Co-Designing Situated Displays for Family Co-Regulation with ADHD Children

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ABSTRACT

Family informatics often uses shared data dashboards to promote awareness of each other's health-related behaviors. However, these interfaces often stop short of providing families with needed guidance around how to improve family functioning and health behaviors. We consider the needs of family co-regulation with ADHD children to understand how in-home displays can support family well-being. We conducted three co-design sessions with each of eight families with ADHD children who had used a smartwatch for self-tracking. Results indicate that situated displays could nudge families to jointly use their data for learning and skill-building. Accommodating individual needs and preferences when family members are alone is also important, particularly to support parents exploring their co-regulation role, and assisting children with data interpretation and guidance on self and co-regulation. We discuss opportunities for displays to nurture multiple intents of use, such as joint or independent use, while potentially connecting with external expertise.

CCS CONCEPTS

• **Human-centered computing → User centered design**; **Empirical studies in collaborative and social computing**; **Ubiquitous and mobile devices**.

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KEYWORDS

Family Informatics, Situated display, Smartwatches, Co-design, ADHD, Health tracking

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1 INTRODUCTION

Family informatics can support family collaboration around collection of, and reflection on, self-tracked data with the goal of improving health and well-being [84]. Health and well-being in the family are interconnected [7, 32], and sharing data among family members can support greater awareness of each other's health [47, 84, 117]. A common interaction paradigm in family informatics systems has been through shared dashboards, or systems that provide visualizations of family data on mobile apps, typically a parent's phone, or more rarely on situated displays (*e.g.,* a tablet on a wall). In these dashboards, each family member's data is typically presented in visually close proximity to support easy comparison or aggregation, such as seeing each other's snacking behaviors [98] or physical activity [95]. Situated displays can be particularly valuable given the convenience of situating data visualization in the shared living space [13, 75]. 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 [55] and distraction [101]. By providing a shared display situated in a common family area, families can conveniently view

shared data and children might become more involved without requiring their own phone or use of a parent's device.

Past work on family dashboards have used techniques such as timelines (*e.g.,* exercise minutes per day [95]) or through symbolic abstractions (*e.g.,* stars for "average healthiness of snacks" each person classified [98]) to support collaborative reflection, or the improvement of communication among the family through sharing knowledge [69]. However, such interfaces often stop short of providing families with much-needed *guidance* around what collaborative actions could be taken to help improve family functioning and health behaviors more broadly [36, 84]. Guiding reflection towards how to regulate health behaviors is particularly important for families with neurodivergent members or those with chronic conditions due to unique coordination challenges that can elevate risks to well-being, such as increased need for supervision, difficulties in adherence to medication and coping strategies, and heightened risk of family conflict [23, 72]. However, our understanding of how situated displays in the home could support guiding members to improve their collective well-being is more limited. There is therefore a need for formative understanding on how families envision home displays to support taking collaborative action in light of the complexities around health and health coordination [1, 84, 88], especially for those with chronic conditions [25, 84].

Collaborative regulation (*i.e., co-regulation*) of experiences and behaviors in Attention Deficit Hyperactivity Disorder (ADHD) families represents a common set of challenges that could benefit from guidance toward reflection and action. ADHD is considered the most prevalent childhood psychiatric condition [10, 30], and ADHD children may have differences in attention, activity level, and impulse control compared to same-age peers [27]. Supporting children in developing self-regulation skills can empower them to manage challenges and promote positive social and emotional well-being [26]. Caregivers, such as parents, play an important role in collaborating with children to support them in developing and using self-regulation skills [48, 78, 97, 115]. ADHD is highly heritable [41], so it is likely that ADHD families have communal health regulation challenges. Recently, there has been growing interest in exploring technology to support parents and ADHD children [112], such as using smartwatches for co-regulation [25, 103]. However, there is a need for further support for families to integrate shared data from multiple members, reflect and assess regulation, and fine-tune efforts [25, 103]. Guiding families in using shared data for co-regulation could potentially be mediated by in-home situated displays. Understanding family needs in this domain also provides opportunity to inform principles for designing situated displays which promote actions toward family functioning more generally.

Given the need for understanding how in-home displays could guide co-regulation practices built on the sharing of health data, and the limited formative research on family needs and values for such technologies in family informatics, we employed a co-design approach with ADHD families. Our aim was to elicit their perspectives on designing situated home displays for using health tracking data in support of co-regulation needs. We first provided an Apple Watch to eight ADHD child participants to track their exercise, moods, and goals for several weeks to stimulate family thinking about the use of tracking for co-regulation. We then held three co-design sessions with each participating family (n=23 participants; 8 ADHD children, 15 parents; 24 total sessions) focused on the design of ambient displays that share each member's wearable-collected data about moods, exercise, and routine goals. Through qualitatively analyzing sessions and resulting design artifacts, we identify opportunities for situated home displays to accommodate the diverse joint and personal needs within a family's co-regulation process, expanding prevailing approaches focused solely on parents tracking or prescribing identical family interactions. In particular, we contribute:

- An understanding that families expect situated displays to help guide them to develop self- and co-regulation skills amidst their complex lives. Families desire system-generated nudges to establish intentional family time for reviewing data together with guidance towards regulation practices, such as encouragement to comfort others and helping plan alternative strategies for future similar situations.
- An understanding that family members wish to independently use situated displays to self- and co-regulate with others. Family members wish for individual guidance tailored to their needs and interests, such as tailoring data views and suggestions on how to contribute to collective regulation. Children wish to be able to independently comprehend personal and family data, while parents seek more complex data manipulation to understand their family data in order to support their parenting practices.
- A discussion on how situated home displays could support multiple intents of use, such as joint or individual use, while potentially connecting with external expertise. Participant-generated designs suggest the value of systems incorporating support from the larger care ecosystem, like bringing context from school educators or suggestions from clinicians.

2 BACKGROUND AND RELATED WORK

Our work builds on previous research on family collaboration to co-regulate behaviors using technology that can mediate and improve communication and assistance. In the next subsections, we summarize prior research on ADHD needs for behavior regulation, how family informatics has supported families in tracking and managing health-related behaviors, and how the use of situated displays has been leveraged for providing insights on tracked data.

2.1 ADHD, Self-Regulation and Family Co-Regulation

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 [71, 81]. It serves as a fundamental mechanism for adaptive developmental tasks across all life stages [71], but typically develops in early childhood [14, 60] and continues to develop throughout adolescence [71].

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 [5, 26], children with ADHD might have additional 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 [27, 102]. 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 [17, 51]. Such obstacles can lead to anxiety, depression and affect their well-being [34] and quality of life [35, 113].

To support ADHD children who experience significant self-regulation challenges, caregivers (*e.g.*, parents, clinicians, teachers, etc.) use co-regulation strategies, such as emotional scaffolding and setting goals to sustain a child's interest in tasks through praise, role modeling, redirection, or restarting tasks [48]. Effective co-regulation strategies could empower children with ADHD to move from co-regulation to self-regulation, and could enhance their confidence and parent-child bonding [45].

Within HCI, research has sought to improve self-regulation for children with ADHD through digital interventions [24], such as through training with serious games [16, 62, 108] or structuring some routines [109, 118]. However, these digital interventions are typically instructive and fall short of offering guidance based on family's lived experiences. Family-focused systems for regulation could thus target family's specific needs, struggles, and strengths if data-driven, such as personalization based on self-monitoring [24] and involving the whole family [84]. There is growing recognition that technologies need to involve children's care networks[111] in managing and promoting regulation while empowering children's expressions of experiences and reflection in order to promote communication beyond symptom tracking alone [112]. There also remains a need to support joint reflection and collaboration between ADHD children and their family [103]. Our work contributes towards involving ADHD children alongside family members to shape technology that considers their collective and individual needs for guiding reflection and taking actions to improve well-being.

2.2 Health Tracking and Family Collaboration

Tracking of health in the family often centers the tracking of children in support of parent's caregiving [18, 49], especially in families with a child with a chronic condition [56, 84]. Tracking of children can give families some peace of mind about their health and well-being [56, 79, 117]. It may also provide parents support to manage children's health, such as monitoring glucose levels for diabetic children [56, 85, 117], evaluate growth and development [58], and potentially support early diagnosis of developmental problems [107]. Additionally, tracking behavior for regulation can support neurodivergent populations, such as with children with attention challenges [25, 103] or autism [6, 68]. A limitation of systems focused on supporting parent tracking of children is that they may create a social dependency on parents [103] and limit child involvement in using and reflecting on data [79]. This risks impeding children's involvement in co-regulating healthy behaviors in the family and lead to tensions when children transition to adulthood and take on the primary responsibility for managing their own health and related behaviors [1, 56]. Another limitation is that while health sensing of physical experiences are increasingly common (*e.g.,* steps and exercise), automation for tracking cognition, such as emotions and mental states, is still maturing [99]. Tracking cognition is more commonly done manually, such as through subjective notes [100]. While manually tracking can be burdensome to sustain [21], families with neurodivergent children often are trained in these sort of practices as part of health interventions [62, 70]. For example, psychosocial treatments for ADHD are alternatives to pharmacological treatments and can rely on parents to monitor and identify challenging behaviors and direct appropriate stimuli, such as praise or removal of privileges [23]. Support for automated and shared cognitive tracking is still a much needed area of research and the HCI community has recently called for efforts in envisioning how the use of data from such technologies could become useful in the future once more accurate [99].

Family informatics approaches to health tracking proposes the involvement of all family members in collecting, integrating, and reflecting on shared data about those involved in order to achieve more collaboration and distribute health tracking management and burdens [83, 84]. Through observing shared health information, family members can better understand each other's behaviors in order to give support and take action for improving their collective health [85, 92, 98]. Previous work has evaluated deployment of data dashboards, like on a web portal [28, 59, 95, 123], tablet [83], or phone app [67, 93, 94, 98] to involve multiple family members in the shared tracking of some health domains. For example, shared views for parents and children have helped promote family physical activity, surfacing exercise performed and motivating collective exercise goals through gamification [92] or social rewards (*e.g.*, storybooks when reaching goals [94]). Work on caregiving for behavioral and mental health has similarly argued that technology could promote collaborative reflection (*i.e.,* "informal documentation and communication practices" [69]) through flexible sharing of data between members of treatment teams [69], and support free expression of experiences and emotions when sharing information between children and their care networks (*e.g.,* educators, clinicians, and parents) [112]. Overall, previous evaluative studies of family health tracking have pointed towards improving family communication as an important component towards shared awareness of specific health-related states and behaviors [56, 83, 90, 95, 98]. However, there is still a need to better understand how to support families in identifying and deciding what actions to take based on their data, especially due to challenges around coordinating and engaging multiple or all family members [84].

Most relevant to our work, prior research has sought to support families with neurodivergent children to guide specific behaviors, sometimes involving tracking [24, 82, 116, 125]. For example, systems have sought to guide completing some household tasks like bedtime and morning routines [109], taking medications [20], and flexible goal-setting [103]. MOBERO [109], a mobile application, assists morning and bedtime routines for parents and their children with ADHD by providing structured tasks and reward tokens. Similarly, the mobile application Medbuddy [20] was designed to support medication management for children with ADHD and their parents by providing consistent adherence goals. The deployment and evaluation of CoolTaco [103] explored the use of smartwatches for parents to provide co-regulation with ADHD children through goal-setting and positive reinforcement, indicating potential for pervasive regulation support even when parents are not immediately present. However, in centering interactions where there is a need

for only one family member, these systems offer limited understanding of how technology can offer guidance around co-regulation. Further, collaborative systems often have been distributed across devices (*e.g.,* each family member has their own device for monitoring the activity [103]), limiting opportunity for shared reflection or support for action. In our work, we unpack how ADHD families envision home displays specifically to integrate shared data and guide reflection towards co-regulation practices.

2.3 Situated Displays for Tracked Data

Dedicated situated displays [13, 119, 121] that are persistently available in the home have facilitated self-centered personal reflection and understanding of self-tracked mood [52, 105], physical activity [40], and behaviors for health recovery [53]. By integrating data into physical environments, situated visualization can conveniently position tracking and reflection in the context of daily living spaces and routines [13, 75]. While personal informatics has self-centered roots [38], the field has increasingly recognized the health's collaborative nature [29, 77] and opportunity for systems to involve others [83]. 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.

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 [75, 121]. 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. They have helped become more aware of each other's sleep habits, such as in Dreamcatcher, which displays daily and weekly sleep tracking on a shared display (*e.g.*, a tablet in the bathroom). Dreamcatcher [83] was reported to help families track together with greater involvement of children and reflect about each other's sleep habits. Displays have also helped families be more connected, such as through tracking and sharing of each other's location [15] or memories in photographs [46]. Such communication can increase social touch and family bonding [15, 46]. Situated displays have also improved awareness of distributed tasks in the home through tracking and displaying household chores, such as Choreflect [87], an ambient display system showing household tasks by adult members. Choreflect was suggested to increase awareness of chores that otherwise could have gone invisible [87]. Overall, these systems have provided a situated interface for equal access and interaction for family members to share data in the home.

Generally, prior research in shared displays point to the opportunities of situated sharing of data for building awareness about tracked behaviors. For families, home displays are a potential means of increasing awareness between members. Given the complex dynamic of co-regulation, questions remain on what sort of guidance parents and children, particularly those with ADHD, would want in a situated in-home display involving family data. In our work, we engage with children and parents to understand families' needs, values, and preferences for how such systems could support their health and well-being.

3 METHODS

We conducted three co-design sessions individually with each of the eight participating families (24 total sessions; 23 participants, 8 children with ADHD, 15 parents). Our study was approved by the university's Institutional Review Board (IRB). In this section, we explain our study recruitment and participants, procedures, qualitative analysis process, and limitations.

3.1 Participants

We required eligible participants to be families participating together, consisting of at least one caregiver and one child aged 8-15 with either a clinical or self-reported ADHD diagnosis. We 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 problems on top of ADHD challenges [91]. We recruited participants in a metropolitan area in the United States. 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 1. All caregiver participants were biologically related to their children, and 7 out of 8 had both parents living at home. We did not recruit siblings of children in our participating families. Siblings were typically below the age range of our IRB approval for participation. We were further concerned that involving multiple children in remote co-design session, especially using the same computer, would add challenges for both the researchers and parents to coordinate. The gender distribution is proportional to the school's demographic and general ADHD diagnostic ratios (*i.e.*, overwhelmingly male) [76, 120]. Families were compensated $100 for their participation.

All parents affirmed that the children presented ADHD symptoms and signed written consent to participate. Children assented to participate verbally. Parents additionally completed two validated assessment tools about the children, SWAN [114] and BASC-3 [96]. The SWAN results indicated above average attention difficulties in all children and hyperactivity/impulsivity challenges in 5 of the 8. The BASC-3 results indicated that 4/8 scored at-risk and 3/8 at clinically significant for attention challenges, and 3/8 at-risk and 3/8 clinically significant for hyperactivity.

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

3.2 Study Procedures

Our study leveraged co-design, a participatory method that collaboratively engages and empowers people in shaping better technologies intended for them [57]. 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 [110, 122]. Following an initial phase where children used Apple Watches to help surface tracking opportunities to the family, families participated in three co-design sessions.

Table 1: Participating families

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

3.2.1 Apple Watch exploration prior to co-design sessions: To stimulate families in envisioning opportunities for behavior tracking and sharing, we asked them to explore collecting different types of data on Apple Watches. We pre-configured and delivered watches for participating children alongside paired phones that stayed in the possession of the parents. 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). We asked participating children to use the watch for at least four weeks before we scheduled co-design sessions. Prior work has indicated that children can understand and benefit from some self-tracking (*e.g.,* [4, 80, 112]), so we encouraged families to explore specific apps which supported different tracking features. We suggested that they could use the built-in passive sensing of movement alongside active exercise tracking, such as for step-counting, bike riding, etc. We also made available a simple custom app that asked how they were feeling by offering colored button options according to the Zones of Regulation Framework [54] three times a day (*e.g.,* blue for when having feelings of low energy, like bored or tired). Finally, we also made available a custom goal tracking app that allowed creating a text-based list of routine goals to be checked off. While the exercise tracking used automated sensing, goal and mood was manually tracked. Current cognitive tracking capabilities are still maturing [99], so our goal with this phase towards our 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 the goal-setting app 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.

3.2.2 Co-design sessions: Similar to prior work [39, 65], we 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 [65], although requiring complex logistic and child-adult collaboration dynamics [39]. To account for this complexity, we 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 two and three researchers were present during sessions to take notes and help manage activities. We 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]"*).

We 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.

In each co-design session, we 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. We then engaged only with the parents. During each session, we 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, we 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, we 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 we would use, and (3) discuss mood tracking and design mood representations. We first explained the design goals and

stimulated 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[1] 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, we then engaged with the child about how the creatures might be feeling and how they would change if feeling something different (*e.g.,* Figure 1a).

Session 2: *Co-designing use of family's shared mood data.* In this session, we focused on understanding how families imagined opportunities to use daily tracked moods given the importance of emotion regulation in children's development [44], ADHD challenges in this space [34], and strategic possibilities for interaction design and technology's role in family emotion regulation [104].

To ease and encourage participant brainstorming, we 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 1b). Inspired by the Bags-of-Stuff technique [124], we 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). We then facilitated family discussion and iterations on the design focused on desired information and ideal features for a home display. Throughout the session, we asked about each member's specific emotion regulation behaviors and family dynamics. We 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. We specifically probed for understanding how families would like to use an interface to jointly reflect 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, we 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 [19, 27, 102]. This session was structured similarly to the previous one. We drew some visual components from prior work on visualizing exercise tracking [2, 37] and goal setting for ADHD children [103] with extrinsic rewards. Our 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 we probed 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, we also probed what a system on a display should do, if anything, in addition to sharing data.

[1]https://miro.com/miroverse/monster-workshop/

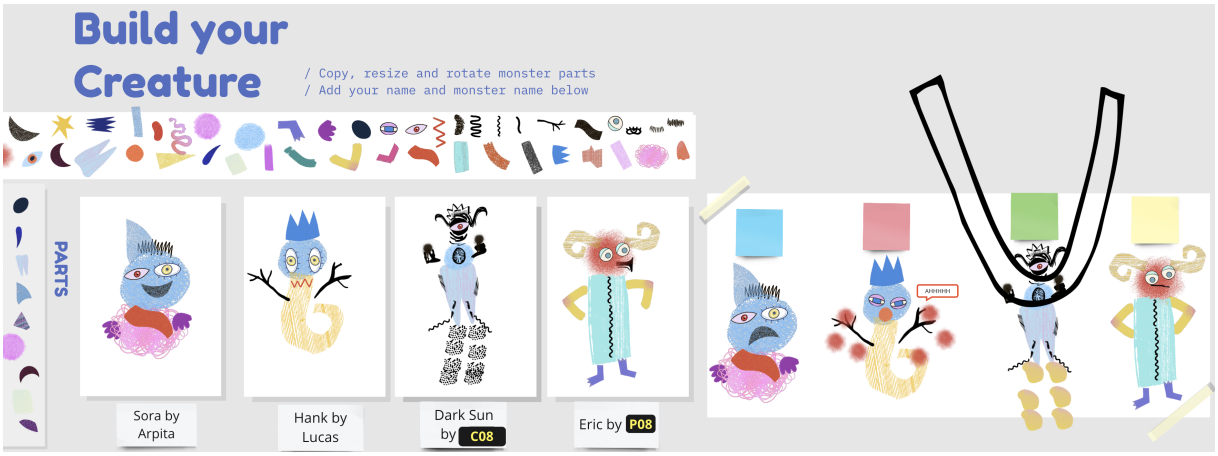
3.3 Analysis

Our qualitative analysis of the co-design sessions drew inspiration from reflexive thematic analysis process [11, 12]. The first three authors first familiarized themselves with the data by reviewing session memos and design artifacts. Researchers then individually observed recordings of six sessions for what participants said, designed, and behaved. Researchers met and brought observational notes, design artifacts, and session excerpts to be used in affinity diagramming, which resulted in an initial codebook. Researchers then met 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". We 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 paper writing process and in regular meetings with the research team.

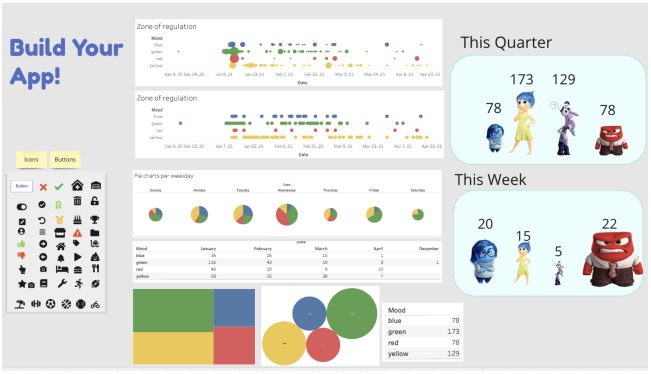
3.4 Limitations

We recognize that our limited number of families may have constrained the extent of our findings. Recruiting neurodivergent populations for research poses known challenges, with convention allowing as few as 5-10 subjects with disabilities [63]. We sought to mitigate the breadth of participant experiences by recruiting both parents and children together, increasing the perspectives we were able to provide on the topic, as well as extensively engaging with our participants over multiple co-design sessions. We also see importance of further understanding co-regulation needs among siblings, as ADHD siblings can have heightened conflict in relationships [72]. Our results 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.

Our results may not fully reflect families that differ in configurations and relationships. Family socialization practices vary culturally [86] and it is likely that results differ for families with and without ADHD from different locations and lifestyles. Our 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 positive collaboration attitudes, wishing to support 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 less 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.



(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 [103], fitness data representations [2], and ephemeral data sharing online [37] which families used to create further components together during sessions.

Figure 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.

4 FINDINGS

Our 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, we detail needs for nudging collaborative reflection and discussion for joint use while enabling learning about and support for ADHD. We then report on needs for technology to empower individuals in their self-reflection and in service of family collaboration.

4.1 Making Family Time Useful for Co-Regulation

As part of our co-design sessions, families suggested that shared displays could help make family time more productive for co-regulation by helping them overcome the normal hectic family routine and facilitating planned joint use. At the same time, aligning system design and use with educational goals could enrich collaboration for building self-regulation skills for better well-being.

4.1.1 Nudging Joint Use Amid Daily Disruptions. Participants described busy daily routines with limited current practices around discussion of how the family is doing. Our 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 our 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 lent Apple Watches for inspiration prior to the co-design studies, some parents were concerned that asynchronous tracking and sharing such as on a watch could focus on an individual level instead of *"overall overview of the family"* (P06). On the other hand, families in our study 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 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.

4.1.2 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: Co-design 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 to help build 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 2 vs. Figure 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.

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

Beyond using an in-home display for collaborative joint use, we 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 well-being 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.

Our findings primarily highlight differences in needs relating to the caregiving role, particularly parents and children. However, we 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, we 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, we detail particular needs we identified for using a family display between different members, especially but not limited to adults and children, given their typical roles in the family.

4.2.1 *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*

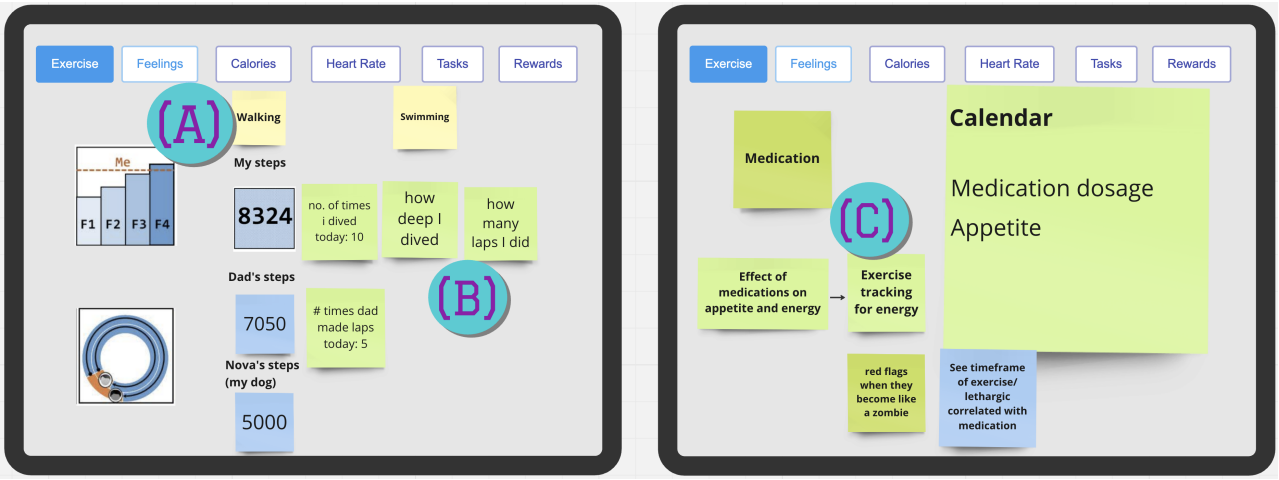


Figure 2: F05 created an interface to compare everyone's step count (A), including the family dog, alongside swimming-specific (B) metrics (*e.g.*, dives, laps). In contrast, P05 reported his personal interest in exercise tracking was to evaluate any negative side-effects of medication to the child's energy level and appetite (C). This highlights distinct goals between the collective and individual use of situated displays.

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.

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: We 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, well-being, 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 well-being. 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 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 collaboration, parents may want nuanced control over what tracked data is displayed in a family display to prevent negative impacts on their children.

Figure 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.

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 [69] and children's care networks [111, 112]. 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 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.

4.2.2 Supporting Child's Independence and Contribution to Other Family Members. Our 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

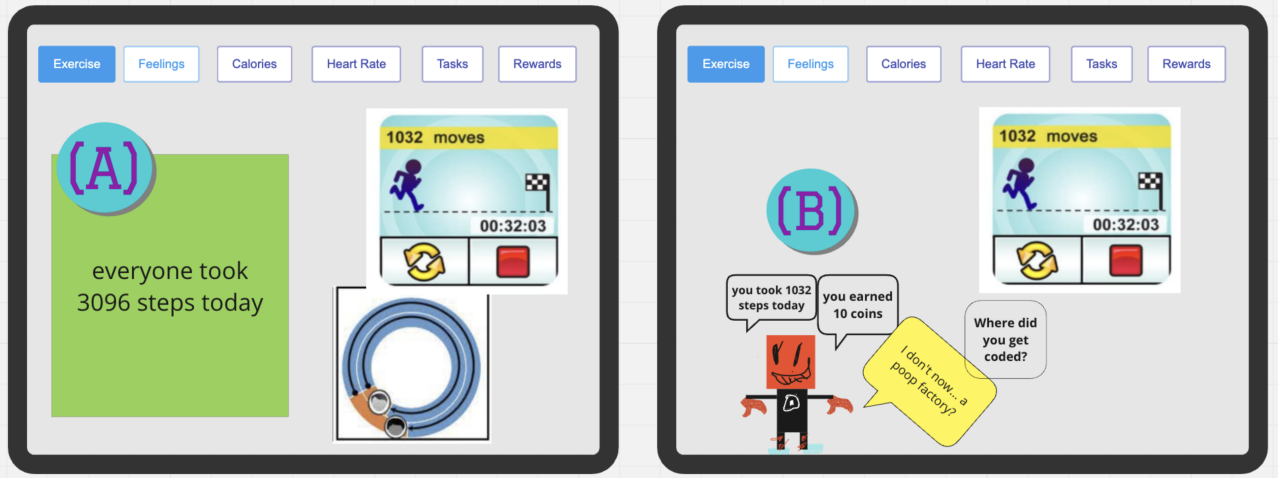


Figure 4: F02 created two separate designs for collective versus individual use of each other's exercise data. In (A), exercise contributes to a shared family goal, whereas in (B) C02 envisioned a chatbot designed as his *"alter ego character, Owltechno"* (P02) to explain his exercise, answer questions, handout points for achieving goals, and tell occasional jokes. C02 explained that the chatbot was for his use alone and not available to others.

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 our 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 in order 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 that 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' well-being 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 in order 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 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, various children-centered exercise visualizations 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 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 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 DISCUSSION

The results of our 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. Past work shows family tracking can promote health via parent-facing systems (*e.g.*, [18, 49]) or by offering identical interactions and data representation for all members in promoting awareness of health states (*e.g.*, [82, 95]). Our work builds on these past findings by examining how in-home displays can be supportive of co-regulation needs and responsive to the context and intentions of use by family members. Our results indicate that families envision such displays as a means of guiding their learning and practice of self-regulation and co-regulation, such as to resolve goal progress or roots of emotion-regulation problems, helping them re-evaluate goals, or comforting 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.

We next describe these opportunities and explore how the results of our work augment and expand existing considerations for the design of family informatics systems. We also specifically focus on design opportunities for supporting ADHD families in co-regulation as a case of moving families from knowledge to action.

5.1 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 [109]) or promoting general awareness about specific domains, some through glanceable displays (*e.g.*, for sleep [83]) or parent-controlled dashboards *(e.g.*, for physical activity [79, 95]). These approaches can be helpful to families for gaining awareness about each other or motivating certain behaviors. Our 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 [28, 56, 95], our 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 [47, 92, 95] and promote healthy practices for moments beyond system use.

Our findings reveal that family informatics systems could support intentional, productive family time focused on collaborative data use. Situated displays might act as reminders and for opportunistic self-reflection [13]. Our 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 [47]. 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 well-being data requires some self-regulation and thoughtful action to plan around routines. Our 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 is 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.

Design considerations: In light of the need for family convergence around shared data, we 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 [64] 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 had a challenging regulation moment 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 [25].

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 [99] 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 [104, 126]. For example, reflection in the form of imagining alternate outcomes [61] 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.

5.2 Guiding Individual Use of Family Data on Situated 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 [83], often catering to children [66, 95, 106]. This has some benefits during joint use to promote inclusion of all members and foster connection with one another [95]. However, our participants revealed that this approach does not fully support their individual goals for understanding and interacting with shared data. We 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 [4], which can constrain how they might use the data or create spaces of misunderstanding between them and other family members. We 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 self-centered reflection [13], our findings suggest that a family-centered approach could benefit individuals by adapting to independent use in addition to modes for joint family engagement while still highlighting shared data.

Our findings indicate that caregivers might benefit from guidance in the complex manipulation of family data to deeply understand behaviors, comprehensively assess risks, and critically self-reflect on their contributions to co-regulation. We observed that parent's interests for independent use are in line with motivations typical of quantified-self [22] or self-experimentation [31] 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 [56] 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 our 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 [3, 4, 89], such as using exercise data as a form of competitive or collaborative game [73, 80, 95]. They might also have differences in their ability to understand health data [4, 80], which highlights that guiding children's reflection in a developmentally appropriate manner is crucial for their engagement with health-related systems. Our child participants did not own a phone, and many other families might have similar preferences given perceived safety and distraction risks [55, 101]. As such, our participants considered that a home display could be a means for children's individualized access and use of family data. Still, we observed that data interpretation skills and understanding of self-regulation influence children's expectations for how the display can support their independent use. Our child participants

explained that systems could help them in making use of family data, especially on 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 [33]. Sensemaking might then be constrained if systems do not provide appropriate levels of interpretation or guidance on how to use family data.

Design considerations: 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 [74]. 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 [25] 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 well-being would be essential to supporting children, their co-regulation partners, and the entire family.

5.3 Designing to Incorporate Expert Guidance Into the Home Display

Our findings indicate that co-regulation at home would benefit from display systems that incorporate collaboration with the experts that families regularly interact with, including school teachers and clinicians. 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 [8, 9]. Past work has suggested the need to consider designs to improve communication between children's broader care ecosystem [69, 112], and our 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. Our participants considered that regulation at school and related events there 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 [43] and work for pediatric care that posits teens could have higher access to health data and participation in their own care partnership with physicians alongside parents [50]. However, feasibility barriers exist [43], including privacy regulations (*e.g.*, FERPA [42] in the U.S.), avoiding information overload to clinicians, and establishing appropriate bidirectional sharing between families and external experts.

Design considerations: 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.

We also see the potential for in-home family systems to export some data to inform external collaboration. Clinicians might benefit from reviewing family co-regulation data when providing family therapy or individual care to a child. Similarly, educators in school might benefit from knowing about some level of children's regulation outside of school to perhaps inform specific instruction or co-regulation for class time. Privacy and health data regulation challenges are certain in such knowledge sharing, and it is also likely that educators and clinicians would not benefit nor wish for continuous streams of family data but perhaps could receive short reports or specific data points relevant to their role. Research on school-family and clinician-family collaboration, possibly also involving situated displays, is a valuable ground for future work.

6 CONCLUSION

Our co-design study with ADHD children and parents indicates needs for in-home displays to promote intentional coming together for skill-building during family joint use, using data from lived experiences to help families evaluate and motivate regulation, acquire self and co-regulation skills, and plan strategies for improvements. Our findings also indicate a need to accommodate diverse individual preferences and needs for using a home display when alone. Parents may want and need to assess risks and evaluate their role-modeling and co-regulation efforts, while children seek assistance with data interpretation and guidance on how to co-regulate other family members. For ADHD families needing enhanced co-regulation support, we suggest designing family systems that help coordinate joint reflection and learning as well as empower independent use. Furthermore, the integration of clinical guidance and co-regulation insights from teachers could augment family co-regulation practices via in-home displays. Overall, our work suggests that in-home displays of tracked family data have the potential to move beyond gaining awareness of health states towards facilitating learning, growth, and the practice of collaborative regulation.

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