *The International Encyclopedia of Media Psychology*, pages 1–8, jun 2020.

[66] R. Drechsler, S. Brem, D. Brandeis, E. Grünblatt, G. Berger, and S. Walitza. ADHD: Current Concepts and Treatments in Children and Adolescents. *Neuropediatrics*, 51(5):315–335, oct 2020.

[67] H. L. Egger, D. Kondo, and A. Angold. The epidemiology and diagnostic issues in preschool attention-deficit/hyperactivity disorder: A review. *Infants & Young Children*, 19(2):109–122, 2006.

[68] J. Elia, P. Ambrosini, and W. Berrettini. Adhd characteristics: I. concurrent co-morbidity patterns in children & adolescents. *Child and adolescent psychiatry and mental health*, 2(1):1–9, 2008.

[69] D. A. Epstein, C. Caldeira, M. C. Figueiredo, L. M. Silva, X. Lu, L. Williams, J. H. Lee, Q. Li, S. Ahuja, Q. Chen, C. Hilby, S. Sultana, P. D. Yari, E. V. Eikey, and Y. Chen. Mapping and Taking Stock of the Personal Informatics Literature. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT 2020)*, 4(4), 2020.

[70] D. A. Epstein, M. Caraway, C. Johnston, A. Ping, J. Fogarty, and S. A. Munson. Beyond Abandonment to Next Steps. In *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI 2016)*, pages 1109–1113, New York, NY, USA, may 2016. ACM.

[71] D. A. Epstein, F. Cordeiro, J. Fogarty, G. Hsieh, and S. A. Munson. Crumbs. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2016)*, pages 5632–5644, New York, NY, USA, may 2016. ACM.

[72] D. A. Epstein, B. H. Jacobson, E. Bales, D. W. McDonald, and S. A. Munson. From "nobody cares" to "way to go!". In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing - CSCW '15*, pages 1622–1636, New York, New York, USA, feb 2015.

[73] D. A. Epstein, S. Ji, D. Beltran, G. D'Haenens, Z. Li, and T. Zhou. Exploring Design Principles for Sharing of Personal Informatics Data on Ephemeral Social Media. *Proceedings of the ACM on Human-Computer Interaction*, 4(CSCW2):1–24, oct 2020.

[74] D. A. Epstein, A. Ping, J. Fogarty, and S. A. Munson. A Lived Informatics Model of Personal Informatics. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp 2015)*, pages 731–742, New York, New York, USA, sep 2015. Association for Computing Machinery, Inc.

[75] J. A. Fails, D. kumar Ratakonda, N. Koren, S. Elsayed-Ali, E. Bonsignore, and J. Yip. Pushing Boundaries of Co-Design by Going Online: Lessons Learned and Reflections from Three Perspectives. *International Journal of Child-Computer Interaction*, page 100476, mar 2022.

[76] C. Fan, J. Forlizzi, and A. K. Dey. A spark of activity: Exploring informative art as visualization for physical activity. In *UbiComp'12 - Proceedings of the 2012 ACM Conference on Ubiquitous Computing*, pages 81–84, 2012.

[77] S. V. Faraone and H. Larsson. Genetics of attention deficit hyperactivity disorder. *Molecular Psychiatry 2018 24:4*, 24(4):562–575, jun 2018.

[78] FERPA, Aug 2021.

[79] G. Ferrara, J. Kim, S. Lin, J. Hua, and E. Seto. A Focused Review of Smartphone Diet-Tracking Apps: Usability, Functionality, Coherence With Behavior Change Theory, and Comparative Validity of Nutrient Intake and Energy Estimates. *JMIR mHealth and uHealth*, 7(5):e9232, may 2019.

[80] M. C. Figueiredo and Y. Chen. Patient-generated health data: Dimensions, challenges, and open questions. *Foundations and Trends® in Human–Computer Interaction*, 13(3):165–297, 2020.

[81] J. R. Gagne, J. Liew, and O. K. Nwadinobi. "how does the broader construct of self-regulation relate to emotion regulation in young children?". *Developmental Review*, 60:100965, 2021.

[82] R. Garg and S. Sengupta. Conversational Technologies for In-home Learning: Using Co-Design to Understand Children's and Parents' Perspectives. In *Conference on Human Factors in Computing Systems - Proceedings*, 2020.

[83] V. Genaro Motti, N. Kalantari, A. Islam, and L. Yaddanapudi. Designing for and with Neurodiverse Users: Wearable Applications for Self-regulation. In *Pervasive Computing Technologies for Healthcare*, pages 553–560. Springer, 2022.

[84] A. Ghanizadeh. Sensory Processing Problems in Children with ADHD, a Systematic Review. *Psychiatry Investigation*, 8(2):89, jun 2011.

[85] M. Gisladottir and E. K. Svavarsdottir. The effectiveness of therapeutic conversation intervention for caregivers of adolescents with adhd: a quasi-experimental design. *Journal of Psychiatric and Mental Health Nursing*, 24(1):15–27, 2017.

[86] C. Golsteijn and E. van den Hoven. Facilitating parent-teenager communication through interactive photo cubes. *Personal and Ubiquitous Computing*, 17(2):273–286, 2013.

[87] R. Gouveia and D. A. Epstein. This Watchface Fits with my Tattoos: Investigating Customisation Needs and Preferences in Personal Tracking. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23)*, New York, NY, USA, April 2023. ACM.

[88] A. Grimes and R. Harper. Celebratory Technology: New Directions for Food Research in HCI. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 467–476, 2008.

[89] A. Grimes, D. Tan, and D. Morris. Toward Technologies that Support Family Reflections on Health. In *GROUP'09 - Proceedings of the 2009 ACM SIGCHI International Conference on Supporting Group Work*, pages 311–320, New York, New York, USA, 2009. ACM Press.

[90] A. C. Gulsrud, L. B. Jahromi, and C. Kasari. The Co-Regulation of Emotions Between Mothers and their Children with Autism. *Journal of Autism and Developmental Disorders*, 40(2):227–237, feb 2010.

[91] B. Hanington and B. Martin. *Universal methods of design expanded and revised: 125 Ways to research complex problems, develop innovative ideas, and design effective solutions*. Rockport publishers, 2019.

[92] D. Harrison, P. Marshall, N. Bianchi-Berthouze, and J. Bird. Activity tracking. In *Proceedings of the ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp 2015)*, pages 617–621, New York, New York, USA, 2015. ACM Press.

[93] G. R. Hayes, K. G. Cheng, S. H. Hirano, K. P. Tang, M. S. Nagel, and D. E. Baker. Estrellita: A mobile capture and access tool for the support of preterm infants and their caregivers. *ACM Trans. Comput.-Hum. Interact.*, 21(3), jun 2014.

[94] W. D. Heizer, S. Southern, and S. McGovern. The Role of Diet in Symptoms of Irritable Bowel Syndrome in Adults: A Narrative Review. *Journal of the American Dietetic Association*, 109(7):1204–1214, jul 2009.

[95] A. Hiniker, B. Lee, K. Sobel, and E. K. Choe. Plan & Play: Supporting Intentional Media Use in Early Childhood. In *Proceedings of the 2017 Conference on Interaction Design and Children*, pages 85–95, New York, NY, USA, jun 2017. ACM.

[96] A. Hiniker, H. Suh, S. Cao, and J. A. Kientz. Screen time tantrums: How families manage screen media experiences for toddlers and preschoolers. In *Conference on Human Factors in Computing Systems - Proceedings*, pages 648–660. Association for Computing Machinery, may 2016.

[97] J. F. Hollis, C. M. Gullion, V. J. Stevens, P. J. Brantley, L. J. Appel, J. D. Ard, C. M. Champagne, A. Dalcin, T. P. Erlinger, K. Funk, D. Laferriere, P. H. Lin, C. M. Loria, C. Samuel-Hodge, W. M. Vollmer, and L. P. Svetkey. Weight Loss During the Intensive Intervention Phase of the Weight-Loss Maintenance Trial. *American Journal of Preventive Medicine*, 35(2):118–126, aug 2008.

[98] Home Food Safety. Desktop Dining Survey: 2011 Results Americans' Food Safety Knowledge and Practice at Work. Technical report, 2011.

[99] M. K. Hong, U. Lakshmi, K. Do, S. Prahalad, T. Olson, R. I. Arriaga, and L. Wilcox. Using Diaries to Probe the Illness Experiences of Adolescent Patients and Parental Caregivers. In *Conference on Human Factors in Computing Systems - Proceedings*. Association for Computing Machinery, apr 2020.

[100] M. K. Hong, L. Wilcox, D. Machado, T. A. Olson, and S. F. Simoneaux. Care partnerships: Toward technology to support teens' participation in their health care. In *Conference on Human Factors in Computing Systems - Proceedings*, pages 5337–5349, New York, NY, USA, 2016. ACM.

[101] M. B. Hoy. Alexa, Siri, Cortana, and More: An Introduction to Voice Assistants. *https://doi.org/10.1080/02763869.2018.1404391*, 37(1):81–88, jan 2018.

[102] B. Hoza. Peer functioning in children with adhd. *Ambulatory Pediatrics*, 7(1, Supplement):101–106, 2007. Measuring Outcomes in Attention Deficit Hyperactivity Disorder.

[103] J. W. Ivy, J. N. Meindl, E. Overley, and K. M. Robson. Token Economy: A Systematic Review of Procedural Descriptions. *Behavior Modification*, 41(5):708–737, sep 2017.

[104] S. Jang, K.-R. Lee, G. Goh, D. Kim, G. Yun, N. Kim, B. K. Lux, C.-W. Woo, H. Kim, and Y.-W. Park. Design and field trial of emotionframe: exploring self-journaling experiences in homes for archiving personal feelings about daily events. *Human–Computer Interaction*, 0(0):1–26, 2023.

[105] E. Jo, H. Bang, M. Ryu, E. J. Sung, S. Leem, and H. Hong. MAMAS: Supporting Parent–Child Mealtime Interactions Using Automated Tracking and Speech Recognition. *Proceedings of the ACM on Human-Computer Interaction*, 4(CSCW1):1–32, may 2020.

[106] T. Jokela, J. Ojala, and T. Olsson. A Diary Study on Combining Multiple Information Devices in Everyday Activities and Tasks. In *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI 2015)*, volume 2015-April, pages 3903–3912, New York, NY, USA, apr 2015. ACM.

[107] J. Jones, Y. E. Yuan, S. Yarosh, B. College, Y. E. Yuan, S. Yarosh, and Y. E. Yuan. Be Consistent, Work the Program, Be Present Every Day: Exploring Technologies for Self-Tracking in Early Recovery. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT 2021)*, 5(4):1–26, dec 2021.

[108] J. Jung, L. Wellard-Cole, C. Cai, I. Koprinska, K. Yacef, M. Allman-Farinelli, and J. Kay. Foundations for Systematic Evaluation and Benchmarking of a Mobile Food Logger in a Large-scale Nutrition Study. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT 2020)*, 4(2):1–25, jun 2020.

[109] R. Karkar, J. Schroeder, D. A. Epstein, L. R. Pina, J. Scofield, J. Fogarty, J. A. Kientz, S. A. Munson, R. Vilardaga, and J. Zia. TummyTrials. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2017)*, volume 2017-May, pages 6850–6863, New York, NY, USA, may 2017. ACM.

[110] D. S. Katz, B. A. Price, S. Holland, and N. S. Dalton. Data, Data Everywhere, and Still Too Hard to Link: Insights from User Interactions with Diabetes Apps. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2018)*, pages 1–12, New York, NY, USA, apr 2018. ACM.

[111] M. Katz. The zones of regulation: A curriculum designed to foster self-regulation and emotional control. *Attention Magazine*, pages 7–8, 2012.

[112] F. Kawsar and J. B. Brush. Home computing unplugged: Why, where and when people use different connected devices at home. In *UbiComp 2013 - Proceedings of the 2013 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, pages 627–636, 2013.

[113] L. K. Kaye, A. Orben, D. A. Ellis, S. C. Hunter, and S. Houghton. The conceptual and methodological mayhem of "screen time". *International Journal of Environmental Research and Public Health*, 17(10):3661, may 2020.

[114] E. Kaziunas, M. S. Ackerman, S. Lindtner, and J. M. Lee. Caring through data: Attending to the social and emotional experiences of health datafication. In *Proceedings of the ACM Conference on Computer Supported Cooperative Work (CSCW 2017)*, pages 2260–2272, New York, NY, USA, 2017. ACM.

[115] F. Kensing and J. Blomberg. Participatory design: Issues and concerns. *Computer supported cooperative work (CSCW)*, 7:167–185, 1998.

[116] J. A. Kientz, R. I. Arriaga, M. Chetty, G. R. Hayes, J. Richardson, S. N. Patel, and G. D. Abowd. Grow and know: Understanding record-keeping needs for tracking the development of young children. *Conference on Human Factors in Computing Systems - Proceedings*, pages 1351–1360, 2007.

[117] D. J. Kim, Y. Lee, S. Rho, and Y. K. Lim. Design opportunities in three stages of relationship development between users and self-tracking devices. In *Conference on Human Factors in Computing Systems - Proceedings*, pages 699–703. Association for Computing Machinery, may 2016.

[118] Y.-H. Kim, J. H. Jeon, B. Lee, E. K. Choe, and J. Seo. OmniTrack: A Flexible Self-Tracking Approach Leveraging Semi-Automated Tracking. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT 2017)*, 1(3):1–28, 2017.

[119] Y.-H. Kim, B. Lee, A. Srinivasan, E. K. Choe, Young-Ho Kim, Bongshin Lee, Arjun Srinivasan, and Eun Kyoung Choe. Data@Hand: Fostering Visual Exploration of Personal Data on Smartphones Leveraging Speech and Touch Interaction. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2021) (CHI '21)*, 21, jan 2021.

[120] A. B. Kocaballi, E. Sezgin, L. Clark, J. M. Carroll, Y. Huang, J. Huh-Yoo, J. Kim, R. Kocielnik, Y.-C. Lee, L. Mamykina, E. G. Mitchell, R. J. Moore, P. Murali, E. D. Mynatt, S. Y. Park, A. Pasta, D. Richards, L. M. Silva, D. Smriti, B. Spillane, Z. Zhang, and T. Zubatiy. Design and evaluation challenges of conversational agents in health care and well-being: Selective review study. *J Med Internet Res*, 24(11):e38525, Nov 2022.

[121] G. Kochanska, K. C. Coy, and K. T. Murray. The development of self-regulation in the first four years of life., 2001.

[122] D. A. Kolb. *Experiential learning: Experience as the source of learning and development*. FT press, 2014.

[123] K. D. Lakes, F. L. Cibrian, S. E. Schuck, M. Nelson, and G. R. Hayes. Digital health interventions for youth with ADHD: A mapping review. *Computers in Human Behavior Reports*, 6:100174, mar 2022.

[124] S. Lanette, P. K. Chua, G. Hayes, and M. Mazmanian. How Much is 'Too Much'?: The Role of a Smartphone Addiction Narrative in Individuals' Experience of Use. *Proceedings of the ACM on Human-Computer Interaction*, 2(CSCW):1–22, nov 2018.

[125] L. Laranjo, A. G. Dunn, H. L. Tong, A. B. Kocaballi, J. Chen, R. Bashir, D. Surian, B. Gallego, F. Magrabi, A. Y. Lau, and E. Coiera. Conversational agents in healthcare: A systematic review. *Journal of the American Medical Informatics Association*, 25(9):1248–1258, 2018.

[126] J. Lau, B. Zimmerman, and F. Schaub. Alexa, Are You Listening? *Proceedings of the ACM on Human-Computer Interaction*, 2(CSCW), nov 2018.

[127] A. Lazar, C. Koehler, J. Tanenbaum, and D. H. Nguyen. Why we use and abandon smart devices. In *UbiComp 2015 - Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, pages 635–646, 2015.

[128] J. Lazar, J. H. Feng, and H. Hochheiser. *Research methods in human-computer interaction*. Morgan Kaufmann, 2017.

[129] J. G. Lee, B. Lee, and E. K. Choe. Decorative, evocative, and uncanny: Reactions on ambient-to-disruptive health notifications via plant-mimicking shape-changing interfaces. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, CHI '23, New York, NY, USA, 2023. Association for Computing Machinery.

[130] K. J. Lee, W. Roldan, T. Q. Zhu, H. Kaur Saluja, S. Na, B. Chin, Y. Zeng, J. H. Lee, and J. Yip. The show must go on: A conceptual model of conducting synchronous participatory design with children online. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, CHI '21, New York, NY, USA, 2021. Association for Computing Machinery.

[131] U. Lee, K. Han, H. Cho, K.-M. Chung, H. Hong, S.-J. Lee, Y. Noh, S. Park, and J. M. Carroll. Intelligent positive computing with mobile, wearable, and IoT devices: Literature review and research directions. *Ad Hoc Networks*, 83:8–24, feb 2019.

[132] I. Li, A. Dey, and J. Forlizzi. A Stage-Based Model of Personal Informatics Systems. *Conference on Human Factors in Computing Systems - Proceedings*, 1:557–566, 2010.

[133] B. Y. Lim, X. Chng, and S. Zhao. Trade-off between Automation and Accuracy in Mobile Photo Recognition Food Logging. In *Proceedings of the Fifth International Symposium of Chinese CHI on - Chinese CHI 2017*, volume Part F1283, pages 53–59, New York, New York, USA, 2017. ACM Press.

[134] S. Lomborg, H. Langstrup, and T. O. Andersen. Interpretation as luxury: Heart patients living with data doubt, hope, and anxiety:. *https://doi.org/10.1177/2053951720924436*, 7(1), may 2020.

[135] A. S. Lu, M. C. Green, and D. Thompson. Using Narrative Game Design to Increase Children's Physical Activity: Exploratory Thematic Analysis. *JMIR Serious Games*, 7(4):e16031, nov 2019.

[136] X. Lu, Y. Chen, and D. A. Epstein. How Cultural Norms Influence Persuasive Design: A Study on Chinese Food Journaling Apps. *DIS 2021 - Proceedings of the 2021 ACM Designing Interactive Systems Conference: Nowhere and Everywhere*, pages 619–637, jun 2021.

[137] E. Luger and A. Sellen. "Like Having a Really Bad PA". In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2016)*, pages 5286–5297, New York, NY, USA, may 2016. ACM.

[138] K. Lukoff, T. Li, Y. Zhuang, and B. Y. Lim. TableChat: Mobile Food Journaling to Facilitate Family Support for Healthy Eating. *Proceedings of the ACM on Human-Computer Interaction*, 2(CSCW):1–28, nov 2018.

[139] Y. Luo. Designing Multimodal Self-Tracking Technologies to Promote Data Capture and Self-Reflection. pages 11–15. Virtual Event, USA. ACM, 2021.

[140] Y. Luo, Y. H. Kim, B. Lee, N. Hassan, and E. K. Choe. FoodScrap: Promoting Rich Data Capture and Reflective Food Journaling through Speech Input. In *DIS 2021 - Proceedings of the 2021 ACM Designing Interactive Systems Conference: Nowhere and Everywhere*, volume 13, pages 606–618, New York, NY, USA, 2021. ACM.

[141] Y. Luo, B. Lee, and E. K. Choe. TandemTrack: Shaping Consistent Exercise Experience by Complementing a Mobile App with a Smart Speaker. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2020)*, pages 1–13, New York, NY, USA, apr 2020. ACM.

[142] M. Luria, R. Zheng, B. Huffman, S. Huang, J. Zimmerman, and J. Forlizzi. Social Boundaries for Personal Agents in the Interpersonal Space of the Home. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2020)*, pages 1–12, New York, NY, USA, apr 2020. ACM.

[143] L. M. Silva and D. A. Epstein. Investigating Preferred Food Description Practices in Digital Food Journaling. In *Proceedings of the ACM Designing Interactive Systems Conference: Nowhere and Everywhere (DIS 2021)*, pages 589–605, New York, NY, USA, jun 2021. ACM.

[144] L. Mamykina, E. Mynatt, P. Davidson, and D. Greenblatt. MAHI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2008)*, page 477, New York, New York, USA, 2008. ACM Press.

[145] G. Marcu, A. K. Dey, and S. Kiesler. Parent-driven use of wearable cameras for autism support: A field study with families. In *UbiComp'12 - Proceedings of the 2012 ACM Conference on Ubiquitous Computing*, pages 401–410, New York, New York, USA, 2012. ACM Press.

[146] G. Marcu, A. K. Dey, and S. Kiesler. Designing for collaborative reflection. In *Proceedings of the 8th International Conference on Pervasive Computing Technologies for Healthcare*, PervasiveHealth '14, page 9–16, Brussels, BEL, 2014. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering).

[147] G. Martin and J. Pear. Coordination: What It Is and How To Do It. *Journal of Career Development*, 6(4):274–278, jun 1999.

[148] A. Matic, G. R. Hayes, M. Tentori, M. Abdullah, and S. Schuck. Collective use of a situated display to encourage positive behaviors in children with behavioral challenges. *UbiComp 2014 - Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, pages 885–895, 2014.

[149] J. L. Matson and J. A. Boisjoli. The token economy for children with intellectual disability and/or autism: A review. *Research in Developmental Disabilities*, 30(2):240–248, mar 2009.

[150] M. McClelland, J. Geldhof, F. Morrison, S. Gestsdóttir, C. Cameron, E. Bowers, A. Duckworth, T. Little, and J. Grammer. Self-Regulation. *Handbook of Life Course Health Development*, pages 275–298, nov 2017.

[151] J. Meyer, J. Kay, D. A. Epstein, P. Eslambolchilar, and L. M. Tang. A life of data - Characteristics and challenges of very long-term self-tracking for health and wellness. *ACM Transactions on Computing for Healthcare*, 1(2):1–4, apr 2020.

[152] A. Y. Mikami and L. J. Pfiffner. Sibling relationships among children with adhd. *Journal of Attention Disorders*, 11(4):482–492, 2008. PMID: 17494830.

[153] A. D. Miller and E. D. Mynatt. Stepstream: A school-based pervasive social fitness system for everyday adolescent health. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '14, page 2823–2832, New York, NY, USA, 2014. Association for Computing Machinery.

[154] D. Miller and R. J. Moore. Virtual agents supporting novice and expert professionals in healthcare. 2020.

[155] E. G. Mitchell, E. M. Heitkemper, and M. Burgermaster. From Reflection to Action: Combining Machine Learning with Expert Knowledge for Nutrition Goal Recommendations. In *Conference on Human Factors in Computing Systems - Proceedings*, pages 1–17, New York, NY, USA, may 2021. ACM.

[156] J. Moore, P. Goffin, M. Meyer, P. Lundrigan, N. Patwari, K. Sward, and J. Wiese. Managing In-home Environments through Sensing, Annotating, and Visualizing Air Quality Data. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT 2018)*, 2(3):1–28, sep 2018.

[157] F. D. Mowlem, M. A. Rosenqvist, J. Martin, P. Lichtenstein, P. Asherson, and H. Larsson. Sex differences in predicting ADHD clinical diagnosis and pharmacological treatment. *European Child and Adolescent Psychiatry*, 28(4):481–489, apr 2019.

[158] M. Müller, M. Harvey, D. Elsweiler, and S. Mika. Ingredient matching to determine the nutritional properties of internet-sourced recipes. In *2012 6th International Conference on Pervasive Computing Technologies for Healthcare and Workshops, PervasiveHealth 2012*, 2012.

[159] E. L. Murnane, X. Jiang, A. Kong, M. Park, W. Shi, C. Soohoo, L. Vink, I. Xia, X. Yu, J. Yang-Sammataro, G. Young, J. Zhi, P. Moya, and J. A. Landay. Designing Ambient Narrative-Based Interfaces to Reflect and Motivate Physical Activity. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2020)*, pages 1–14, New York, NY, USA, apr 2020. Association for Computing Machinery (ACM).

[160] D. W. Murray and K. Rosanbalm. Promoting Self-Regulation in Adolescents and Young Adults: A Practice Brief. *Office of Planning, Research and Evaluation*, pages 11–15, 2017.

[161] M. Nebeling. XDBrowser 2.0: Semi-Automatic Generation of Cross-Device Interfaces. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2017)*, volume 2017-May, pages 4574–4584, New York, NY, USA, may 2017. ACM.

[162] M. Nebeling and A. K. Dey. XDBrowser. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2016)*, pages 5494–5505, New York, NY, USA, may 2016. ACM.

[163] J. Niess and P. W. Woźniak. Supporting Meaningful Personal Fitness: The Tracker Goal Evolution Model. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2018) - CHI '18*, volume 2018-April, pages 1–12, New York, New York, USA, apr 2018. ACM Press.

[164] H. Oh, J. Nguyen, S. Soundararajan, and R. Jain. Multimodal Food Journaling. In *Proceedings of the 3rd International Workshop on Multimedia for Personal Health and Health Care - HealthMedia'18*, pages 39–47, New York, New York, USA, 2018. ACM Press.

[165] K. O'Leary, T. Dong, J. K. Haines, M. Gilbert, E. F. Churchill, and J. Nichols. The Moving Context Kit: Designing for Context Shifts in Multi-device Experiences. In *DIS 2017 - Proceedings of the 2017 ACM Conference on Designing Interactive Systems*, pages 309–320, New York, NY, USA, jun 2017. ACM.

[166] K. D. O'Leary and R. Drabman. Token reinforcement programs in the classroom: A review. *Psychological Bulletin*, 75(6):379–398, jun 1971.

[167] A. Orben. The Sisyphean Cycle of Technology Panics. *Perspectives on Psychological Science*, 15(5):1143–1157, sep 2020.

[168] G. A. O'Reilly, L. Cook, D. Spruijt-Metz, and D. S. Black. Mindfulness-based interventions for obesity-related eating behaviours: A literature review. *Obesity Reviews*, 2014.

[169] I. Oygür, D. A. Epstein, and Y. Chen. Raising the Responsible Child: Collaborative Work in the Use of Activity Trackers for Children. *Proceedings of the ACM on Human-Computer Interaction*, 4(CSCW2):1–23, oct 2020.

[170] I. Oygür, Z. Su, D. A. Epstein, and Y. Chen. The Lived Experience of Child-Owned Wearables: Comparing Children's and Parents' Perspectives on Activity Tracking. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2021)*, pages 1–12, New York, NY, USA, may 2021. ACM.

[171] S. Park and Y.-K. Lim. Investigating User Expectations on the Roles of Family-shared AI Speakers. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2020)*, pages 1–13, New York, NY, USA, apr 2020. ACM.

[172] B. F. Pennington and S. Ozonoff. Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry*, 37(1):51–87, 1996.

[173] R. Perou, R. H. Bitsko, S. J. Blumberg, P. Pastor, R. M. Ghandour, J. C. Gfroerer, S. L. Hedden, A. E. Crosby, S. N. Visser, L. A. Schieve, S. E. Parks, J. E. Hall, D. Brody, C. M. Simile, W. W. Thompson, J. Baio, S. Avenevoli, M. D. Kogan, L. N. Huang, and Centers for Disease Control. Mental health surveillance among children–United States, 2005-2011. *MMWR supplements*, 62(2):1–35, 2013.

[174] L. Pina, K. Rowan, A. Roseway, P. Johns, G. R. Hayes, and M. Czerwinski. In situ cues for ADHD parenting strategies using mobile technology. In *Proceedings - PERVASIVEHEALTH 2014: 8th International Conference on Pervasive Computing Technologies for Healthcare*, pages 17–24. ICST, jul 2014.

[175] L. Pina, S.-W. Sien, C. Song, T. M. Ward, J. Fogarty, S. A. Munson, and J. A. Kientz. DreamCatcher: Exploring How Parents and School-Age Children can Track and Review Sleep Information Together. *Proceedings of the ACM on Human-Computer Interaction*, 4(CSCW1):1–25, may 2020.

[176] L. R. Pina, S. W. Sien, T. Ward, J. C. Yip, S. A. Munson, J. Fogarty, and J. A. Kientz. From Personal Informatics to Family Informatics: Understanding Family Practices around Health Monitoring. In *Proceedings of the ACM Conference on Computer Supported Cooperative Work (CSCW 2017)*, pages 2300–2315, New York, New York, USA, feb 2017. Association for Computing Machinery.

[177] K. H. Pine and M. Liboiron. The politics of measurement and action. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, CHI '15, page 3147–3156, New York, NY, USA, 2015. Association for Computing Machinery.

[178] S. Pizza, B. Brown, D. McMillan, and A. Lampinen. Smartwatch in vivo. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2016)*, pages 5456–5469, New York, NY, USA, may 2016. ACM.

[179] G. Polanczyk, M. S. De Lima, B. L. Horta, J. Biederman, and L. A. Rohde. The worldwide prevalence of ADHD: A systematic review and metaregression analysis. *American Journal of Psychiatry*, 164(6):942–948, 2007.

[180] M. Porcheron, J. E. Fischer, S. Reeves, and S. Sharples. Voice Interfaces in Everyday Life. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2018)*, volume 2018-April, pages 1–12, New York, NY, USA, apr 2018. ACM.

[181] K. Potapov, A. Vasalou, V. L. Stanford, and P. Marshall. What do Teens Make of Personal Informatics? Young People's Responses to Self-Tracking Practices for

Self-Determined Motives. In *Conference on Human Factors in Computing Systems - Proceedings*, 2021.

[182] M. Rabbi, M. H. Aung, M. Zhang, and T. Choudhury. MyBehavior. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing - UbiComp '15*, pages 707–718, New York, New York, USA, 2015. ACM Press.

[183] S. Raj, K. Toporski, A. Garrity, J. M. Lee, and M. W. Newman. "My blood sugar is higher on the weekends": Finding a Role for Context and Context-Awareness in the Design of Health Self-Management Technology. In *Conference on Human Factors in Computing Systems - Proceedings*, 2019.

[184] M. Randriambelonoro. Assessing Activity of Daily Living through Technology-Enabled Tools: Mobility and Nutrition Assessment: MiranaBot: A Nutrition Assessment Use Case. *Health Informatics*, pages 27–47, 2022.

[185] V. V. Raval and B. L. Walker. Unpacking 'culture': Caregiver socialization of emotion and child functioning in diverse families. *Developmental Review*, 51(March 2016):146–174, mar 2019.

[186] V. V. Raval, B. L. Walker, P. M. Cole, S. E. Martin, and T. A. Dennis. Emotion Regulation as a Scientific Construct: Methodological Challenges and Directions for Child Development Research. *Child Development*, 51(March 2016):146–174, mar 2019.

[187] J. C. Read, S. MacFarlane, and C. Casey. Endurability, engagement and expectations: Measuring children's fun. In *Interaction design and children*, volume 2, pages 1–23. Shaker Publishing Eindhoven, 2002.

[188] S. M. Rebro, R. E. Patterson, A. R. Kristal, and C. L. Cheney. The Effect of Keeping Food Records on Eating Patterns. *Journal of the American Dietetic Association*, 98(10):1163–1165, oct 1998.

[189] B. Reeder and A. David. Health at hand: A systematic review of smart watch uses for health and wellness. In *Journal of Biomedical Informatics*, volume 63, pages 269–276. Academic Press Inc., oct 2016.

[190] R. Reid, A. L. Trout, and M. Schartz. Self-regulation interventions for children with attention deficit/hyperactivity disorder. In *Exceptional Children*, volume 71, pages 361–377, 2005.

[191] W. Reitberger, M. Kastenmiller, and G. Fitzpatrick. Invisible work: An ambient system for awareness and reflection of household tasks. In S. Berkovsky and J. Freyne, editors, *Persuasive Technology*, pages 180–191, Berlin, Heidelberg, 2013. Springer Berlin Heidelberg.

[192] O. K. Richards, G. Marcu, and R. N. Brewer. Hugs, Bible Study, and Speakeasies: Designing for Older Adults' Multimodal Connectedness; Hugs, Bible Study, and Speakeasies: Designing for Older Adults' Multimodal Connectedness. *Designing Interactive Systems Conference 2021*, 17.

[193] U. Ritterfeld, M. Cody, and P. Vorderer. *Serious games: Mechanisms and effects*. Routledge, 2009.

[194] Y. Rogers and P. Marshall. Research in the wild. *Synthesis Lectures on Human-Centered Informatics*, 10(3):i–97, 2017.

[195] J. Rooksby, M. Rost, A. Morrison, and M. Chalmers. Personal tracking as lived informatics. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2014)*, pages 1163–1172, New York, NY, USA, apr 2014. ACM.

[196] G. D. Rosenblum and M. Lewis. *Emotional Development in Adolescence*, chapter 13, pages 269–289. John Wiley and Sons, Ltd, 2006.

[197] R. M. Ryan and E. L. Deci. Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being. *American Psychologist*, 55(1):68–78, 2000.

[198] H. Saksono, C. Castaneda-Sceppa, J. Hoffman, M. S. El-Nasr, V. Morris, and A. G. Parker. Social Reflections on Fitness Tracking Data: A Study with Families in Low-SES Neighborhoods. In *Conference on Human Factors in Computing Systems - Proceedings*, page 14. ACM, 2019.

[199] H. Saksono, C. Castaneda-Sceppa, J. Hoffman, V. Morris, M. S. El-Nasr, and A. G. Parker. StoryMap: Using Social Modeling and Self-Modeling to Support Physical Activity Among Families of Low-SES Backgrounds. In *CHI Conference on Human Factors in Computing Systems (CHI '21)*, page 14, 2021.

[200] H. Saksono, C. Castaneda-Sceppa, J. Hoffman, V. Morris, M. Seif El-Nasr, and A. G. Parker. Storywell: Designing for Family Fitness App Motivation by Using Social Rewards and Reflection. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2020)*, pages 1–13, New York, NY, USA, apr 2020. ACM.

[201] H. Saksono, C. Castaneda-Sceppa, J. Hoffman, M. Seif El-Nasr, V. Morris, and A. G. Parker. Family Health Promotion in Low-?SES Neighborhoods: A Two-Month Study of Wearable Activity Tracking. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2018)*, volume 2018-April, pages 1–13, New York, NY, USA, apr 2018. ACM.

[202] H. Saksono, A. Ranade, G. Kamarthi, C. Castaneda-Sceppa, J. A. Hoffman, C. Wirth, and A. G. Parker. Spaceship Launch: Designing a Collaborative Exergame for Families. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing*, pages 1776–1787, New York, NY, USA, feb 2015. ACM.

[203] N. Salkind. Behavior Assessment System for Children. *Encyclopedia of Measurement and Statistics*, apr 2007.

[204] J. Sandbulte, E. K. Choe, and J. M. Carroll. Towards family-centered health technologies that support distributed families on sustainable healthy practices together.

Proceedings of the Association for Information Science and Technology, 57(1):1–11, 2020.

[205] M. R. Sanders and K. M. T. Turner. The Importance of Parenting in Influencing the Lives of Children. In *Handbook of Parenting and Child Development Across the Lifespan*, pages 3–26. Springer International Publishing, Cham, dec 2018.

[206] C. Schaefbauer, D. Kahn, A. Le, G. Sczechowski, and K. Siek. Snack Buddy: Supporting Healthy Snacking in Low Socioeconomic Status Families. In *CSCW 2015 - Proceedings of the 2015 ACM International Conference on Computer-Supported Cooperative Work and Social Computing*, pages 1045–1057, 2015.

[207] S. Schirra and F. R. Bentley. "It's kind of like an extra screen for my phone": Understanding Everyday Uses of Consumer Smart Watches. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems*, pages 2151–2156, New York, NY, USA, apr 2015. ACM.

[208] C. Schneegass, M. L. Wilson, H. A. Maior, F. Chiossi, A. L. Cox, and J. Wiese. The future of cognitive personal informatics. In *Proceedings of the 25th International Conference on Mobile Human-Computer Interaction*, MobileHCI '23 Companion, New York, NY, USA, 2023. Association for Computing Machinery.

[209] J. Schroeder, J. Hoffswell, C. F. Chung, J. Fogarty, S. Munson, and J. Zia. Supporting patient-provider collaboration to identify individual triggers using food and symptom journals. In *Proceedings of the ACM Conference on Computer Supported Cooperative Work (CSCW 2017)*, pages 1726–1739, 2017.

[210] S. Schuck, N. Emmerson, H. Ziv, P. Collins, S. Arastoo, M. Warschauer, F. Crinella, and K. Lakes. Designing an ipad app to monitor and improve classroom behavior for children with adhd: iselfcontrol feasibility and pilot studies. *PLOS ONE*, 11(10):1–13, 10 2016.

[211] S. M. Schueller, M. Neary, J. Lai, and D. A. Epstein. Understanding people's use of and perspectives on mood-tracking apps: Interview study. *JMIR Ment Health*, 8(8):e29368, Aug 2021.

[212] S. R. Self-brown and S. Mathews. Effects of Classroom Structure on Student Achievement Goal Orientation. *The Journal of Educational Research*, 97(2):106–112, 2010.

[213] M. Seo, J.-H. Kim, and P. David. Always Connected or Always Distracted? ADHD Symptoms and Social Assurance Explain Problematic Use of Mobile Phone and Multicommunicating. *Journal of Computer-Mediated Communication*, 20(6):667–681, 11 2015.

[214] K. Shiels and L. W. Hawk. Self-regulation in ADHD: The role of error processing. *Clinical Psychology Review*, 30(8):951–961, dec 2010.

[215] G. Shin, Y. Feng, M. H. Jarrahi, and N. Gafinowitz. Beyond novelty effect: a mixed-methods exploration into the motivation for long-term activity tracker use. *JAMIA Open*, 2(1):62–72, 12 2018.

[216] S. H. Sicherer and H. A. Sampson. Food allergy: Epidemiology, pathogenesis, diagnosis, and treatment, 2014.

[217] K. A. Siek, K. H. Connelly, Y. Rogers, P. Rohwer, D. Lambert, and J. L. Welch. When Do We Eat? An Evaluation of Food Items Input into an Electronic Food Monitoring Application. In *2006 Pervasive Health Conference and Workshops*, pages 1–10. IEEE, nov 2006.

[218] L. M. Silva, F. L. Cibrian, C. Bonang, A. Bhattacharya, A. Min, E. Monteiro, J. A. Beltran, S. E. B. Schuck, K. D. Lakes, G. R. Hayes, and D. A. Epstein. Co-designing situated displays for family co-regulation with adhd children. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*, CHI '24, New York, NY, USA, 2024. Association for Computing Machinery.

[219] L. M. Silva, F. L. Cibrian, D. A. Epstein, A. Bhattacharya, E. A. Ankrah, E. Monteiro, J. A. Beltran, S. E. Schuck, K. D. Lakes, and G. R. Hayes. Adapting Multidevice Deployments During a Pandemic: Lessons Learned From Two Studies. *IEEE Pervasive Computing*, 21(1):48–56, jan 2022.

[220] L. M. Silva, F. L. Cibrian, E. Monteiro, A. Bhattacharya, J. A. Beltran, C. Bonang, D. A. Epstein, S. E. B. Schuck, K. D. Lakes, and G. R. Hayes. Unpacking the lived experiences of smartwatch mediated self and co-regulation with adhd children. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, CHI '23, New York, NY, USA, 2023. Association for Computing Machinery.

[221] P. Slovak, A. Antle, N. Theofanopoulou, C. Daudén Roquet, J. Gross, and K. Isbister. Designing for emotion regulation interventions: An agenda for hci theory and research. *ACM Trans. Comput.-Hum. Interact.*, 30(1), mar 2023.

[222] J. Snyder, M. Matthews, J. Chien, P. F. Chang, E. Sun, S. Abdullah, and G. Gay. MoodLight: Exploring personal and social implications of ambient display of biosensor data. In *CSCW 2015 - Proceedings of the 2015 ACM International Conference on Computer-Supported Cooperative Work and Social Computing*, pages 143–153, 2015.

[223] K. Sobel, A. Bhattacharya, A. Hiniker, J. H. Lee, J. A. Kientz, and J. C. Yip. "It wasn't really about the Pokémon": Parents' perspectives on a location-based mobile game. In *Conference on Human Factors in Computing Systems - Proceedings*, volume 2017-May, pages 1483–1496, New York, NY, USA, may 2017. ACM.

[224] S. Song, J. Kim, B. Kang, W. Park, and J. Kim. BebeCODE: Collaborative Child Development Tracking System. In *Conference on Human Factors in Computing Systems - Proceedings*, volume 2018-April, 2018.

[225] T. Sonne and M. M. Jensen. Chillfish: A respiration game for children with adhd. In *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction*, TEI '16, page 271–278, New York, NY, USA, 2016. Association for Computing Machinery.

[226] T. Sonne, J. Müller, P. Marshall, C. Obel, and K. Grønbæk. Changing Family Practices with Assistive Technology: MOBERO Improves Morning and Bedtime Routines for Children with ADHD. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2016)*, pages 152–164, New York, NY, USA, may 2016. ACM.

[227] T. Sonne, C. Obel, and K. Grønbæk. Designing real time assistive technologies: A study of children with adhd. In *Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction*, OzCHI '15, page 34–38, New York, NY, USA, 2015. Association for Computing Machinery.

[228] K. Spiel, E. Hornecker, R. M. Williams, and J. Good. ADHD and Technology Research – Investigated by Neurodivergent Readers. In *CHI Conference on Human Factors in Computing Systems*, pages 1–21, New York, NY, USA, apr 2022. ACM.

[229] E. Stefanidi, J. Schöning, S. S. Feger, P. Marshall, Y. Rogers, and J. Niess. Designing for care ecosystems: A literature review of technologies for children with adhd. In *Proceedings of the 21st Annual ACM Interaction Design and Children Conference*, IDC '22, page 13–25, New York, NY, USA, 2022. Association for Computing Machinery.

[230] E. Stefanidi, J. Schöning, Y. Rogers, and J. Niess. Children with adhd and their care ecosystem: Designing beyond symptoms. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, CHI '23, New York, NY, USA, 2023. Association for Computing Machinery.

[231] P. Steinhauer, J. Santa-Barbara, and H. Skinner. The Process Model of Family Functioning. *The Canadian Journal of Psychiatry*, 29(2):98–111, mar 1984.

[232] T. W. Strine, C. A. Lesesne, C. A. Okoro, L. C. McGuire, D. P. Chapman, L. S. Balluz, and A. H. Mokdad. Emotional and behavioral difficulties and impairments in everyday functioning among children with a history of attention-deficit/hyperactivity disorder. *Preventing Chronic Disease*, 3(2):1 – 10, 2006. Cited by: 105.

[233] J. M. Swanson, S. Schuck, M. M. Porter, C. Carlson, C. A. Hartman, J. A. Sergeant, W. Clevenger, M. Wasdell, R. McCleary, K. Lakes, and T. Wigal. Categorical and Dimensional Definitions and Evaluations of Symptoms of ADHD: History of the SNAP and the SWAN Rating Scales. *The International journal of educational and psychological assessment*, 10(1):51, apr 2012.

[234] R. S. F. Tarbox, P. M. Ghezzi, and G. Wilson. The effects of token reinforcement on attending in a young child with autism. *Behavioral Interventions*, 21(3):155–164, jul 2006.

[235] A. Tavakoulnia, K. Guzman, F. L. Cibrian, K. D. Lakes, G. Hayes, and S. E. B. Schuck. Designing a wearable technology application for enhancing executive functioning skills in children with adhd. In *Adjunct Proceedings of the 2019 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2019 ACM International Symposium on Wearable Computers*, UbiComp/ISWC '19 Adjunct, page 222–225, New York, NY, USA, 2019. Association for Computing Machinery.

[236] R. Thomas, S. Sanders, J. Doust, E. Beller, and P. Glasziou. Prevalence of Attention-Deficit/Hyperactivity Disorder: A Systematic Review and Meta-analysis. *Pediatrics*, 135(4):e994–e1001, apr 2015.

[237] E. Thomaz, I. Essa, and G. D. Abowd. A practical approach for recognizing eating moments with wrist-mounted inertial sensing. In *UbiComp 2015 - Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, pages 1029–1040, 2015.

[238] F. E. Thompson and A. F. Subar. Dietary Assessment Methodology. In *Nutrition in the Prevention and Treatment of Disease*, pages 5–46. Elsevier Inc., jan 2013.

[239] V. Ting and J. A. Weiss. Emotion Regulation and Parent Co-Regulation in Children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, 47(3):680–689, mar 2017.

[240] T. Toscos, K. Connelly, and Y. Rogers. Best intentions: Health monitoring technology and children. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, page 1431–1440, New York, NY, USA, 2012. Association for Computing Machinery.

[241] C. Trattner, D. Elsweiler, and S. Howard. Estimating the Healthiness of Internet Recipes: A Cross-sectional Study. *Frontiers in Public Health*, 5, feb 2017.

[242] K. N. Truong, G. R. Hayes, and G. D. Abowd. Storyboarding: An empirical determination of best practices and effective guidelines. In *Proceedings of the 6th Conference on Designing Interactive Systems*, DIS '06, page 12–21, New York, NY, USA, 2006. Association for Computing Machinery.

[243] C. C. Tsai, G. Lee, F. Raab, G. J. Norman, T. Sohn, W. G. Griswold, and K. Patrick. Usability and Feasibility of PmEB: A Mobile Phone Application for Monitoring Real Time Caloric Balance. *Mobile Networks and Applications*, 12(2-3):173–184, jun 2007.

[244] B. Vandenberghe, J. Vanhoof, R. Voorend, D. Geerts, and F. Dobbels. The 'Self' as Barrier for Self-Management Technologies in Healthcare? In *Proceedings of the 12th EAI International Conference on Pervasive Computing Technologies for Healthcare*, pages 336–346, New York, NY, USA, may 2018. ACM.

[245] T. Z. Warfel. *Prototyping: a practitioner's guide*. Rosenfeld media, 2009.

[246] O. Weisberg, A. GalOz, R. Berkowitz, N. Weiss, O. Peretz, S. Azoulai, D. Kopleman-Rubin, and O. Zuckerman. Tangiplan: Designing an assistive technology to enhance executive functioning among children with adhd. In *Proceedings of the 2014 Conference on Interaction Design and Children*, IDC '14, page 293–296, New York, NY, USA, 2014. Association for Computing Machinery.

[247] S. White and S. Feiner. Sitelens: Situated visualization techniques for urban site visits. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '09, page 1117–1120, New York, NY, USA, 2009. Association for Computing Machinery.

[248] E. G. Willcutt. The Prevalence of DSM-IV Attention-Deficit/Hyperactivity Disorder: A Meta-Analytic Review. *Neurotherapeutics*, 9(3):490–499, jul 2012.

[249] W. Willett, Y. Jansen, and P. Dragicevic. Embedded Data Representations. *IEEE Transactions on Visualization and Computer Graphics*, 23(1):461–470, jan 2017.

[250] K. Wu, M. H. Tran, E. Petersen, V. Koushik, and D. A. Szafir. Data, data, everywhere: Uncovering everyday data experiences for people with intellectual and developmental disabilities. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, CHI '23, New York, NY, USA, 2023. Association for Computing Machinery.

[251] S. Yarosh, S. Thompson, K. Watson, A. Chase, A. Senthilkumar, Y. Yuan, and A. J. Brush. Children asking questions: Speech interface reformulations and personification preferences. In *IDC 2018 - Proceedings of the 2018 ACM Conference on Interaction Design and Children*, pages 300–312, 2018.

[252] J. Yip, T. Clegg, E. Bonsignore, H. Gelderblom, E. Rhodes, and A. Druin. Brownies or bags-of-stuff? domain expertise in cooperative inquiry with children. In *Proceedings of the 12th International Conference on Interaction Design and Children*, IDC '13, page 201–210, New York, NY, USA, 2013. Association for Computing Machinery.

[253] N. D. Zasler, M. F. Martelli, and H. E. Jacobs. Neurobehavioral disorders. *Handbook of Clinical Neurology*, 110:377–388, Jan 2013.

[254] S. Zhang, Y. Zhao, D. T. Nguyen, R. Xu, S. Sen, J. Hester, and N. Alshurafa. NeckSense. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT 2020)*, 4(2):1–26, jun 2020.

[255] Y. Zhao, Y. Kim, C. Apodaca, R. Casanova-Perez, S. Haldar, S. R. Mishra, J. C. Dunbar, A. Pollack, and W. Pratt. Supporting Goal-Based Collaboration for Hospitalized Children. *Proceedings of the ACM on Human-Computer Interaction*, 5(CSCW1):1–22, apr 2021.

[256] J. Zia, J. Schroeder, S. Munson, J. Fogarty, L. Nguyen, P. Barney, M. Heitkemper, and U. Ladabaum. Feasibility and Usability Pilot Study of a Novel Irritable Bowel Syndrome Food and Gastrointestinal Symptom Journal Smartphone App. *Clinical and Translational Gastroenterology*, 7(3):e147, mar 2016.

[257] J. K. Zia, C.-F. Chung, J. Schroeder, S. A. Munson, J. A. Kientz, J. Fogarty, E. Bales, J. M. Schenk, and M. M. Heitkemper. The feasibility, usability, and clinical utility of traditional paper food and symptom journals for patients with irritable bowel syndrome. *Neurogastroenterology & Motility*, 29(2):e12935, 2017.

[258] B. J. Zimmerman. Self-regulated learning: Theories, measures, and outcomes. In J. D. Wright, editor, *International Encyclopedia of the Social & Behavioral Sciences*, pages 541–546. Elsevier, Oxford, second edition, 2015.

[259] M. Zwi, H. Jones, C. Thorgaard, A. York, and J. A. Dennis. Parent training interventions for attention deficit hyperactivity disorder (adhd) in children aged 5 to 18 years. *Cochrane Database of Systematic Reviews*, (12), 2011.