SLEEP MANAGEMENT AS A COLLABORATIVE WORK FOR THE FAMILY: DESIGNING SLEEP MANAGEMENT SYSTEMS TO IMPROVE BEDTIME ROUTINE

By

Ji Youn Shin

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ABSTRACT

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Sleep is a vital health issue. In families with young children, sleep problems can influence the physical, emotional, and behavioral health of all family members. Previous studies have investigated sleep as an individual activity, rarely considering the interconnected aspects of sleep among family members. To understand the social aspects of family sleep, this dissertation consists of two studies which can help researchers and designers understand the core issues of family sleep and address them through the design of sleep-support technology. In the first study, I identified sleep as a complex experience entangled with the social dynamics between family members. For example, children's sleep means time not just for children to rest, but for a parent to have self-care. The results suggested how the boundaries that define sleep in terms of time (at night), space (in bedrooms), and unit of analysis (individual-focused) limit designers' opportunities to tackle the deeper sleep issues of families. I also suggest "division of labor" as an important but rarely discussed design concept to enhance family sleep, and as a promising design theme for home technologies that address issues emerging from social dynamics between household members. In the second study, by incorporating the identified themes from the first stage, I designed and tested two types of family-based sleep management prototypes. These prototypes redistributed the sleep-relevant tasks among family members and provided them with chances to reflect on the difficulties and values involved in the tasks. Through the in-the-wild study deploying two design prototypes in home settings, this study empirically revealed the

importance of considering social dynamics as a design factor for family sleep management technologies. Implications of future design are discussed.

I dedicate this dissertation to my loving parents: my dad Yongju Shin and my mom Miok Kim. I knew I could always go back home if I wanted to, and that gave me the strength to put everything on the other side of the world.

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CHAPTER 1: INTRODUCTION

Good sleep is a critical determinant of health and wellness. For adults to maintain a healthy life, the National Sleep Foundation recommends at least seven hours of sleep duration (the total daily amount of sleep) and 85% sleep efficiency (the ratio of total sleep time to time in bed). However, one in three adults (people older than 18 years old) living in the United States does not meet the recommendation (Hirshkowitz et al., 2015; The Centers for Disease Control and Prevention's (CDC) Morbidity and Mortality Weekly Report). It has become a critical public health issue that affects more than fifty million individuals in the United States (Meltzer & Mindell, 2007; Meltzer & Montgomery-Downs, 2011; Shin, Kim, & Grigsby-Toussaint, 2017).

When defining and assessing sleep quality, studies often consider several measures, including sleep duration and sleep efficiency (Reed & Sacco, 2016). Unhealthy sleep can be defined as insufficient sleep, irregular sleep patterns, or insomnia, but it also includes sleep disorders, such as sleep apnea. The negative effects of unhealthy sleep (e.g., low alertness, emotional regulation) can impinge on daytime functions, such as work or school (Oort, Kerkhof, Meijer, Bögels, & Dewald, 2010; Sonne, Müller, Marshall, Obel, & Grønbæk, 2016). Furthermore, chronic sleep deficiency often negatively impacts an individual's health and causes diseases, including high blood pressure and type 2 diabetes (Liu et al., 2013; Liu, Wheaton, Chapman, & Croft, 2013). Studies showed that multiple factors can impact an individual's sleep quality, including but not limited to daytime activities, naps, diet, technology use, smoking, medication, home environment, cultural practices, mental health, and illness (Carney, Edinger, Meyer, Lindman, & Istre, 2006; Driver & Taylor, 2000; James, Kristjánsson, & Sigfúsdóttir, 2011; Smaldone, Honig, & Byrne, 2007). To address those issues, the growing availability of smart devices has made several home-based sleep support technologies possible and created new

opportunities for researchers to support individual's sleep quality at low cost (Ko et al., 2015; Silva, Rodrigues, de la Torre Díez, López-Coronado, & Saleem, 2015). For instance, Fitbit has 31 million users and Apple Watch has 100 million users in 2021 (Laricchia, 2022; Pratap, 2021). Studies have shown that technologies can accurately capture individuals' sleep traits and behaviors and provide guidance to improve sleep quality (Aji et al., 2021; Choe, Lee, Kay, Pratt, & Kientz, 2015). These studies commonly considered an individual as a unit of analysis.

Recent studies have broadened their focus from the individual to the family, and - especially for families with young children - to the sleep environment (Dahl & El-Sheikh, 2007; Meltzer & Mindell, 2007; Meltzer & Montgomery-Downs, 2011). For example, when children have abnormal sleep, it often impinges on the quality of the parents' sleep, causing increased stress and fatigue. Recent survey data indicated that more than 50% of American parents lose an average of thirty minutes of sleep each night because of their children's awakening during the night (Meltzer & Mindell, 2007; Meltzer & Montgomery-Downs, 2011). Children crying negatively influenced the quality of the parents' sleep and daytime functioning (Meijer & van den Wittenboer, 2007). On the other hand, parents' beliefs about sleep, their habitual behaviors (e.g., listening to the music or watching TV at night), and increased stress levels from work can also have a negative impact on children's sleep patterns (Dahl & El-Sheikh, 2007). Because sleep problems can influence the physical, emotional, and behavioral health of the whole family, it is critical to address family sleep issues.

To support sleep in the home context, HCI studies have applied family system frameworks (Bowen, 1993) to understand barriers that interfere with family sleep quality and provide design implications for future sleep support technologies. By focusing on how the family's interconnectedness influences its health management, the studies investigated the

importance of supporting sleep for the family's bedroom environment (Choe, Consolvo, Watson, & Kientz, 2011; Kay et al., 2012), collective sleep information tracking (Pina et al., 2020), and collaborative bedtime or morning routine management (Chan et al., 2017; Cherenshchykova & Miller, 2019; B. Lee, Murthy, Lee, Krishnaswamy, & Rosenfeld, 2017; Sonne et al., 2016).

Compared to the body of literature that views sleep as an individual behavior (Aji et al., 2021; Min et al., 2014), this body of literature focuses more on the relational aspects of sleep behaviors in the actual home setting. However, despite efforts to see the family as a unit of analysis to support sleep behaviors, these studies still viewed sleep as a behavior that was tied to morning and nighttime, and that happened primarily in the bedroom setting. They did not capture the critical issues underlying family sleep that originated from family relationships or dynamics, as the studies were focused on specific times and spaces (e.g., bedtime, morning routine, and bedroom). Although some studies had perspectives on sleep that included participants' daytime activities as well as nighttime behaviors (Bauer et al., 2012; Choe et al., 2015), these studies considered individuals as distinct from families. The specific needs of families, including interactions between family members, and issues arising from the transition to parenthood, were not addressed.

Building on the previous studies that emphasized the importance of family-centered approach to understand an individual's sleep behaviors, my dissertation suggests expanding the view of sleep behaviors and looking beyond the family's sleep routine and bedroom settings. I design and test two types of family-based sleep management technologies; these technologies are intended to challenge existing social dynamics in the homes and provide household members with chances to reflect on their interconnectedness in managing daily routines.

In Chapter 2, I review related studies and identify a gap in the field. In Chapters 3 and 4, I introduce a two-phase study with a qualitative semi-structured interview to generate design implications for a novel sleep management system and a field deployment study, respectively. Chapter 5 includes a discussion of the two studies, followed by the design implications of family-centered sleep technologies in Chapter 6, and limitations and future work in Chapter 7. I conclude the study in Chapter 8.

1.1 Contributions

My dissertation makes three main contributions to the design and HCI communities.

First, this work suggests how expanding the view of family sleep can help researchers and designers understand the deeper issues of family sleep problems. This study provides a valuable addition to the current literature on sleep-support technologies by suggesting the broadening of existing boundaries (time, space, unit of analysis), which has not been considered critical to perspectives on family sleep.

Second, this work proposes "division of labor" and "family interconnectedness" as design concepts when developing technologies for family sleep management. The study extends the previous discussion on division of labor in designing technologies for family's collaboration and coordination, and on broadening the scope of sleep-support technologies to consider social dynamics as a design theme.

Third, this work shows how health technologies designed for multiple users with discrepant motivations and needs can use design factors and strategies to engage each user, especially children, with increased motivation during their bedtime routines.

CHAPTER 2: RELATED WORK

Medical studies have investigated how individuals' sleep behaviors can accurately be captured and enhanced with technology-mediated solutions (Aji et al., 2019; Baron, Duffecy, Reid, Begale, & Caccamo, 2018; Horsch et al., 2017). The early medical studies were performed in laboratory settings; however, recent studies have increased the attention paid to home settings. HCI studies have focused on everyday settings by examining the usability of personal smart technologies to enhance sleep and enable healthy sleep management (Choe et al., 2011). In addition to these two types of sleep studies, I also present how previous studies of home technology have investigated families' collaboration and division of labor, which I found to be an essential design factor for families' sleep technologies. As I review these four lines of investigation, I explain the need to reframe the definition of "family sleep" within the HCI context.

2.1 Medical studies understanding sleep via individuals' sleep monitoring

Medical literature has focused on two broad areas: 1) the accurate capture of sleep information in clinical lab settings; and 2) home-based therapeutic solutions via smart technologies.

Researchers in sleep medicine literature have considered sleep an unconscious activity that can only be assessed with sensing technologies in controlled environments, such as a laboratory. Such studies typically rely solely on the data captured by those technologies in clinical settings (Keenan & Hirshkowitz, 2011; Liu, Ploderer, & Hoang, 2015). In those studies, "sleep disorders" (or "sleep problems") are defined as changes in sleeping patterns that negatively influence an individual's health (Medic, Wille, & Hemels, 2017). The most common sleep disorders are insomnia, night terrors, sleepwalking, and sleep apnea (Altevogt & Colten,

2006). They are often diagnosed with polysomnographic (PSG) monitoring: tracking brain waves, heart rate and breathing, oxygen level, muscle tone, leg movements, and eye movements (Guillodo et al., 2020). PSG-facilitated diagnoses can be quite accurate but require spending a night in a clinic while wearing sensors. Historically, however, PSG has been unable to measure the influence of an individual's environment, which typically includes other family members, such as a spouse or children.

The growing availability of smart devices (including wearable PSG trackers and actigraphy) was a breakthrough that made the diagnosis of sleep problems in the home settings possible (Aji et al., 2019, 2021; Chinoy et al., 2021; Guillodo et al., 2020). This improved accessibilities of sleep-therapy, such as simple meditations or exercises, to populations that previously lacked the resources to participate in clinical sleep studies (Babson, Ramo, Baldini, Vandrey, & Bonn-Miller, 2015; Koffel et al., 2018). Recent studies have examined the accuracy of sleep information provided by technology-mediated devices and the benefits of the targeted treatments they enable (Aji et al., 2021; Choi et al., 2018; Luik, Machado, & Espie, 2018). They investigated the ability of various sensors, including accelerometers, gyroscopes, and microphones, to accurately track users' sleep information. In particular, researchers have developed mHealth apps (Babson et al., 2015; Bhat et al., 2015; Fino et al., 2020; Koffel et al., 2018; Kuhn et al., 2016; Miller et al., 2017) and measured the effectiveness of the apps in improving an individual's sleep quality. For example, Fino et al. compared the ability of four smartphone-based apps to effectively detect sleep/wake states with movement and sound sensors (Fino et al., 2020).

Other studies in home settings focused on behavioral sleep therapy through technologies, such as cognitive behavioral therapy for insomnia. Sleep Bunny is an app-based service that

provides users with a brief, telephone-based, coaching manual for improved sleep quality (Baron et al., 2018). Participants were satisfied with the app's usability and showed improvement in sleep. Horsch et al. tested a mobile health app that delivered sleep-aid services to participants who suffered from insomnia (Horsch, Brinkman, Eijk, & Neerincx, 2012; Horsch et al., 2017).

As such, the growing availability of smart technologies was a breakthrough, as it enabled moving sleep assessment from the lab setting to the home environment. These studies provided a number of behavior guidelines through technologies, such as relaxation exercises in bed, maintaining a sleep diary, and education in sleep studies within a medical field.

2.2 HCI studies exploring sleep as individual issues that incorporate more collaborative factors

A large body of literature has examined how interactive technologies can improve sleep quality and thereby the general wellness of individuals (Abdullah, Matthews, Murnane, Gay, & Choudhury, 2014; Bauer et al., 2012; Cherenshchykova & Miller, 2019; Choe et al., 2011, 2015; Min et al., 2014; Ravichandran, Sien, Patel, Kientz, & Pina, 2017). Although medical literature has focused primarily on diagnosing sleep problems and providing therapeutic solutions, recent HCI studies have begun to consider how family members in the home setting affect an individual's sleep hygiene (i.e., recommendations that improve an individual's sleep and behaviors that pertain to physical and mental relaxation) (Choe et al., 2011). By suggesting action plans, studies explored ways to improve an individual's sleep. Studies can be categorized into two groups: 1) technologies that support transitional moments, such as morning and bedtime routines in the bedroom settings, and 2) technologies that help individuals' sleep management in relation to other social actors.

The most common sleep-aid technologies in HCI have been alarm clocks and routine reminder systems for transitional moments in bedroom settings (Choe et al., 2011; Kim, Kientz, Patel, & Abowd, 2008; Landry, Pierce, & Isbell, 2004; Ozenc et al., 2007; Schmidt, 2006). By providing useful information, these technologies support users' bedtime or morning tasks. For example, a study developed a system that provides contextual information, including schedule, traffic, and weather, and thus enables users to adjust their wakeup times and other routines (Landry et al., 2004). The Reverse Alarm Clock, developed by Ozenc et al. enabled children to know whether they should go back to sleep instead of getting up (Ozenc et al., 2007). These studies suggested the use of tailored bedtime and morning routine support for users and improved practices regarding sleep.

The second group of studies investigated individuals' sleep management in relation to other social actors. They investigated the effects of sleep-related information sharing within the users' social networks (Kim et al., 2008; Schmidt, 2006) and environmental factors that affect sleep (Kay et al., 2012). For example, Schmidt et al. showed the usefulness of setting users' specific routines, such as wakeup and bedtime, based on the schedules of other family members (e.g., wakeup is when children get out of bed) and sharing information about users' sleep behaviors (Schmidt, 2006). Aliakseyeu et al. captured information regarding family members' sleep or users' specific daily routines and suggested individualized wake-up times (Aliakseyeu, Du, Zwartkruis-Pelgrim, & Subramanian, 2011). Studies have also highlighted design opportunities by examining the influence of environment and family settings on sleep (Choe et al., 2010; Kay et al., 2012). They developed technologies to capture environmental factors that affect sleep and suggested design implications (Kay et al., 2012).

As an extension of these studies that examined the social aspects of sleep, more recent studies have investigated collaborative aspects of sleep among family members (Pina et al., 2017). In these studies, sleep is considered as a set of interconnected behaviors among family members, particularly those with young children (Chan et al., 2017; Cherenshchykova & Miller, 2019, 2020; Pina et al., 2020). Their results showed how interactive sleep data tracking among family members contributed to sustainable behavior changes and improved their health. For example, Pina et al. developed a family-centered, sleep-tracking tool, DreamCatcher, for parents and their school-aged children to track their sleep data with wrist-worn sleep sensors and report their mood (Pina et al., 2020). Unlike previous research that primarily targeted adults, this study looked at children as users of sleep-tracking technology. Other studies focused on routine support in specific contexts, including the lives of dual-income families (Chan et al., 2017) and ADHD (Attention deficit hyperactivity disorder) support (Sonne et al., 2016). In their ethnographic study, Cherenshchykova and Miller also discussed the importance of rituals and family activities, and suggested design implications for families of young children (Cherenshchykova & Miller, 2019, 2020).

In recent sleep studies, the definition of sleep has been reshaped by focusing on the collaborative aspects of sleep within family social dynamics. However, these studies still viewed sleep as a human behavior tied to morning and nighttime behaviors that happened primarily in the bedroom (Cherenshchykova & Miller, 2019, 2020). Although a few studies take a family collaborative practices approach to managing sleep (Pina et al., 2017; Pina et al., 2020), they focused on tracking sleep data or associated mood, rather than on considering family relationships or dynamics as crucial design requirements. Similarly, although several studies discussed the impact of daytime activities outside the bedroom and the need for peripheral

displays to improve behaviors for healthy sleep (Bauer et al., 2012; Choe et al., 2015), these studies focused on individuals outside the context of their families. In these studies, individuals were a unit of analysis or users, and the unique needs of families, including sleep-related matters that arose from relationships, dynamics, and interactions among householders, were not addressed. Because of these limitations, more profound issues of family sleep—in particular, those that stem from the transition to being parents of young children, and main issues underneath sleep management in family—are less studied.

2.3 Household work and division of labor

The home has been described as one of the most dynamic environments in human life (Sixsmith, 1986). Individuals attribute symbolic meanings to their homes in various ways in response to multiple factors, identity, gender roles, responsibilities, and relationships with family (Bell, Blythe, & Sengers, 2005; Jenkins, 2017). Also, division of labor is highly associated with the wellbeing of household members (Blair & Johnson, 1992). Therefore, how household members negotiate their roles and work in the home environment is a necessary consideration when designing a new social technology targeted for multiple actors in the home, as are any other factors affecting the division of labor (Forlizzi, 2007).

Household work is work which is performed to maintain a home or support family members, and which typically is unpaid (Shelton & John, 1996). It is often measured by labor time (i.e., household members' time spent on a list of household work). Division of labor is the process of separating household work into different tasks. In the family, household work is often performed by different household members, distributed by gender and generation (Punch, 2001). In family studies, researchers examined how people negotiate the division of labor. Although various factors serve as determinants of the division of labor, including marital status (South &

Spitze, 1994) employment status (Chen, 2005), culture (Pinto & Coltrane, 2009), and ideology (Blair & Johnson, 1992), gender is one of the most critical factors that affect the determination of role and responsibility in the home (Blair & Johnson, 1992; Cohen, 2004; Shelton & John, 1996).

Multiple studies have investigated relationships between gender and division of labor in couples in the home environment. In those studies, perceptions of fairness towards the division of household labor are considered an essential factor to determine whether or not people feel satisfaction in their family life (Shelton & John, 1996; Thompson, 1991). They showed that women perceived reduced levels of depression, and increased levels of well-being in their family life and marital relationships, when they consider that their husband shares house chores (Coltrane, 2010; Lye & Biblarz, 1993; Shelton & John, 1996). On the other hand, men's satisfaction was influenced not by their perceptions of whether labor was divided fairly, but rather by the amount of time they spent on household labor (Blair & Johnson, 1992).

In relation to gender roles, STS scholars discussed how mass production of labor-saving domestic technologies (e.g., dishwashing, vacuuming, laundry, and dusting) influenced the division of labor in the home (Cowan, 1983; Shelton & John, 1996). Many early forms of labor-saving technologies did not actually fulfill their purpose and instead merely shifted labor. Cowan described this phenomenon as "ironic": newly implemented appliances changed social expectations on the levels of work to be accomplished by women (Cowan, 1983). For instance, although the washing machine was developed as a labor-saving device, this did not reduce the workload; rather, it changed standards of clothing hygiene. This line of literature points out that technologies have functioned to reallocate women’s labor to newly added tasks, and applied high standards to domestic chores (Shelton & John, 1996).

As the percentage of nuclear-family households decreases, more recent studies have examined the unique characteristics and situations that influence the division of labor in home settings. Studies showed that the type of household (e.g., single, divorced, or same-sex, with or without children) (Patterson, 1995) influenced how families negotiate chores and collaboratively accomplish household tasks with other family members.

For instance, same-sex couples have a more equal division of labor, regardless of employment status. A study on the division of labor in same-sex (male) couples showed that participants expressed greater satisfaction in their division of labor, compared to heterosexual couples. Also, they reported an increased level of satisfaction when there was less discrepancy between their ideal division of labor and actual practices (Tornello, Sonnenberg, & Patterson, 2015). Division of labor was not affected by whether a father and child were biologically related. Conversely, in female couples, the children's biological mother tended to spend more time on childcare, while the non-biological mother tended to be more involved in pair employment. However, they still shared household work and were equal decision-makers (Patterson, 1995).

Several studies have examined how culture affects the division of labor within the family. For example, in China, Japan, and South Korea, women's satisfaction in marriage was negatively related to their stress from housework. Chinese participants reported greater satisfaction in their marriages than those from the other two countries. This was explained by the Chinese cultural ideology of gender equality that differs from those of the other two countries (Oshio, Nozaki, & Kobayashi, 2013). Generally, studies show that in countries where egalitarian gender norms (i.e., beliefs that spouses should work equally at home) are pervasive, people tend to show a reduced level of satisfaction in their marital relationships when chores are divided unequally (Greenstein, 2009).

Although most studies focused on the division of household labor between married couples, some studies examined the division of labor in parent-child relationships, or between siblings. A study investigated chores in the family with children between 2 and 17 (White & Brinkerhoff, 1981). The results showed that 84% of the children in the sample did regular chores around the house. Other studies more directly examined how the interaction between parents and children influenced children's participation in household work. For example, Hammond and Carpendale showed how mothers promoting children's participation in household work, positively affected children's temperament and helpfulness (Hammond & Carpendale, 2015). Conversely, parents' lack of clear expectations and consistency negatively influenced children's participation in their household work (Klein, Graesch, & Izquierdo, 2009).

Division of labor in siblings was another area that researchers examined. Although gender is one of the critical factors that influence the allocation of adults' tasks, children's division of labor is determined by age, birth order, and number of siblings (Punch, 2001). For example, researchers showed that older children were more likely to be involved in household chores than younger children. Also, although both boys and girls equally participated in work, as children become older, girls spend more hours for household work than boys (White & Brinkerhoff, 1981). Types of chores also vary depending on the gender of children.

Given the importance of considering the generational division of labor, in this study, "division of labor" is a broadly defined term that encompasses the partition of household work among family members regardless of how they are related, including couples, parent-child, and siblings.

2.4 Home technologies for family collaboration that affirm or challenge existing social dynamics

In previous home technology studies, families' collaboration has been continuously investigated as important design factors; however, there were two ways of dealing with family collaboration. One group of studies understand families' existing ways of collaboration and follow them as a way to enhance their existing strategies. The other group seeks how technologies can challenge existing social dynamics by looking at division of labor and gender roles.

First, studies have investigated the role of technologies in facilitating families' collaboration of domestic work. By promoting family members' awareness of each other's location (Brown et al., 2007), schedule (Neustaedter & Bernheim Brush, 2006), and current status (e.g., emotion, health data), studies showed how technologies helped the family coordinate their daily routines and achieve tasks (e.g., health goals) when they are together in the home, and apart. Examples include work coordination in specific home contexts (e.g., farm (Leshed, Håkansson, & Kaye, 2014)), calendars that facilitate communication of schedule between family members (Bødker & Grönvall, 2013; Neustaedter & Bernheim Brush, 2006; Plaisant, Clamage, Hutchinson, Bederson, & Druin, 2006), reminder systems (Davidoff, Zimmerman, & Dey, 2010), effective errand coordination (Sohn, Lee, Zhang, Dearman, & Truong, 2012), parents managing their children's routine (Davidoff, Ziebart, Zimmerman, & Dey, 2011; Palen & Hughes, 2007), facilitating the family relationships (Shin, Rheu, Huh-Yoo, & Peng, 2021), and improving health management (Grimes, Tan, & Morris, 2009; Lukoff, Li, Zhuang, & Lim, 2018). For example, to alleviate difficulties in managing the family routine, Neustaedter et al. developed a family-centered calendar, LINC, which facilitated family's awareness of other

members' activities and changes (Neustaedter & Bernheim Brush, 2006). This increased awareness was identified as a facilitator which enabled an effective management of family routine in a more flexible manner.

While the first group of studies focused on more surface level of family collaboration by using their existing relationships or social dynamics, the other group of studies investigated how technologies challenge existing social, gender, and power dynamics among family members (e.g., division of labor, gender roles). They showed the relationships between social dynamics in the home environment, and the use of new and existing home technologies (Bell et al., 2005; Bell & Dourish, 2007b, 2007a; Bell & Kaye, 2002; Forlizzi, 2007; Forlizzi & DiSalvo, 2006; Tolmie, Crabtree, Rodden, Greenhalgh, & Benford, 2007; Wagman & Parks, 2021). For example, Forlizzi's interview study showed how the attributes of robotic technology (e.g., autonomous, semi-intelligent) challenge the existing social dynamics among family members, particularly regarding families' division of labor and gendered roles (Forlizzi, 2007; Forlizzi & DiSalvo, 2006). Similarly, Rode investigated how families collaboratively work on digital housekeeping, particularly computer security and privacy matters (Rode, 2010). The study results suggested that gender identity is the critical determining factor that shapes the role and responsibilities on domestic work within the family. By highlighting the importance of credibility for the appropriate use of Location-Based Service (LBS), Boesen et al. also showed how system design should consider the power relationships within the home (Boesen, Rode, & Mancini, 2010). These studies showed how sociotechnical systems can influence and reshape the existing social roles, responsibilities, and dynamics of the home environment.

Building upon these previous studies, my study seeks how technology design can challenge existing family dynamics rather than affirm families' current ways of managing their

sleep issues. I design the family-sleep management systems that incorporate division of labor and family interconnectedness and implications from their experiences with the system. By designing and implementing family-based sleep technologies in the home, this study provides opportunities to consider family members' collaborative and balanced role in managing sleep in their day-to-day lives.

2.5 Research questions

Based on the previous work, I developed five research questions that guide this dissertation project: 1) How do families work towards establishing their sleep routine in everyday lives, particularly with young children?; 2) What are the facilitators that help, and barriers that hinder, families in managing sleep routine?; 3) How does the implementation of family-based sleep management tools influence families' sleep management practices and their existing social dynamics?; 4) What are the perceptions of families in using family-based sleep management tools that intend to challenge existing social dynamics within the home context?; 5) What are the design implications of home technologies targeted for improving family sleep management and wellness? To investigate these research questions, I conducted a two-phase study. For the first two research questions, I conducted forty semi-structured interviews with twenty parents of young children and captured their daily experiences with managing sleep in their family (Study 1). The findings from the first study inform the design of two types of family-centered sleep management systems that will be used in the second study. For the next three questions, I conducted an in-the-wild study that includes field deployment for two weeks and semi-structured interviews with families of young children (Study 2).

CHAPTER 3: STUDY 1

In this initial phase of my dissertation, I interviewed twenty parents of young children to understand their current practices of sleep management in the family context. Understanding how families work towards establishing their sleep routine in everyday lives, and identifying facilitators and barriers in managing sleep, allowed me to discover core issues in sleep in the home context that have not been discussed as the central theme in previous sleep studies. Study 1 was published at the ACM CHI Conference on Human Factors in Computing Systems in May 2022 (DOI: 10.1145/3491102.3517535) (Shin, Peng, & Lee, 2022).

3.1 Methods

In spring 2021, I had two separate sessions with each of the twenty participants. Data were collected in forty semi-structured interviews over Zoom video conferencing. With participants' permission, all of the interviews were audio-recorded and transcribed verbatim. Each session lasted approximately forty-five minutes. To better understand participants' sleep environment and sleep management practices, it is important to observe participants' home environment and relevant artifacts that are mentioned during the semi-structured interview. Due to the reason, I originally wanted to conduct in-home interviews (Shin, Chaar, Davis, Choi, & Lee, 2021); however, the university's institutional review board did not permit in-person contact with the research participants, because of the COVID-19 pandemic. Therefore, whenever participants mentioned their sleep environments, or artifacts they used to help manage sleep, I asked them to photograph these environments and artifacts, and to share the photographs with us afterward. They include participants' home environment, sleep assistive devices (fans, white noise machines, etc.), and children's toys. The photographs and associated narratives functioned as supplemental materials that allowed me to have a comprehensive understanding of

participants' descriptions. I also took field notes during each interview and referred to them during data analysis. The university's Institutional Review Board provided ethical approval for this study.

3.1.1 Positionality statement

One of the important considerations in qualitative studies is reflecting the researcher's positionality with respect to the study (Schlesinger, Edwards, & Grinter, 2017; Sweet, 2020; Wyche, 2020). In this section, I consider my positionality as a researcher in relation to the family-based technology design, and to the parents of young children, which provides a deeper understanding of ethical considerations and potential biases in conducting the study.

I have more than seven years of experience conducting design-oriented HCI research in the context of family-based health and wellness, in healthcare facilities and homes in the United States. As a designer who was trained in a traditional design field, I have studied and developed emerging technologies, including mHealth apps.

I am in my mid-thirties, a mother of a seven-year-old who attends an elementary school in the Midwestern United States. Commonalities between participants and me — being a woman in the Midwest, and the parent of a young child—provided opportunities to prompt participants' answers based on my background knowledge in parenting, and facilitated interaction during the interviews. Sharing similar backgrounds mitigated potential power dynamics between the researcher and participants that could easily have framed participants' knowledge as less legitimate or important. Also, showing sympathy for participants' experiences and knowledge, and using respectful language, allowed participants to lead the conversation with rich examples from their daily lives.

3.1.2 Semi-structured interviews

Each participant participated in two separate interviews. The first interview focused on mapping activity, allowing participants to actively lead the conversation without pre-determined interview questions; the second interview focused on a set of questions about the family's sleep (see Appendix A). Because I wanted to learn about participants' experiences with their family's sleep without a pre-determined frame, I applied a map-making activity so that participants could freely share their experiences, perspectives, and feelings (Lee, Šabanović, & Kwak, 2017; Lee, Tan, & Šabanović, 2016).

Inspired by Clarke's situational map (Clarke, 2007), participants devised their own map about their sleep issues during map-making activities (see figure 1). At the beginning of the first Zoom session, participants were given three keywords: 'sleep,' 'family,' and 'me.' Using sticky notes, whiteboards, or virtual drawing tools, participants generated twenty words that were related to the initial three keywords and explained how each of the twenty words was associated with their everyday life. Participants also chose the five most essential words to explain the three keywords that the interviewer had presented and explained how they related to each other. Throughout these processes, participants were permitted to conceptualize what "sleep behavior" is, based on their own experiences and views. Participants could freely construct the components and features of family sleep behaviors and identify what they considered relevant. Therefore, I did not restrict participants' discussions (e.g., by discussing only nighttime activities). If I had asked specific questions without first map-making, I would have framed participants within the researchers' definition of 'sleep behavior' rather than their own. The map-making allowed me to learn the genuine opinions of participants and their experiences related to their family's sleep, regardless of prevailing academic views of the topic. While they explained their maps,

participants actively initiated and led discussions, and I probed if more explanations were needed. Participants' explanations about their map were audio-recorded for data analysis. The interviews also helped me to establish rapport with my participants, which led me to invite them for the following phase of the study.

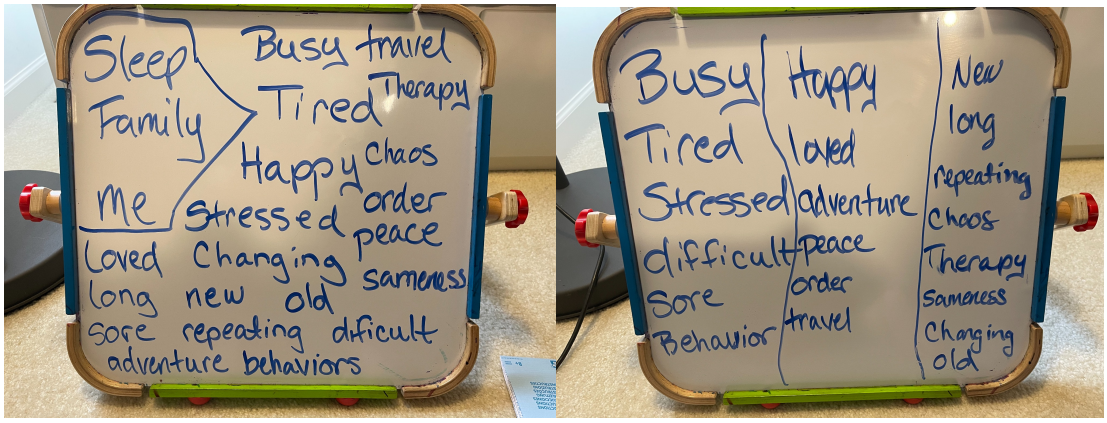

Figure 1. Examples of mapping activity outcomes during participants' first interview sessions.

3.1.3 Participants

Participants were twenty parents of young children. I recruited participants from the university's group mailing for parents and by word of mouth. Potential participants were screened using a Qualtrics survey to determine their eligibility. They were required to be (1) experiencing low sleep quality; (2) parents of at least one child aged between two and seven years; (3) comfortable with reading and speaking English; (4) willing to participate in video conferencing interviews (i.e., able to access to internet and with a camera-enabled device able to connect); (5) a resident in the United States of America; (6) willing to engage in a mapping activity; and (7) able to provide informed consent. I emailed participants who met the inclusion criteria and scheduled their first interview session after the participants signed informed consent.

I note that children were not the participants of the current study, and we only include parents' views on their family's sleep management practices.

The participants included eighteen women and two men (eighteen mothers and two fathers). The mean age of the study participants was 38.3 years (ranging from 27-47 years). The majority were married or in a domestic partnership (18/20 [90%]), women (18/20 [90%]), employed full-time (14/20 [70%]). In addition, 11/20 [55%] of participants were White and 8/20 [40%] were Asian. Annual household incomes ranged from less than $10,000 (1/20 [5%]), $75,000 - $99,999 (3/20 [15%]), $100,000-$200,000 (9/20 [45%]) to more than $20,0000 (2/20 [10%]). See demographic information for Table 1.

3.1.4 Data analysis

I applied a grounded theory approach for my study (Charmaz, 2014). A constructivist approach enabled us to understand participants' experiences and opinions without a predetermined frame. During the data collection period, the research team regularly held group meetings to share emerging themes from the map-making activities and interviews. I presented interesting findings and identified patterns to team members and discussed further interview directions. I used the field notes and the photographs provided by the participants to help me become familiar with the interview themes and contexts. These regular discussions allowed me to iteratively modify the interview questions to better evoke participants' experiences and ideas related to their family's sleep behaviors and facilitate identification of data patterns for further investigation.

ID	Pseudonym	Age	Gender	Occupation	Race	Child(ren)'s Age	Other Family Member(s)	Household Income ($)
P1	Jessica	27	F	Unemployed	Asian	2(F)	Husband	Less than 10,000
P2	Bryan	33	M	Student	Asian	2(F), 5 (F)	Wife	25,000 - 34,999
P3	Amanda	41	F	Full time	Asian	6(F)	Parents (Mother and Father)	75,000 - 99,999
P4	Michael	46	M	Student	White	6(F), 11(M), 16(M)	Wife	75,000 - 99,999
P5	Nicole	32	F	Full time	Asian	2(F)	Husband	More than 200,000
P6	Michelle	33	F	Full time	Asian	5(M), 6(M),10(M)	Husband	75,000 - 99,999
P7	Amber	37	F	Full time	White	3(M), 6(M)	Husband	100,000 - 200,000
P8	Lauren	40	F	Full time	Asian	6(M)	Husband	100,000 - 200,000
P9	Danielle	33	F	Student	Asian	3(F), 5(M), 6(M)	Husband	10,000 - 14,999
P10	Lisa	47	F	Full-time	White	4(M)	Husband	100,000 - 200,000
P11	Mary	32	F	Full-time	White	1(F), 3(F)	Husband	100,000 - 200,000
P12	Maria	41	F	Unemployed	White	8 [a] (M), 9(M), 11(M)	Husband	100,000 - 200,000
P13	Angela	43	F	Full-time	White	3(M), 4(M)	Single Parent	50,000 - 74,999
P14	Lindsay	41	F	Full-time	White	6(M), 13(F)	Husband	100,000 - 200,000
P15	Tara	39	F	Full-time	Asian	6(F)	Husband	25,000 - $34,999
P16	Leslie	43	F	Full-time	White	6(M), 8(M)	Husband	100,000 - 200,000
P17	Karen	38	F	Full-time	White	3(F), 7(M)	Husband	More than 200,000
P18	Jasmine	45	F	Full-time	White	6(F), 8(M)	Husband	100,000 - 200,000
P19	Julie	37	F	Self-employed (part-time)	White/ American Indian	1(F), 3(F), 5(F)	Husband	100,000 - 200,000
P20	Kristine	38	F	Full-time	White	5(F), 7(F)	Husband	Prefer not to answer

Table 1. Demographic information of twenty participants. Note: [a] P12's youngest child was seven when the participant was recruited, and turned eight shortly before the interview took place. M=Male, F=Female. Pseudonyms were used to de-identify participants.

Using NVivo Pro 12, I performed open coding for forty transcripts with these primary focuses. Because we focused primarily on the family's social dynamics and the unique underlying situations that affected their sleep, open coding resulted in codes that represented the family dynamics, associated challenges, and relationships with sleep. This allowed me to have upper-level themes that encompass the subthemes. Initial open coding of the transcripts yielded 1161 discrete codes regarding families' daily routines and sleep-related issues. I iteratively aggregated codes based on their commonalities until they were mutually exclusive; this resulted in 86 representative codes. These 86 codes were used to perform affinity diagramming. Each of 86 codes was written on a separate sticky note, and clustered by their relationships, including similarity, differences as well as hierarchy. The affinity diagramming resulted in three levels of themes, and allowed us to identify upper-level themes that encompass the subthemes. For example, high-level themes include 'opportunity for parents' alone-time after children's sleep,' 'time management and sleep,' and 'appropriate division of labor.' Mid-level themes include 'parents' small activities for self-care,' 'parents' strategies to keep stable routine,' and 'motivations of having stable routine.' Low level themes include 'influences of naptime,' 'delay in children's routine and parents' sleep,' 'reminder system,' and 'transition object for bed.'

3.2 Results

In my study, parents shared their opinions about the importance of a healthy sleep routine and described various factors that disrupted their family's healthy sleep. Those disruptive factors included children coming into their parent's room at night, night terrors, frequent bathroom use, movement of family members in bed, balancing naps and nighttime sleep, discrepant schedules among family members, and disciplinary issues with children who disregard routine. Families also shared their efforts to find or create physical sleep environments that suited them. These

findings, such as the benefits of providing low light and soothing sounds or white noise, echoed previous studies of family sleep (Cherenshchykova & Miller, 2019, 2020; Choe et al., 2010).

The results indicate that the most critical factors that affected the family's sleep involved more than the nocturnal bedtime routine. The deeper issues of sleep stem from the transition to parenthood, and to being expected to provide constant attention and care for their children. The participants noted that, after they had children, their criteria to determine whether they had "good sleep quality" shifted from an individual experiencing sound sleep at night to more complex issues involving family dynamics. For example, good sleep can be achieved only if the children have an early bedtime and sleep through the night. If a child's sleep routine was not settled, this drastically affected the sleep of parents and siblings. This new perspective on good sleep shows that collaboration among family members is essential.

In this section, I report major findings in my participants' experiences with family sleep, which are associated with family dynamics and individual situations. They include: 1) children's sleep means an opportunity for parents' alone-time and self-care; 2) managing both daytime and evening routine is essential for on-time, quality sleep; 3) appropriate 'division of labor' and mutual care in the home to achieve a family sleep routine; and 4) challenges emerge when family dynamics are altered.

3.2.1 Children's sleep means an opportunity for parents' alone-time and self-care

When participants described their daily, sleep-associated routine, they frequently discussed how their lives had changed drastically after they became parents. For the participants, alone-time and opportunities for self-care were possible only during children's sleep. Attending to a child's basic needs took much time and labor from parents and made it hard to focus on self-care during the daytime.

Thirteen participants (13/20) described this time as "my time," "me-time," and "time for me-things" and said that they used this time to improve their self-care and unwind from the pressure of the day's obligations, including work, study, and childcare. Because of their busy routines, they found relaxation time - both physical and mental - to be more precious.

For example, Karen mentioned that although she enjoyed and valued the time with her children most, having multiple roles throughout the day made her desire a chance to relax in the evening.

I think it's the time that you can be selfish. I don't think it's the most valuable time, I like being with them. But I think it's necessary. It's the only time that you can get to breathe. And honestly, by that time, by 8:15 at night, when we've been up since 7:00, and we've been with kids the whole time, and working full-time jobs and cooking dinners, making lunches... there's nothing left of me by that point. So I'm just going to lie on the couch. So I don't think it's my most valuable time of the day, but I think it is my most relaxing time. It's really normal time I feel relaxed in the day. (Karen, 38 years old, mother of two children)

As the quote shows, her alone-time provided her with comfort, relaxing moments, and opportunities to focus on her own needs instead of her family's schedule and routines. Other participants shared how they secured more extended self-care time by giving their children a fixed bedtime. For Amber, securing self-focused time for parents was as important as inculcating healthy everyday habits for her children. For this reason, she gives her sons a countdown before bedtime.

We have a relatively strict routine. For a few reasons. I just want to instill healthy sleeping habits for my kids, but also we want our kids to go to bed so that we can have a few hours to ourselves. Yeah. So at, or maybe 10 minutes before bedtime ... We'll give them a countdown. We'll say, "It's 10 minutes before bedtime, five until bedtime, one minute." (Amber, 37 years old, mother of two children)

In a similar way, Nicole mentioned that she would do anything for her daughter's regular, early bedtime at 7 pm because it provides her with more free time; this is her only opportunity to focus on herself.

To me, I would sacrifice anything just to put her to sleep early… So keeping her doing this routine is stressful, but personally, as long as she cooperates, this is not stressful for me at all. In fact, actually I love this. The reason why I say that is, because once we put her down to sleep, we have all the time to ourselves, and it's pretty much the only time I have to myself. (Nicole, 32 years old, mother of a child)

Therefore, she encouraged her daughter to follow a strict bedtime by the time she was five months old, which provided Nicole with great satisfaction. She mentioned that if she ever has a second child, she will follow the same sleep education and patterns for that child as well.

For parents of children who did not follow a routine, limited opportunities for self-care had a significant impact on their own sleep time. Participants mentioned that although both mother and father are engaged in bedtime routine, children often make requests to their mothers at bedtime (including for their mother to stay with them, or bring them water, or give them

another hug). When children sleep less soundly, this often leads to revenge sleep procrastination, particularly for mothers: staying up late to have time for themselves, despite being aware of the probable negative consequences the next day.

For example, participants Julie and Kristine described how their children's unhealthy sleep routines reduced their self-focused time, which made their sleep drastically later. Because Kristine's daughter would fall asleep only at 11 pm after making multiple excuses not to sleep (e.g., more water, another hug), Kristine often stayed up until 2 am to have some time for herself. One of Julie's three daughters repeatedly - and loudly - disobeyed the bedtime routine. Julie and her husband were concerned that this would disturb the other children's sleep. Calming the child at the end of the day took a significant amount of time and energy, and Julie said that she wanted to have more time for herself afterward - which led to bedtime revenge procrastination.

But since having kids, I oftentimes will... After that then they go to bed is that I feel is my time. And so I want to extend that my time as long as I can. So I go to bed at 11:30 sometimes almost midnight if it's the coming towards the weekend. Like, last night I didn't go to bed until midnight because I just wanted that time…And so that helps me just kind of... Even though I know I'm going to be tired in the morning and I know I shouldn't... I really should just go to bed for my mental health, maybe not my physical health, but for my mental health I stay up later just doing me things. (Julie, 37 years old, mother of three children)

During my interviews, nine parents also shared how they used their free time after children's bedtime to ease the tension built up from their daily routines. After their children fell asleep, parents indulged in activities that they could not do during the day, including hobbies

(e.g., sewing and knitting) and self-improvement (e.g., reading books)(see figure 2 and 3). As a single mother, Angela had difficulties when her two sons spent the whole day with her because of illness (and, later, because of the pandemic). On such days, after her sons went to bed, she would knit. Her yarn collection helped her stay centered (see figure 2).

Yeah. So yeah, knitting and yarn are definitely things that make me feel centered, and help me breathe again. I think part of that is the rhythm of working through a row of knitting. It really helps me to breathe and center myself, so that's good. (Angela, 43 years old, mother of two children)

Figure 2. Angela's yarn collection, which makes her feel relaxed and centered.

Figure 3. Kristine's sewing machine and quilts.

The most frequently mentioned self-care activity that helped parents wind down at night was reading a book. Nicole said:

I also read before I go to bed. I don't do that every night, but I would say 80% of the times, I would read and that helps me sleep for sure… When I think about the non-fiction I read last year, they were mostly self-improvement books, or self-help books. (Nicole, 32 years old, mother of a child)

Other participants mentioned that they preferred to rest their minds with "mindless" activities — e.g., sewing television or social media —so that they can wind themselves down from the busy daytime routines (see figure 3). These examples show that children's sleep provided parents with the time to engage in self-care activities.

In summary, the results show that the criteria for "good sleep" drastically change when people become parents. The most important sleep agenda for the participants was their children's sleep, because it provides self-care time for the parents. This self-focused time is guaranteed only with the children's fixed bedtime routine and sound sleep.

3.2.2 Managing both daytime and evening routine is essential for on-time, quality sleep

To meet their primary goal of having children sleep, my participants reported that time management was crucial throughout the entire day. However, for families with young children, time is always a limited, valuable, and collective resource. How the family managed their time throughout the day affected the structured and on-time bedtime routine that led to a good sleep for both children and parents. During the interview, they shared how they planned their family's routines around their children's needs, such as naptimes and school schedules. According to my participants, mothers are usually in charge of planning and coordinating families' schedule. The participants said they always had "a list of things to do" in their head to maintain structured schedules. They emphasized the importance of maintaining a stable daytime routine to have a relaxed evening, and the combination of the two could result in a satisfactory day.

For example, eight participants (8/20) mentioned that with young children, planning their daytime activities to include regular nap times was a critical factor for a successful evening routine and stable sleep. Bryan's children often stayed up past 11pm if their daytime nap had lasted too long, and this made it difficult for him to plan daytime schedules. To avoid having irregular activities (e.g., shopping, dinner out) affect the sleep routine, many families planned such activities for after the children's naptime. Mary reported how her family tried to avoid scheduling anything around her daughter's naptime. Also, she shared how she planned everyday physical activities during the day and maintained better sleep quality for her child.

I'm trying this thing this year to do a thousand hours of play outside. So we've, even yesterday, we were outside two and a half hours. So I'm really trying that. And I've realized that the days that we're outside longer, we're more tired, so she's sleeping better. So that's helpful to me too. (Mary, 32 years old, mother of two children)

The daytime schedules and also the evening bedtime schedules and routines had an impact on the stable sleep of a family. Six participants (6/20) shared that they had a relatively early dinner, so that they could go to bed to prepare for their next day - especially if it was a regular school day. Maria's children were attending online school due to the pandemic, but the family has maintained an early sleep time so that they will be able to resume in-person school without complications.

Whereas now we're a bit more relaxed, because you can't win because they're not that tired. But I think we'll be more strict because they are going to go back to school part-time here in the next few weeks. So you have to get up, catch the bus and all that stuff. (Maria, 41 years old, mother of three children)

Although parents planned daytime schedules carefully, they did not always succeed. If children's bedtime routine were delayed or interrupted and they did not fall asleep on time, the parents' evening routine and bedtime were also affected, and eventually parents felt more fatigue. Tara's daughter falls asleep quite late, and this affects her own sleep time. Because she can only sleep when she has finished her housework and can begin preparing for the next day only after her daughter has fallen asleep, she needed to stay up until midnight.

After she goes to bed, I need to do some housework and I also need to prepare for my job. Some work for my job too. I teach and I need to prepare the teaching materials... It's because during the day I have to be with her and only after she went to bed or fall asleep, I can work. I can do whatever I need to do… I always tell myself that good for our health and you should go to bed early. Go to bed early, go to bed early, but every day I end up with bed... Yesterday, I went to bed at 2:00am. (Tara, 39 years old, mother of a child)

These quotes suggest that children's irregular sleep patterns and late sleep directly influenced their parents' evening routines.

To manage the family's time and secure a certain amount of sleep at night, parents used various strategies to maintain their children's bedtime routine. These included rewards, reminders, comfort objects (e.g., emotionally significant stuffed animals) and communication strategies. Karen created a reward basket to motivate her children to maintain a healthy routine (see figure 4). If children followed their responsibilities (e.g., using the bathroom appropriately at bedtime), they had a chance to choose a small toy from the basket. Kristine's family created a token system using yarn-wrapped balloons (see figure 5). Children receive three of them each night, and may 'spend' them on getting out of bed for any reason they want (e.g., a drink of water, or another hug) at a cost of one token each time. Maria needed to verbally remind her sons to follow the routine every night.

And then about 9:30, used to be 9:00 but lately they ask for an extension of their bedtime. 9:00, 9:30 we get upstairs. And honestly the kids, they're being loud, they're jumping around, they're

goofing around. Guys, it's time to get to bed, you're going to be tired tomorrow. We're tired, we want to sleep, get to bed. (Maria, 41 years old, mother of three children)

Figure 4 (left). Participant's reward basket for children's improved routines.
Figure 5 (right). Participant's yarn tokens for children's improved routines.

Nicole's daughter was still developing literacy skills, and thus used a more visual reminder system: a chart with pictures of morning, naptime, and bedtime responsibilities (see figure 6). The chart helped the child maintain the routine, regardless of which adult was in charge - mother, father, or even a babysitter. Nicole mentioned that she particularly desired for a more structured routine for her daughter to alleviate her postpartum anxiety and having the chart was definitely helpful for securing more sleep and rest for herself.

This subsection shows that a family's bedtime at night appears to be affected by time management throughout the day, and by a stable evening routine; these also provide improved sleep for both children and parents. The connection between the routine and their quality of nighttime sleep led parents to develop different strategies for their children to maintain bedtime stability.

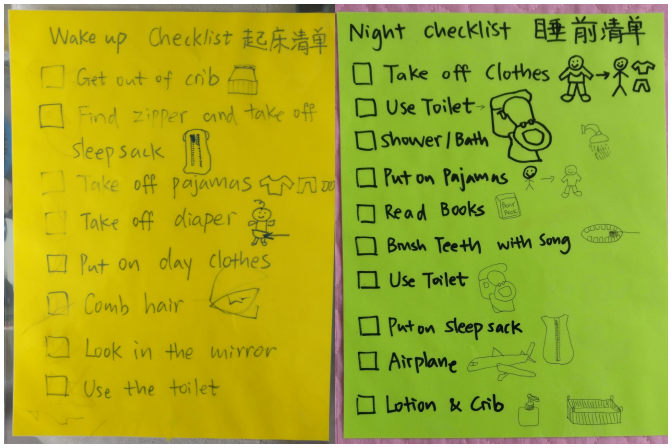

Figure 6. Nicole created a chart with pictures of bedtime and morning responsibilities.

3.2.3 Appropriate 'division of labor' and mutual care in the home to achieve a family sleep routine

The findings suggested that the implementation of appropriate household management strategies was critical for a successful sleep routine for the participants. To successfully collaborate to manage their routine, parents divided their tasks depending on their daily schedule, and taught children small household responsibilities to manage the family life effectively. Many participants mentioned that having other relatives nearby (e.g., the children's grandparents, aunts, and uncles) was helpful in terms of coordinating their lives. Furthermore, participants told me that they provided more sleep for their other family members by adjusting their responsibilities to accommodate each other's needs. Although these practices happened throughout the day and were not restricted to bedtime or nighttime sleep, participants noted that coordination of efforts and division of labor affected the family's routine and eventually their sleep.

Twelve participants (12/20) mentioned that their families divided their housework based on who was available at a given time. This was the most frequently mentioned type of coordination of labor and was particularly helpful for securing sufficient amounts of sleep for parents. For instance, if one of the parents were in charge of the family's morning routine, the

other parent contributed more to the family later in the day. Kristine and her husband took turns putting their children to bed, depending on which parent had work the next day: that parent could go to bed early without having to manage the children's bedtime routine.

So for us, even actually when it comes to putting the kids to sleep and stuff, it all depends on who's working the next day because I work during the week and he works the weekends… When I'm at work all day, he'll cook dinner. When he's at work, I'll cook. (Kristine, 38 years old, mother of two children)

Kristine mentioned that she and her husband try to handle their responsibilities as a "team." For her and her husband to get enough sleep, it is necessary to help each other. Similarly, Nicole's husband was a morning person as he wakes up before 6am, whereas Nicole herself was not; therefore, he was in charge of their daughter's morning routine, and Nicole could get more sleep even after their daughter woke up. In the case of six out of twenty households where mothers are stay-at-home parents or part-time employees, mothers in the family had dominant childcare responsibility as their spouses had more intensive work schedules. In these cases, participants emphasized the importance of role-sharing with their husbands to get necessary things done during the day (e.g., going to a clinic appointment or bank) or have time to breathe (e.g., having a break during her busy routine). Jessica shared that they switched their weekday roles on the weekend (e.g., a father spends more time with the child), which helps her to understand her husband and vice versa.

Seven parents (7/20) emphasized the importance of teaching children small household responsibilities, so that they would know what was expected of them in the family and be able to

contribute to the household as they grew. This role-sharing enabled parents to have more help in accomplishing the routine, and children could better understand their household structures and rules. In Michael's family, as the oldest son became able to take care of his siblings, the parents could leave them by themselves for limited amounts of time. When one parent had to leave home before the other could return, the children could stay by themselves if the school had closed for a snow day. In that case, they divided the responsibilities among the children and efficiently reduced tension about who would do what.

In other words, the older brother wasn't watching him, he was watching himself, but the older brother was responsible for the youngest, for the sister. So that was our approach to it. So that we think help reduce the tension between the boys who are responsible for their sister. (Michael, 46 years old, father of three children)

Because of Michael 's busy routine as a PhD student, structure was particularly important for his sleep schedule. If part of his routine were obstructed, he needed to stay late on campus and finish his work. Teaching his children household responsibilities eased the demands on him and his wife and helped them maintain their schedule and be on time for tasks throughout the rest of the day.

For some participants, having relatives nearby was quite helpful. For instance, Amanda lived with her parents; as a result, she was able to briefly catch up on lost sleep while her parents helped take care of her daughter.

And if [my parents] feel I don't have enough sleep, they will watch my daughter for maybe one hour, two hours in the afternoon, so I can take a longer nap, sometimes. (Amanda, 41 years old, mother of a child)

To provide more rest for other family members, participants flexibly adjusted their responsibilities to accommodate each other's needs. Although it can involve greater sacrifice for one party, the other party has more time for rest and is able to maintain wellness. On weekends, Karen and her husband take turns sleeping with their youngest daughter, who frequently comes to their bedroom at night. If one of them sleeps with the child, it is convenient to put her back to sleep when she wakes up.

My husband and I actually on the weekends we split [the task], so one of us will sleep on Friday night and sleep in [her daughter's] bed while the other parent sleeps with [her daughter]. And on Saturday night, we switch so that you can sleep all the way through. (Karen, 38 years old, mother of two children)

As the quote shows, in this way, the other parent can sleep through the night, and the other party can have a more extended amount of sleep until morning.

This subsection showed how the effective division of labor can help a family achieve a successful sleep routine. Participants' experiences showed that sharing roles, responsibilities, and providing care are necessary to manage their everyday lives and improve their families' sleep. In particular, my results indicated that the division of labor, which was critical to managing sleep, involved not just spouses, but also older siblings and extended family members.

3.2.4 Challenges emerged when family dynamics are altered

Although families tried to establish and maintain a desirable bedtime routine and healthy sleep, they were not always able to do so when life situations changed - either expectedly or unexpectedly. My results showed that many factors dynamically influenced family routines and sleep patterns, including the developmental stage of the children and changing life circumstances (e.g., travel, visitors, and the COVID-19 pandemic). All of my participants (20/20) devised various coping strategies to handle these changes. The effectiveness of these strategies is critical for maintaining sleep.

First, children's needs change as they enter new developmental stages, and thus parents are asked to meet new requirements. One participant described her parenting and disciplining efforts as “just trying to figure it out as it goes.” For my participants, parenthood and family life are learning processes that involve new requirements, mistakes, and reflection. They shared how their ongoing and continuous efforts improved their sleep training and helped them establish a stable life as a family. For example, in Michael’s family, children’s screen time at night was an ongoing discussion topic as children became older. Because children’s screen time had a significant impact on their sleep and associated parental stress, parents frequently discussed how much screen time was allowed for each child, and when they could use the devices. As the children grew, the family's rules on bedtime screen use changed based on their schedules and needs. Angela also shared her perceived need for continuous learning when training her children with a stable sleep routine. She mentioned that although she found effective strategies that initially seemed to work for her children’s sound sleep, they often did not work when children met new developmental stages.

I feel like every time we start to get to a stage where I feel like we kind of understand how this is going, they're always growing and changing…And I feel like we're still a work in progress, right? We're still tweaking things as they go. But we've figured out some good stuff that is working. And once I figure out something that's working, I'm sticking with it. (Angela, 43 years old, mother of two children)

For her, there was no 'one size fits all' bedtime strategy applicable to different periods of her children's developmental stages. She learned to be flexible and established good strategies. In Jasmine's family, her children, aged six and eight, recently developed a fear of the dark. To comfort them, she and her husband spent extra time with them, and moved the two children's beds into the same room. This was a significant success, because it both assuaged the children's fear and facilitated the family's evening routine.

And so we put the beds in the same room, and now they feel like they're not alone because they are a little bit afraid of the dark, and those things, so. It's around 9:30, or maybe a little bit later by the time all of that is done. They usually fall asleep within 10 minutes, I'd say… Getting them, I think that was actually a really big key to moving forward. (Jasmine, 45years old, mother of two children)

As the quote suggests, they developed the new strategy based on their children's recent behavior patterns associated with sleep, and the newly implemented bedtime environment was successful for the family.

Figure 7. One participant's children recently started to sleep together as they entered a new developmental stage: being afraid of the dark.

For my participants, training children to accept a bedtime routine involves many tests and a learning process. They emphasized the importance of acknowledging that parents also can learn from uncertainty and new experiences, and use them as an opportunity to improve the family's lives (see figure 7).

Visits were another frequently mentioned alteration to family routine: either by the family to another region or by a guest to the family's home. Such visits involved sleep environment changes and breaks in routine (e.g., shifted bedtime) and often had a residual negative impact on the family's sleep after the regular routine had resumed. To alleviate the impact on their routine, five families (5/20) shared that they developed strategies for sound sleep, such as keeping the same bedtime as on normal days or traveling with children's attachment toys or white noise generators. Karen mentioned that whenever they were on a trip, they still had "quiet time" and kept the children on the same bedtime. Because she has two children under seven, keeping a structured routine even during a trip is important for their physical and emotional condition.

We try as much as possible to keep our daily routine. So if we take a vacation, we still try to have quiet time and bedtime might be a little bit later, but we still follow everything. (Karen, 38 years old, mother of two children)

During the interview, three participants (3/20) mentioned that the degree of adherence to bedtime routines depended on with whom they traveled and their travel destination. If they were visiting people with whom they did not have as strong a bond, it was more difficult to insist on adhering to their own family practices.

It depends a little bit on who we're with. So we'll often stay with [my wife's] brother's family. They're probably a bit stricter than we are about routining in TV and stuff. But like one of the things that's challenged there is their kids go to bed really early, and they wake up really early. And me as a cardinal sin above all is waking up early because that's the time that I want to get up and read, I don't like that. So when my kids, when they get up at 6:00 AM at their cousin's house, I'm not a big fan of that because then they're worn out and they're tired, or we'll sometimes stay with [my wife's] cousin. They don't have any rules. They have no rules about when kids go to bed, about video games and it drives me crazy….Like we stay with my mom and dad, or often I'll just tell them, get off... I'll tell my kids, get off the TV, go do something. When we're there, then we'll insert ourselves in the situation. But when we're with cousins, then it's maybe less so, I guess. (Michael, 46 years old, father of three children)

Unexpected circumstances and issues, such as the COVID-19 pandemic, were significant contributors to less sound sleep and increased anxiety and fatigue. During the interviews,

mothers, particularly those who worked full-time (14/20), related their difficulties in maintaining schedules because the pandemic had caused imbalances between work and family lives. Uncertainty led participants to worry about changes to their life circumstances (e.g., work and school now being done from home). Many had not slept well (i.e., woke up more than 10 times a night), and some had insomnia (i.e., took more than an hour to fall asleep). For example, Angela, who was a single mother for two sons, had established stable sleep patterns for her children before the pandemic. But, once the pandemic began, one of the children awakened screaming every twenty minutes. To comfort him, she stayed with him until he slept again, but this was time- and energy-consuming and negatively impacted her own sleep and daytime functions. To alleviate the difficulties associated with unexpected circumstances, other participants engaged in simple therapy (e.g., online counseling, parenting groups) or meditation, and tried to have open communication with their families. Amber often had the opportunity to explain her feelings and situation to her children. Explaining difficulties openly provided comfort to the family. Because of her husband's obligation for work, she was the one who spent most of the time with her children and worked from home at the same time.

I don't know if this is necessarily the best plan or not, but particularly during this pandemic, sometimes I'm just not having a good day. There's just a lot happening for me. And I'll tell them, "Honey, it's a hard day for mommy today, and I'm just kind of feeling a little stressed out, a little frustrated," whatever the case may be. And it doesn't necessarily make my day easier, but I think it's made my kids very understanding of when I am just sort of on my last nerve with them. (Amber, 37 years old, mother of two children)

She mentioned that after explaining the situation to her children and giving them some space from each other, they recognized her difficulties and talked about their feelings more openly. She tried to have daily, open conversations, which helped her family to become relaxed at the end of the day.

This subsection shows the necessity to understand family sleep from a transactional perspective. Established bedtime routines and strategies often were not sustained when internal or external factors changed life situations. Through trial and error, participants had to continuously find the best approaches that worked for their families.

3.3 Design implications

The findings from the interview study suggested how considering the social roles of sleep-support technologies (e.g., division of labor) can provide insights into technologies designed for home settings. The findings also showed that broadening the issues of sleep from individual to the whole family can help researchers, as well as users more deeply understand families' experiences of managing their lives for improved sleep. By considering family interconnectedness in managing sleep, designers and HCI researchers can take a more critical view of the issues.

First, my interview study addressed the importance of considering ***the division of labor*** in home settings (i.e., how they divide their work and share roles) when families maintain a stable sleep routine. This would be possible by reallocating labor (Rode, 2010) in managing family sleep routine. The integration of division of labor into the design of sleep-support technology can change the social dynamics among family members so that particular family members can no longer be considered to have sole responsibility for managing the family's sleep and instead can

strive to secure their own time and sleep. Therefore, assigning particular tasks related to children's routines to a particular family member can be one of the possible design directions.

Second, family-centered sleep technologies could focus on family's interconnected nature in managing sleep. In Study One, my participants' experiences showed that successful collaboration is necessary to achieve good sleep for families. Sharing roles, responsibilities, and providing care are necessary to manage their everyday lives and improve their families' sleep. In the new family-centered system, for example, systems can visualize ***the family's interconnectedness***, and they can provide families with opportunities to consider ***neglected but critical issues***, thereby improving their routine wellness behaviors. Here, I use "family interconnectedness in sleep" to refer to the status of one family member's sleep being influenced by another family member's behaviors. Visually showing the interconnectedness nature of the family, particularly for children, can be one of the potential design directions in this context.

In the next section, I discuss how these identified themes were used to develop two family-centered sleep-management systems that were deployed in participants' homes in the field deployment phase (Study 2).

CHAPTER 4: STUDY 2

Study 2 builds on Study 1 by 1) designing two types of family-based sleep management tools that incorporate main design implications from Study 1; 2) deploying two family-based sleep management systems in the home context for two weeks and understanding their perceived changes in the family routine practices; 3) understanding how families leveraged the systems from semi-structured interviews with families; and 4) suggesting future design implications of the family-based home technologies.

Study 2 is a feasibility assessment of the working prototypes. By deploying working prototypes of a family-centered sleep management system in the home environment, this phase of the study aimed to examine the family's experience with, and acceptance of, using technologies to help achieve a healthy bedtime routine. Based on these findings, I discuss how the user experience of sleep management systems can be further improved to support family's collaborative practices during their bedtime routine. Implications derived from the current phase will be used for future iterative design phases.

4.1 Overview of system design

In Study 1, through interviews with my participants, I found that although the bedtime routine and bedroom environment are critical to maintaining good sleep, they are not the *only* aspects relevant to understanding family sleep. Similarly, although the division of labor is emphasized as essential to maintaining stable routine in families' lives, it has not been used in sleep-management technologies as a design concept. In collaboration with two developers (app developer, programmer), I designed two types of sleep-management technologies that aimed to 1) incorporate the division of labor into the sleep management of families (System 1), and 2) expand the perspectives on family sleep by considering the family's interconnectedness which is

an invisible but critical component of family sleep (System 2). I describe detailed design components and concepts and relationships with the findings from the earlier phase in Table 2.

Main Findings	**Design components/ concepts**	**Systems**
Children's sleep & parents' self-care	The brightness of the heart lamp depending on children's behaviors (family connectedness)	2
Importance of structured and stable routine	Instrumental music to wind down children at their bedtime Stuffed animal to provide comfort (soft materials) Light token system to provide children with behavioral boundaries and guideline Prompt to follow a regular routine through pre-assigned tasks at specific time	1, 2
Balanced division of labor and care	Role-assignment in routine tasks	1
Challenges due to changes (e.g., travel, visitor, pandemic): Providing explanations for children, balancing consistency and flexibility in following bedtime routine to alleviate issues	Portable size (travel) Customizable routine/ role assignment (travel, visitor)	1, 2

Table 2. Design components and concepts derived from findings in Study 1.

4.1.1 Design rationale

After generating overall design directions with four main themes, I also laid out other design components for two systems, including type of stuffed animal, music played in the system, and shape and color of the lights. These design components are based on the factors identified as facilitators of family sleep during the interviews in Study 1.

For example, many parents mentioned that their child had a stuffed animal that functioned as a comfort object in their bed. As children developed an attachment to their stuffed animals when they were young, they felt it necessary to hold their stuffed animals during

bedtime. Based on this finding, I developed System 1 using stuffed animals (see figure 8). Many children in Study 1 had a fear of the dark, and thus they had an indirect light either in their bedroom or hallway while they slept to alleviate the issue. This inspired me to develop System 2, a heart-shaped lamp that could function indirectly at bedtime. Similarly, families often used soothing sounds or white noise to comfort children at night, and this inspired me to consider instrumental songs in the system design (see figure 9). Furthermore, Kristine's yarn tokens, and other families' stories of their children frequently making requests or coming to their parents' bedroom at night, inspired me to develop three-light tokens. By the provision of clear guidelines, children can learn how to follow the routine. Also, parents' reward charts or baskets to promote children's positive behaviors were direct models for the reward system in the app. In summary, each design component of the two systems was based on my participants' strategies and experiences related to their children's sleep (identified in Study 1).

There is also the possibility of personalizing and diversifying these components based on participants' preferences and traits. For example, each family could choose a type of stuffed animal that had meaning to them or specific music that reflects a family's shared memories. This information might easily be elicited from co-design activities with families. However, as the study aimed to test the feasibility of the four main themes identified in Study 1, I focused on the main design concepts presented in table 2. I kept other tangible design factors simple at this stage of the project. As a result, stuffed animals are chosen from the best-selling items from a popular brand (Jellycat). Similarly, music was provided from a playlist of the top 20 Disney instrumental songs, rather than being specific songs that are meaningful to each family. As well, the lamp was shaped like a heart (to represent love), and its light was red, which is less disruptive to sleep.

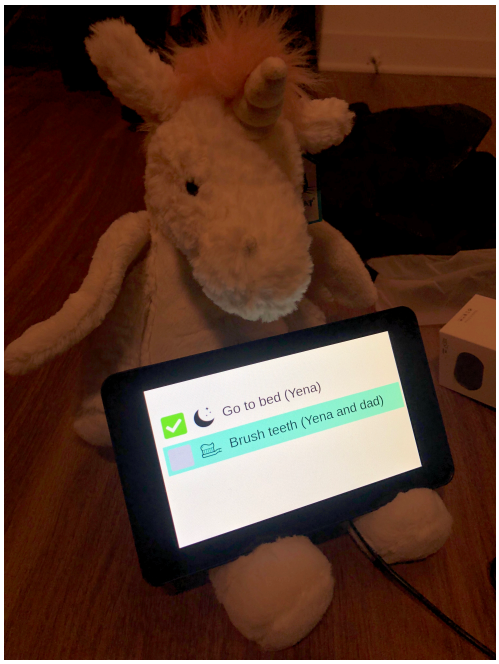

Figure 8. System 1 displays family's routine tasks and associated family members.

Figure 9. System 2 includes a heart-shaped light and three round lights.

4.1.2 Design process

After I developed detailed design ideas, I followed the iterative design method to create working prototypes. I first used storyboarding methods to contextualize the potential design of a family-based sleep system within the actual user environment (see figure 10). Storyboarding is a design method that illustrates an actual user scenario of design outcomes, and projects user

experiences (Truong, Hayes, & Abowd, 2006). It facilitates the communication of a design idea to others involved in the process, and allows designers to consider potential weaknesses and benefits of design outcomes.

To visualize detailed design ideas of both System 1 and 2, initial low-fi prototyping was done with Littlebits coding kits and electronics building kits to generalize initial design ideas (see figures 11-13). With the storyboard results, these low-fi prototypes were used to communicate basic design concepts and themes with the programmers. Over the four-month period, I regularly communicated with programmers and developed tangible design outcomes.

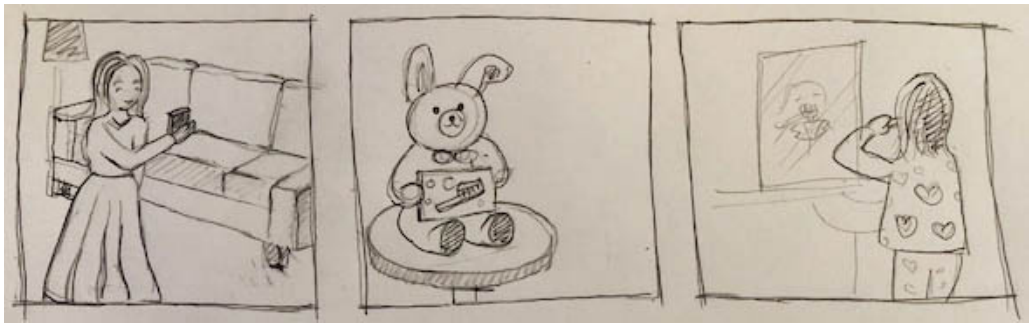

Figure 10. Example of storyboarding.

4.1.3 System 1: a companion for families to work together on children's healthy routines

By incorporating the concept of division of labor into the system design, this system aimed to provide users with opportunities to collaboratively work towards healthy sleep routine within the family context. To challenge the existing division of labor, I generated a function of assigning particular tasks related to children's routines to a specific family member.

The system has three main components: an iPhone-based mobile app, a screen mounted in a stuffed animal, and a Raspberry Pi computer. Parents registered their unique ID in the app. A

script on the Raspberry Pi needed to be configured with the participant's unique ID and connected to the home Wi-Fi in order for it to successfully read data posted from the mobile app.

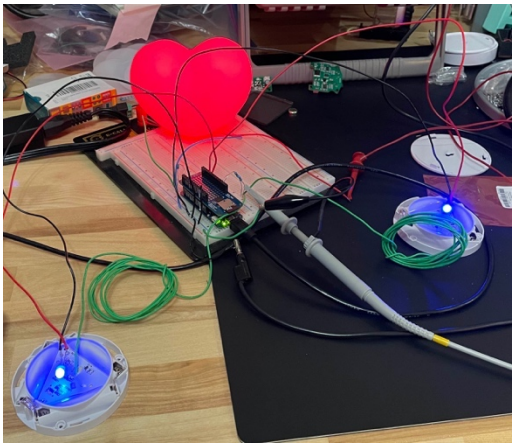

Figure 11 (top). Low-fidelity (lo-fi) prototyping with LittleBits coding kits.
Figure 12 (bottom). Electronics building kits to generalize initial design ideas.

The app allows parents to set up a tailored routine for their children at a specific time, and assign a particular routine task to a certain household member (see figure 14). In the system, parents can choose 11 routine tasks, including "Clean up Toys," "Eat Dinner," "Bath Time," Use the Potty," and etc. Participants can choose a task from the dropdown menu in the app and set up a specific time for the task. The list of routine tasks is elicited from the participants' descriptions on their children's bedtime routine during the interview phase. There is also a blank option which allows participants to make their own routine task for in case they want to add a task which is not listed in the system. The routine is stored on the mobile app using the Core Data

framework for iOS, which is an object graph that wraps an SQLite backing store. The saved routine is repeated everyday unless parents change it manually.

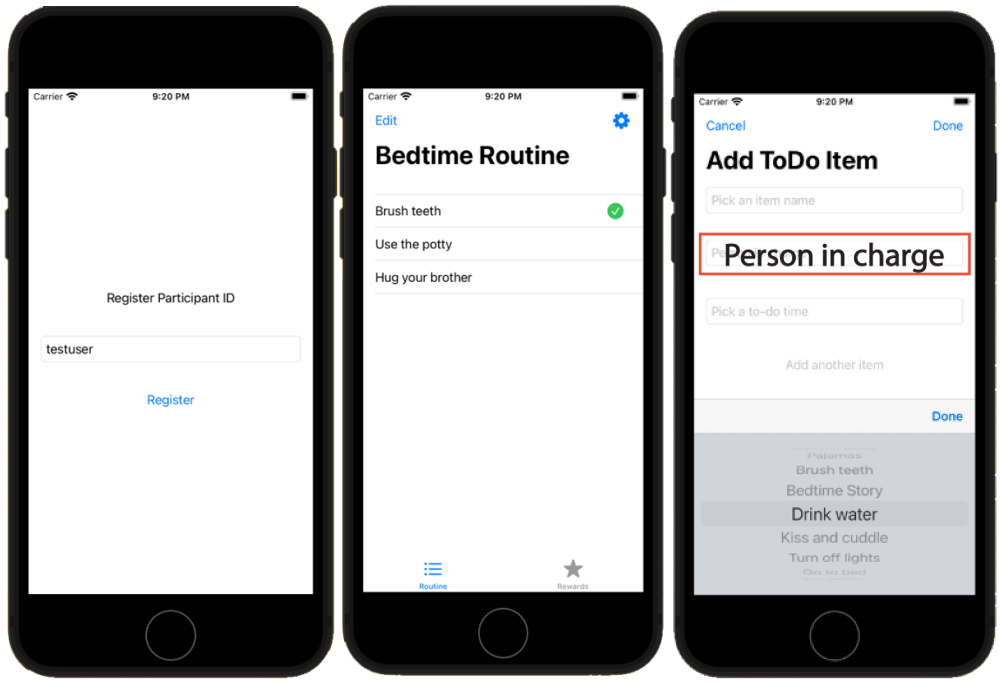

Figure 13. Screenshots of the iPhone-based app.

Once the routine is created, it send a read-only version of the TODO list to the server over an encrypted SSH connection using an API Key/Secret only known to the app and server. A flat file of the read-only data is stored in a directory dedicated to the participant and identified by their unique ID.

Studies showed that listening to classical music (e.g., instrumental piano music) before bedtime is effective to reduce sleep disorders as it can alleviate stress (De Niet, Tiemens, Lendemeijer, & Hutschemaekers, 2009). Disney movies are one of the popular sources of media content for children in the U.S. Half of U.S. homes with children under 10 years old have already subscribed to Disney Plus (Spangler, 2020), and its content, including movies and music, is

actively being consumed by young children. The system includes a playlist of the 20 most popular Disney songs from 2021; parents can assign songs to tasks. At the pre-set time, the stuffed animal hardware displayed an icon of a specific routine task and associated household members and played an instrumental Disney song related to a task (see figure 14).

For example, at 7:30 pm, the screen displays a bathtub icon, the word “Daddy,” and plays “Under the Sea.” Through the information on the screen and music being played, a child can recognize the time for a bath with their father. Instead of parents making constant verbal reminders for their children, the stuffed-animal companion will work as a mediator between parents and children to accomplish their daily tasks before bed.

The stuffed animal hardware, running a Raspberry Pi in kiosk mode, displays a web page generated on the server using React.js to show each item in the list and who is responsible. The React.js app is programmed to poll the server for updates to the data every 15 seconds. Whenever a task is completed, a new iteration of the read-only data is pushed from the mobile app to the server (see figure 15). Therefore, once the child completes each task, parents can check its status through the app. If the child follows their assigned routine well, parents can reward the child through the app.

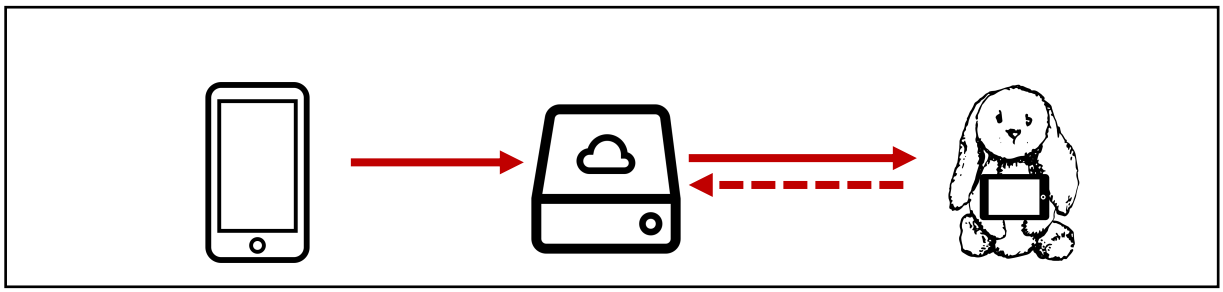

Figure 14. A simple diagram showing how the system communicates with the server and the app.

4.1.4 System 2: a lighting system for families to understand the family connectedness in managing sleep

For this interface, I applied the concept of family interconnectedness to the system design. In the current sleep management practices in the home context, children can hardly know the meaning or impact of disregarding bedtime routine on other family members' routine. From children's perspectives, the lack of parents' self-focused time and decreased quality of sleep due to their behaviors are invisible issues regardless of how critical they are. By providing children with opportunities to consider the consequences of their behaviors on other family members' status, including family's sound sleep, this second system aims to guide family members to establish a healthy routine as a family. The system has three main components: an iPhone-based mobile app, three round lights, and a heart-shaped light.

Each night, children turn the three round lights on at bedtime. A micro SD card stored in the light array needs to be configured with the participant's unique ID and the home Wi-Fi SSID and password prior to plugging in the light array. The lights function as post-bedtime tokens, and children may 'spend' them on getting out of bed for any reason they want (e.g., a drink of water or another hug) at the cost of one token each time. Whenever children call their parents to make a request, parents are be asked to turn each light off after they respond to children's needs. The brightness of the heart-shaped light increases with the number of round lights.

Once the light array is powered up, it posts its current status as a 3-character string to the web server over encrypted SSH connection using an API Key/Secret only known to the hardware and server. The status posts to the server whenever a light is switched on or off. When the server receives an updated status, it appends the entry to a text file along with a Unix epoch timestamp for when the log was received (see figure 16).

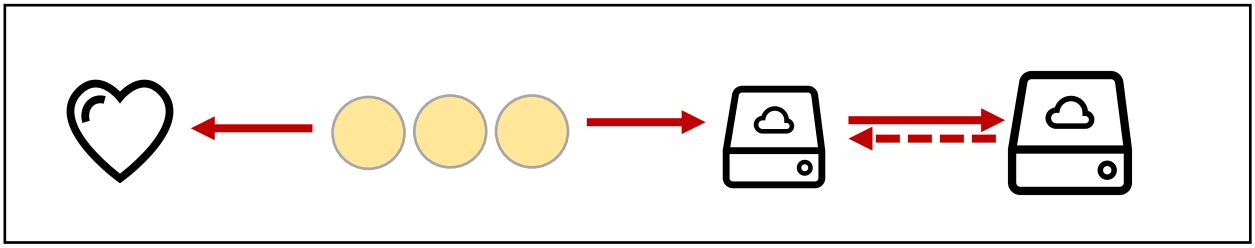

Figure 15. A simple diagram showing how the system communicates with the app.

Each night, the number of unused round lights are stored as a reward on the parent's app (see figure 17). The mobile app, after registering the participant's unique ID, begins polling the server every 15 seconds for light status updates. Each time the log data is received, it is parsed and grouped by date to include all log events within a predefined 24-hour period (e.g., if the end of a night is considered 8:00 am the next morning, then the app will group light events between 8am and 8am in a given day). After grouping the light events, the app iterates over each group to get the light status for all three lights in the array since they were last registered as "All On". Then, a log will be saved for each light-off event in the group, and rewards awarded for each light remaining on.

This system allows children to consider the meaning of their bedtime behaviors on other family members' time and routine by visually presenting their behaviors with lights.

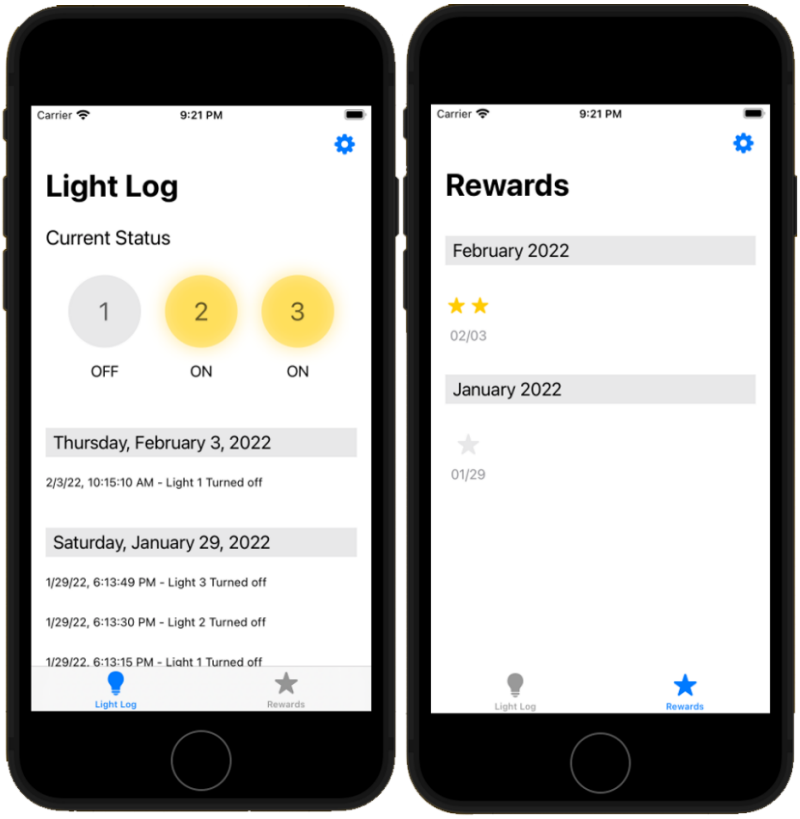

Figure 16. Screenshots of the iPhone-based app.

4.2 Study methods

Data was collected through a two-week field deployment in participants' homes and follow-up semi-structured interviews over Zoom video conferencing within a week after the field study. I used the field deployment study as it was necessary to understand how users adopt the systems and incorporate them into their bedtime routines where other social actors and factors come into play. A two-week period is within the common range for field deployment studies (e.g., one week (Jones & Merritt, 2017), two weeks (Heshmat et al., 2020)) where participants can adopt technology-mediated platforms in their everyday lives and share their perceptions of them. Because child participants were aged between 2 and 7, semi-structured interviews were not ideal to elicit their perceptions (Hong, Lakshmi, Olson, & Wilcox, 2018; Poole & Peyton, 2013; Shin & Holtz, 2020; Woodward et al., 2018). Therefore, over the two-week periods, they were

asked to engage in simple drawing activities and fill out columns to express their perceptions regarding the use of the prototype (see Appendix B). Each family received $30 for their participation in the field study, and another $20 as their compensation if they participated in the follow-up interview. All 12 families completed both field deployment and interviews; at least one adult was present in each interview. The university's Institutional Review Board provided ethical permission for this study.

4.2.1 Participants

Participants were 12 families with children between 2 and 7 years old. The eligibility criteria of the participants were the same as in Study 1. To understand how families of children in this age group use family-based sleep management systems, I recruited 8 families from Study 1. Because this study required frequent researcher-participant interaction, during both the two-week period and the post-study interview, working with participants who already had developed rapport with the researcher provided rich data. These returning participants had stronger sense of a ownership as continuous collaborators, because I developed these prototypes based on their feedback in Study 1. I also recruited 4 more families by word of mouth. As a result, 6 of 12 families had both parents participating in the post-study interview and sharing their insights. In 11 of 12 households, the mother was the contact person and the main participant. This number of participants was within the normal range for field deployment study (an in-the-wild study) of a technology-mediated platform, particularly with families; for instance, recent HCI studies in the home context included two (Heshmat et al., 2020; Yarosh, 2015) four (Golsteijn & Van Den Hoven, 2013), six (Swan & Taylor, 2008), and seven (Jones & Merritt, 2017) families. Because researchers should closely work with the participants to monitor whether the systems function appropriately, this number of families is manageable. Since it was critical to understand the

perspectives of multiple household members in the home, priority was given to people who could actively participate in the field deployment phase and follow-up interview with their family members.

The interview participants included 17 participants (11 mothers and 6 fathers) from 12 households. The mean age of the study participants was 39 years (ranging from 33-47 years). All participants were married or in a domestic partnership (17/17 [100 %]), female (11/17 [64.7%]), employed full-time (12/17 [70.6%]). In addition, 11/17 [64.7%] of participants were White and 6/17 [35.2%] were Asian. Annual household incomes ranged from $75,000 - $99,999 (1/12 [8.3%]), $100,000-$200,000 (7/12 [58.3%]) to more than $200,000 (2/12 [16.7%]). 2 families lived in townhomes (2/12 [16.7%]), 1 family lived in an apartment (1/12 [8.3%]), and the rest of the families lived in a single-family house (9/12 [75%]). In household where more than one child used the system, the system was placed in family's shared space (e.g., kitchen, living room) whereas it was placed in their bedroom or hallway next to children's bedroom when only one child was the main user of the system. Therefore, four families used the system in their shared space (e.g., kitchen 2/12 [16.7%], living room 2/12 [16.7%]), and eight families used the system in their bedroom (5/12 [41.7%]) or hallway 3/12 [15%] next to their children's bedroom. See demographic information for Table 3 and 4.

Family Information	Household Members	Household Income ($)	Types of residence	Types of system	Use environment
Family A	**Mother [P1], Father [P2]**, Child (2, F), **Child (4, F),** Child (6, F)	100,000 -200,000	Single-family house	System 1 (routine companion)	Bedroom
Family B	**Mother [P3],** Father**, Child (2, F), Child (4, F)**	100,000 -200,000	Single-family house	System 1 (routine companion)	Kitchen
Family C	**Mother [P4], Father [P5]**, **Child (6, F)**, Child (8, F)	Prefer not to answer	Single-family house	System 2 (light of care)	Hallway
Family D	**Mother [P6],** Father, **Child (4, F), Child (7, F)**	Prefer not to answer	Apartment	System 1 (routine companion)	Living room
Family E	**Mother [P7], Father [P8], Child (2, M), Child (4, F)**	More than 200,000	Townhome	System 1 (routine companion)	Kitchen
Family F	**Mother [P9],** Father, Child (1, M), **Child (6, F)**	More than 200,000	Single-family house	System 2 (light of care)	Bedroom
Family G	**Mother [P10], Father [P11], Child (4, M), Child (7, M)**	100,000 -200,000	Single-family house	System 1 (routine companion)	Living room
Family H	Mother, **Father [P12]**, **Child (6, F)**, Child (11, M), Child (16, M)	75,000 - 99,999	Single-family house	System 2 (light of care)	Bedroom
Family I	**Mother [P13], Father [P14] Child (7, M),** Child (9, F)	100,000 -200,000	Single-family house	System 2 (light of care)	Hallway
Family J	**Mother [P15],** Father, Child (1, M), **Child (7, M),**	100,000 -200,000	Single-family house	System 1 (routine companion)	Bedroom
Family K	**Mother [P16],** Father, **Child (7, M),** Child (14, F)	100,000 -200,000	Single-family house	System 2 (light of care)	Hallway
Family L	**Mother [P17],** Father, Child (1, M), **Child (5, F)**	100,000 -200,000	Townhome	System 1 (routine companion)	Bedroom

Table 3. Field study participants. Note: [P] indicates that the individual participated directly in the interview. Children's ages are given in the parentheses, and users of the system were bolded. F=Female, M=Male.

	Pseudonyms	Age	Gender	Race	Occupation
P1	Julie	38	F	White/American Indian	Part-time
P2	Ron	35	M	White	Full-time
P3	Mary	33	F	White	Full-time
P4	Kristine	39	F	White	Full-time
P5	Rick	41	M	White	Full-time
P6	Anna	40	F	Asian	Unemployed
P7	Joyce	35	F	Asian	Part-time
P8	Kyle	36	M	Asian	Full-time
P9	Kim	36	F	Asian	Full-time
P10	Amber	38	F	White	Full-time
P11	Jared	38	M	White	Full-time
P12	Michael	47	M	White	Student
P13	Leslie	46	F	White	Full-time
P14	Walter	41	M	White	Full-time
P15	Lauren	41	F	Asian	Full-time
P16	Lindsay	42	F	White	Full-time
P17	Meghan	37	F	Asian	Unemployed

Table 4. Interview participants. Note: F=Female, M=Male. Pseudonyms were used to de-identify participants.

4.2.2 Field deployment

During the field deployment phase, one parent worked with at least one child for two weeks to establish bedtime routines. In each household, one adult reached out to me and expressed their willingness to participate in the study; this adult served as contact person, communicating with me at least five times. This was also the parent who chose which child

would participate in the study (if they had multiple children in the relevant age group). Once participants agreed to participate in the study, they signed the consent form and were asked their preferred way of receiving the package (see figure 17). I delivered the package of study materials to 10 participants' homes, and sent the package to the other 2 participants' homes via FedEx. Participants who used System 1 received the package consisting of a stuffed animal platform, iPad, children's drawing form, reward stickers, and instructional material. Participants who used System 2 received a heart-shaped light and three round lights instead of a stuffed-animal platform; the rest of the materials were the same (see figure 18). All participants were given the choice of having the researcher install the device in their homes, and of receiving information directly from the researcher. 8 participants chose this option; the other 4 installed the system by following the instruction sheet (see Appendix C). For these 4 participants, I also offered optional support via Zoom conferencing call and email.

Figure 17. Each participant received a package from the researcher.

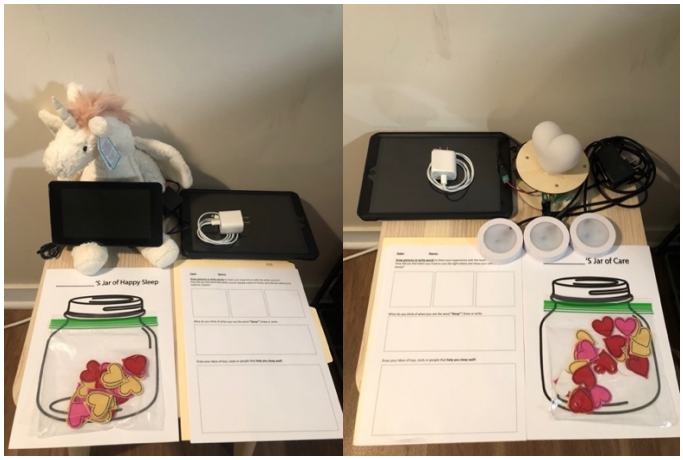

Figure 18. Contents of the packages.

Although one adult and one child were the primary users of the app and the system, other family members were encouraged to participate. To facilitate the collaborative use, I installed the app on iPad and borrowed it for participants, rather than used the participants' personal devices.

To understand the influences of two different concepts (division of labor, family interconnectedness) on the family dynamics in a more straightforward manner, participants were asked to use one of the two prototypes (System 1 and 2) and share their experiences with the particular function. Also, during this feasibility test phase, it was necessary to keep the prototype simple due to the risk of unexpected errors of the system in the wild. The type of system assigned to each family was decided based on the child participant's age and developmental stage regarding their ability to experience empathy. Empathy is an emotional response and reactive experience based on comprehension of another person's emotional state (Eisenberg, Spinrad, & Sadovsky, 2006). A study with preschoolers showed an increased level of empathy between the ages of 5 and 8 (Hughes Jr, Tingle, & Sawin, 1981). Children begin to consider other people's perspectives and develop empathy at around five years old (Strayer, 1993). Based on the theoretical background, I assigned system 2, which requires the basic understanding of other family members' status (empathy), to older children (5-7 years old). System 1 was assigned

to children between 2 and 7 years. As a results, 7 families were assigned to System 1, and 5 families were assigned to System 2.

After participants received their systems, the contact person from each family were asked to introduce the system to the rest of the household members. To avoid participants having overly-specific expectations for the systems (e.g., more sophisticated services), I refrained from using terms such as "robot: when I first provided the systems. Participants were asked to introduce them to their family members, in their own words, as systems that help with bedtime routine. Those who used System 1 were asked to discuss roles and responsibilities among household members when initially setting up their routine using the system. Participants who received System 2 were asked to explain the meaning of the heart-shaped and round lights to their child when initially setting up the system. I also provided children with an assent form and asked their parents to explain general information about the study and how they would participate. During the field deployment phase, I also asked participants to photograph their use environments, including the place where they installed the system (see figures 19).

After participants initially set up the system, they were asked to use it as part of their children's bedtime routine for two weeks. Children was asked to fill out a simple drawing / word completion form to express their feelings towards the system, and 10 children were able to complete the form (see figure 20). Children in this age group are still developing their literacy skills, and non-verbal ways (e.g., comic boarding, drawing activities) to express their perceptions and experiences are common (Hiniker, Sobel, & Lee, 2017).

Before the follow-up interview, parents were asked to understand children's outcomes and explain them to me. These drawing functioned as supplemental materials that allowed me to have an understanding of children's perception towards the sleep-support system, as well as

triggers during the interview, rather than stand-alone data. I also took field notes during the interview and used them as references during data analysis.

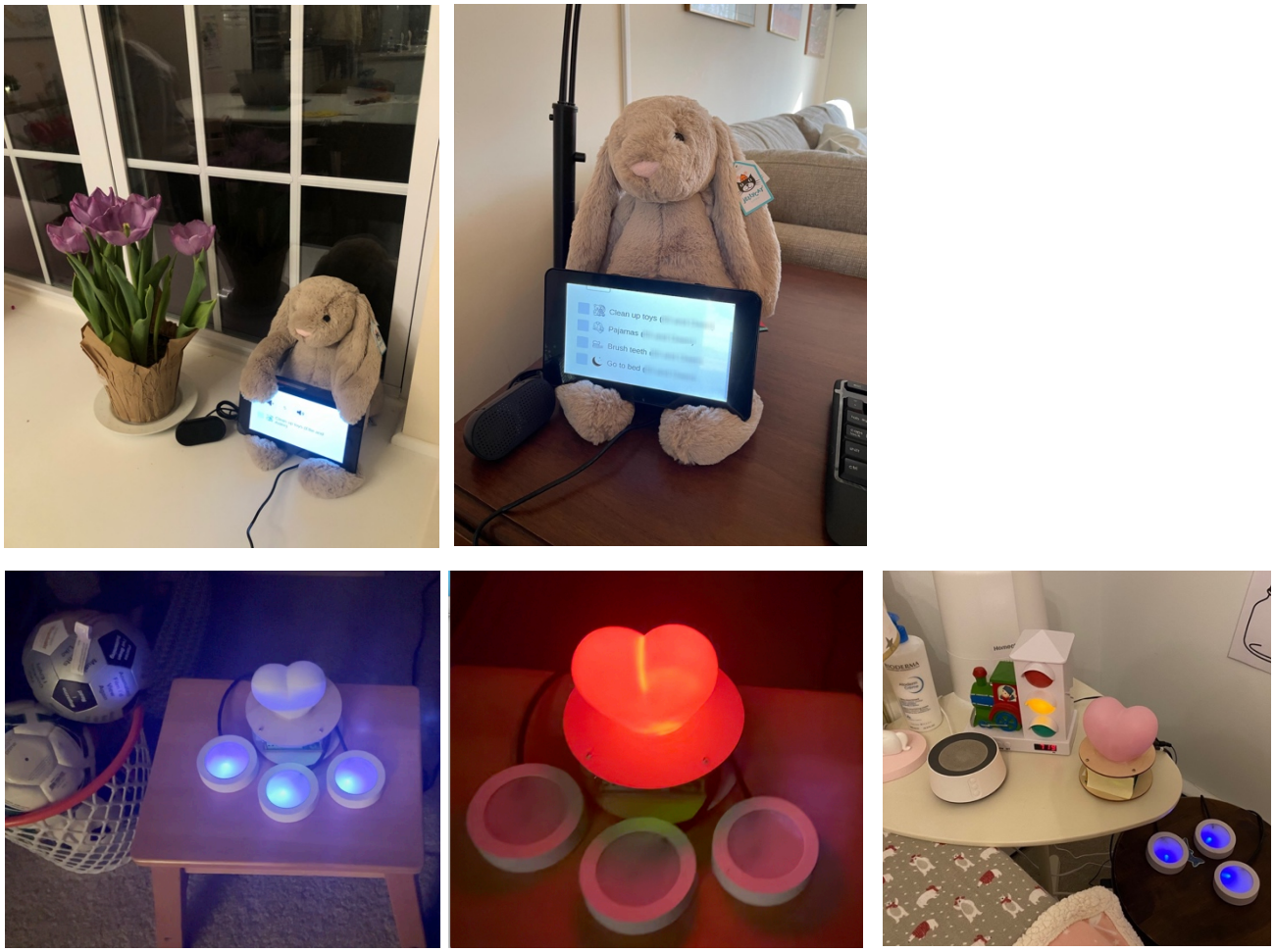

Figure 19. Participants photographed their use environments.

During the study period, I communicated with parents at least five times to ask whether they had experienced unexpected issues with their devices, and to verify that they had understood instructions properly and installed the devices appropriately. Two participants notified me of system errors during the study; they received new platforms.

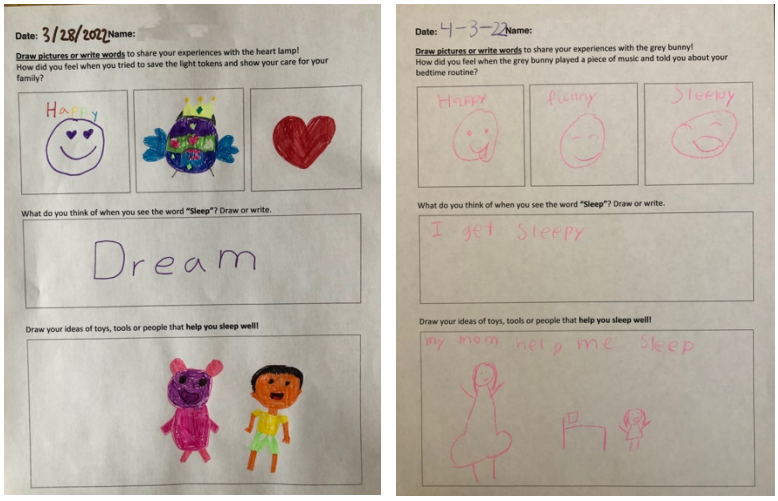

Figure 20. Children's drawing outcomes.

4.2.3 Semi-structured interviews

Within a week after the field deployment phase, parents were invited for a 30-minute semi-structured interview with the researcher via Zoom. All participants were from two-parent families, and I asked both mothers and fathers to share details of their experiences with the system. To minimize influences from the other parent, I interviewed each parent alone. New participants were asked to provide demographic information and general information about their family's sleep routine, technologies used, concerns, and strategies related to family's sleep (see appendix). Returning participants from Study 1 were asked to briefly share any changes they experienced, including family life circumstance changes (e.g., custody arrangement, new family members) or new concerns and effective strategies related to their bedtime routine/ daily lives.

The interview included in-depth questions about participants' experiences with the sleep-management system (see Appendix A). Main themes of the interview included details about how participants used the system, how the system affected their everyday routine practices, family members' perceptions of changes they had experienced, facilitators that helped participants to use the system effectively, barriers that hindered use of the system, spaces where participants

placed the system, and positive and negative experiences with the design features. When participants mentioned their sleep behaviors, I asked them to photograph associated environments and artifacts, and to share the photographs with me afterward. Collected photographs and related narratives functioned as supplemental materials that give me a comprehensive understanding of participants' experiences with the system. The interviews were audio-recorded with participants' consent and transcribed verbatim for data analysis.

4.2.4 Data analysis

In the current study, I analyzed the conversations from the interviews with each participant. To analyze the interview data, I applied a grounded theory approach (Charmaz, 2014). This allowed me to capture families' insights with two sleep management systems and have in-depth discussion on the influences of the technologies on their daily routines, without a predetermined frame; I was also able to explore further design implications. I used the drawing outcomes and photographs provided by the participants to help the data analysis. During the data collection I iteratively modified the interview questions to better evoke participants' experiences and implications for further iterations of the system design. To perform open coding, I used NVivo Pro 12 for transcripts from the semi-structured interviews. Once the initial coding was done, I iteratively aggregated 727 codes based on their commonalities until they were mutually exclusive; this resulted in 67 representative codes that are used for affinity diagramming.
I wrote each of the 67 codes on a separate memo pad, and clustered them depending on the relationships among the codes: similarity, differences, and hierarchy. This yielded three different levels of themes: high, middle, and low. High-level themes include 'parents coordinate family routine,' 'a third-party mediator between parents and children,' and 'influences on division of labor.' Mid-level themes include 'children reacted to routine device without further notification'

and ‘system sets a boundary by telling the beginning of bedtime.’ Low-level themes include ‘mom taking charge of coordinating child's extracurricular activities,’ and ‘influences of child’s sleep on sibling's.’ Upper-level themes encompass the subthemes.

4.3 Results

In my field study, participants discussed how the systems influenced their existing family sleep routine and how these two systems created changes in dynamics related to their sleep management in the home environment. They also discussed design ideas and provided suggestions for further iterations of the systems, based on their experiences. As participants shared experiences on using systems in their daily routines, they mentioned how the systems had influenced their existing practices, and explained the difficulties they were experiencing with regard to managing these routines (e.g., children disregarding bedtime routine, managing multiple children’s bedtime, parents’ challenges in coordinating routine). They also discussed with me the parenting practices and strategies they have learned over time (e.g., reward and/or punishment system, sharing chores with children). These findings also supported my findings from Study 1.

In the results section, I present emerging themes in twelve families’ experiences with the systems, supported by direct quotes I obtained during the interviews. My participants’ experiences showed that the system have four major influences in their home environment. They are: 1) the system functions as a third-party mediator between parents and children to facilitate family routine; 2) the system triggers changes in the division of labor by inviting family members to share responsibilities; 3) the system creates opportunities of self-care time for parents after children’s bedtime routine; and 4) the system reminds parents of family routine and facilitates coordination.

4.3.1 The system functions as a third-party mediator between parents and children to facilitate family routine

During my interview, one of the most frequently discussed themes was how the system acted as a neutral third-party mediator during bedtime routines, creating behavioral guidelines for children and providing clear expectations. Although most families have a bedtime routine, children do not necessarily comply with it, and it is the parents' task to remind them. This can create much tension between parents and children, and be a significant stressor that negatively impacts family relations. Therefore, smooth transition from their dinner time to bedtime routine is an important task for most families - but also a difficult one. With System 1 and 2, families were able to 1) alleviate unnecessary tension between parents and children and 2) achieve spontaneous and active engagement of children in their routine tasks.

4.3.1.1 System as mediator alleviating unnecessary tension between parents and children

Participants in both Systems 1 and 2 mentioned that— unlike when parents give children instructions, which the children may ignore — the systems set relatively agreeable criteria and behavioral boundaries as a mediator, which led to an effective bedtime routine for both children and parents. Parents mentioned that children's reactions toward the system made bedtime routines easier.

Six of twelve participants who used System 1 indicated that the system provided them with clear boundaries for children's routines. For example, Julie indicated that System 1 set a definite end for her daughter's playtime. When a given song was played, this was an indication to her daughter that whatever task was ongoing had to stop by the time the song was finished. The system became a way for them to define an unambiguous end of one phase of the schedule

and transition to the next, so that the child would not request more things from her parents at bedtime.

The one that has more difficulty, the one that would take a really long and for us to go through her routine. [Their middle daughter] was the one that we were using it with, just because it was a way for us to get a definite end for her to kind of stop her from requesting more and more, more. Like, I want another book, I want another song, I want to like... This is the time and I know the song's over, it's moved on another step, now we're doing this now. So that was very helpful for her. (Julie, 38 years old, mother of three children)

Previously, the girl would consistently ask her parents for more delays, regardless of prior agreement on bedtime routine. Her disregard created significant disruptions in other family members' bedtime routine, including her siblings' bedtime and parents' free time at the end of the day. With the system, however, she knew when to move on to the next task, and eventually was able to sleep on time.

Two users of System 2 mentioned that having clear behavioral boundaries (i.e., only three extensions are allowed after bedtime routine) helped their children to clearly be aware of "the beginning of bedtime" and what was expected from them. Walter discussed the clear indicator of family's bedtime routine as a greater benefit of the System 2.

I could see that being part of a routine, especially for a younger. When you're sort of trying to say, "This is bedtime now." And maybe turning that light on, would indicate that, "Okay, now it's time to go to bed." (Walter, 41 years old, father of two children)

Similarly, Kristine mentioned that when her daughter attempted to leave her bedroom multiple times, she reminded her to refer to the number of lights that were left, so as to encourage compliance with the expected routine.

4.3.1.2 System as mediator encouraging children's spontaneous and active engagement in their routine tasks

Based on my findings, it appears that the two systems provided opportunities for their children to not only comply with the rules but also to actively engage with the routine. Parents - mainly those who used System 1 - shared that often, children reacted to the system without parents' further verbal prompts at bedtime: continuous verbal reminders which had previously been a necessary component of regular bedtime routines.

Parents shared how children's positive appraisal towards the system design, including Disney instrumental songs, and appearance of the system, provided opportunities for children's to spontaneously participate in their routines. They mentioned that children expressed positive emotions, including happiness and excitement, when they used the system. Children wanted to touch System 1, and to keep the bunny and the unicorn stuffed animals even after the field study was completed. These positive feelings resulted in children's active participation during their bedtime routines. For example, when the system started to play music, children immediately got up and ran to the system to check which bedtime tasks (e.g., changing into pajamas, brushing their teeth) they were supposed to do. On one occasion, Meghan's daughter missed the bathtime music, and was so disappointed by being unable to dance along with it before her bath that she cried.

Two families specifically mentioned that their children personified the system and waited for the bunny and unicorn to play music. Joyce shared how her two children, two and four years old, were excited about the routine that the system provided for them.

They were so excited to follow the rules, the new rules that bunny tells them…So we use for those three [two clean ups and bedtime] and it works really well, I would say. So whenever they hear the music, they automatically know, oh, it's time to clean up. And I will, I will go to clean. (Joyce, 35 years old, mother of two children)

Similarly, Julie and Ron's children named the system "Mama Unicorn" because children thought the system was taking care of them, saying, "Mama Unicorn says it's time to go to bed."

Other families shared how the systems provided children with chances to engage in their routines with greater motivation. Users of both Systems 1 and 2 wanted to show how well their children behaved and met expectations. Among twelve families, seven families used the reward sticker chart and compensated their children's behaviors, whereas five families did not use the chart. Regardless of the reward system, children showed strong motivation.

Lauren's son, who used System 1, always wanted to go faster than the system and completed the bedtime routine even before music was played. Although his parents did not use the reward system for the full two-week study period, the child was enthusiastic about meeting the expectations provided by the system, and "winning" what he perceived as a game.

After that [first couple of days], he always wants to beat it. He wants to be faster than the device. Because he just wants to beat the system. He wants to be faster than the system. (Lauren, 41 years old, mother of two children)

Children who used System 2 also displayed similar behaviors, as they tried to save unused lights and wanted to show how well they did. Kristine discussed how proud she was the first time she was able to save all three lights. She was highly motivated by the challenge of getting through the night without using any of her lights, and would even plug the system in and turn it on herself.

She [her daughter] is like, I got this. And so, she would plug it in and then start the system because she was so excited. She did that for the whole thing. I didn't have to worry about turning it on at all the entire time. So having that interaction, she was just like, yes, I can do this… The first time she did all three [saved all three lights], like [husband] said, she's like, I'm not going to use any today and stuck to it. And she was so proud. (Kristine, 39 years old, mother of two children)

Michael and Lindsay also discussed how much their children were interested in keeping the lights on. Michael said using the system was a kind of "game" for her child. Although these families did not use the reward system or other compensation for motivating the children, saving all three lights nonetheless became a high priority for their children.

Families provided three major suggestions to make systems more effective as behavioral mediators. First, they requested that the behavioral guidelines for children be more sophisticated.

Specifically, they wanted clearer boundaries between "acceptable" post-bedtime behaviors (e.g., using the toilet) and "unacceptable" (e.g., using a tablet).

Secondly, participants requested more flexibility, so as to accommodate the different levels of flexibility in each family's routine. As System 1 is designed to provide a serial bedtime routine established by the users, families who do not strictly remain within this routine can experience difficulties. Participants mentioned that if the system had different levels of flexibility, they could benefit regardless of how closely they adhered to the schedule.

Lastly, participants pointed out the need to accommodate children's differing preferences for the stuffed animal and the music played by the system (preferences which might be influenced by gender and age). Although parents of girls and younger boys (up to 4 years old) mentioned their children's positive reaction to the Disney instrumental songs and appearance of the stuffed animal (bunny and unicorn), two parents of seven-year-old boys pointed out that if System 1 will be used by seven-year-old boys, it would be necessary to accommodate their preferences on design themes, as they might perceive the current themes to be "too girlish" and immature.

This subsection shows how two systems mediated children and parents during bedtime, and positively influenced family bedtime routines. The systems reduced unnecessary tension between parents and children, as well as promoted children's spontaneous engagement and improved motivation in their routine tasks.

4.3.2 The system triggers changes in the division of labor by inviting family members to share responsibilities

Another theme discussed during the interviews was the changes in the family's division of labor triggered by the systems. The importance of well distributed division of labor was also

addressed in my previous study. In both Study 1 and 2, participants noted that coordination of daily schedule and division of labor among household members affected the family's routine, and eventually their sleep. After using the systems, couples in my study had opportunities for clearer agreements and rules on household tasks. They expressed that equal role distribution in the household is a necessary precursor for a family with young children to have stable routine.

In Study 2, 11/12 parents further discussed their interest in division of labor to help their children grow into independent and responsible members of society. They said that, as parents, they felt rewarded whenever they saw their children learn new skills or play a new role in society (e.g., family, school, sports team). Therefore, as the children grew, the parents gave them adequate levels of freedom and autonomy, which they tried to balance with support. The two systems fulfilled parents' needs by enabling children to take more active roles at home. Parents mentioned that by allocating specific chores for children and thereby teaching responsibility, they triggered 1) redistribution of household tasks and responsibilities with their children or partners (System 1) and 2) conversation around care work and responsibilities in the family.

4.3.2.1 The system triggers redistribution of household tasks and responsibilities

System 1 created opportunities for children to engage in more household chores, both during the day and during their bedtime routine. Three families used the system to remind their children about sharing the household chores before bedtime. Joyce and Kyle's two children relatively had good sleep hygiene, as they slept through the night once they fell asleep. However, parents struggled to engage them in evening routine behavior, such as putting away toys before their bedtime. If the family's evening routine is disrupted, this negatively influences the overall structure of family life, including regular bedtime and parents' self-time at the end of the day. To

allocate tasks to children and teach them their roles as family members, parents used System 1 throughout the day.

So we set a time, one alarm in the morning to clean up time and one alarm in the afternoon for another cleanup time before we go to bed, after dinner. (Joyce, 35 years old, mother of two children)

Kyle, the father, shared that after the family began using System 1, the children started actively participating in chores.

I think it was basically every day at the specific time it would play the music. And I was actually surprised to see our kids react very positively to the device. As in, I think it was the very next day that the music started playing and my daughter, she immediately recognized and she's like, "Oh, it's time to clean up." So I was very surprised to see that. (Kyle, 36 years old, father of two children)

Similarly, the findings suggested that the system enabled Meghan's family to clean up their living room and children's playroom every evening after dinner. As her daily schedule was packed with two young children, her house was easily messed up by her 1and 5 years old children. Thus, regular cleanup has been necessary for the family. Whenever the music was on, her five-year-old daughter assisted her in cleaning the house.

Other families shared how System 1 created opportunities for both parents (mothers and fathers) to participate in children's bedtime routine.

Mary was working from home, she was the primary caregiver for their two children. She would take care of them during the day while completing the required tasks for her job, such as participating in video conference calls. While the family used the system, there was an instance when her husband did not follow the routine: he neglected to help the children change into their pajamas for bed, and she had to prompt him to participate.

There was one time, because I put pajamas on the kids or something, and I put both of us down as the responsible parent [on System 1], and [her husband] was doing something and I was like, "Well, it says we're both supposed to, [husband's name]. You're going to have to [put them in their pajamas.]" (Mary, 33 years old, mother of two children)

Similarly, Lauren is the parent in charge of their son's bedtime routine, because her husband was not good about time management in everyday life and often did not keep their son's bedtime. This resulted in unbalanced role distribution between her and her husband, especially for their older son's bedtime routine. However, with the system, the husband could easily refer to what their son was supposed to do at a specific time for bedtime and help her while she was with their younger child.

I was the one who said everything [for her son during the bedtime]. But then [her husband] knows that when one of the things goes on, then he would look at it, what is it about, and then, he

would tell him, "Okay, time to go do this, or time to go do that." So he would help to remind him. (Lauren, 41 years old, mother of two children)

4.3.2.2 The system triggers conversation about care and responsibilities in family

While System 1 functioned as a tool that prompts household members to take a more active role around bedtime, System 2 created an opportunity for families to have a conversation about children's roles and responsibilities at bedtime. Four families reported how they used the device to discuss the meaning of care work, and the challenges involved in the work. Michael shared how he used the system to teach his seven-year-old daughter her responsibilities in the household.

We talked about, "This [System 2] will be a reminder for you to stay in bed and to not get out of bed unnecessarily," and I really did, I appreciated the phrasing. We're like, "This is a way that you can show love and care for us, is for you to be able to be responsible for yourself in that regard." So that was the type of terminology that we used. (Michael, 47 years old, father of three children)

Lindsay mentioned that although she did not use a terminology that is directly related to care or taking household responsibilities through the system, it prompted her to have more dialogue with her son about his post-bedtime behaviors. Instead of simply yelling at him to go back to his bed, the system allowed her to talk to him and ask why he came down; by knowing his specific reasons for getting out of bed, she was better able to encourage him to go back. The

visual cues (three round lights and bright changes of the heart lamp) helped the children understand the consequences of their behaviors more intuitively.

This subsection shows how the two systems provided participants with opportunities to alter the division of labor by prompting family members to begin particular behaviors at specific times, or enabling discussion of children's responsibilities to the family.

4.3.3 The system's effect on parents' opportunities for self-care

As with from Study 1, parents in Study 2 expressed difficulties with having "self-care time" to engage in exercise or other simple activities, due to their childcare obligations and work schedules. Although a majority of the families went back to their "pre-COVID lives" (e.g., children went back to in-person learning), many parents still worked from home while they took care of young children. To secure their mental wellness and quality of sleep, seven participants particularly described the importance of their self-care time after children's bedtime. They watch television, engage in simple exercises or SNS, or learn new skills (e.g., languages). In line with their needs, participants discussed that 1) the two systems created opportunities for parents to have a more stable evening routine by allowing them to have time for themselves; however, they also desired 2) more robust systems that could help them maintain their own sleep schedules and go to bed regularly after spending a reasonable amount of time for themselves.

4.3.3.1 The system created opportunities for self-focused time

First, while they shared their experiences with the system, parents described how much they desired to secure adequate time at the end of the day to ease their tension and secure mental wellness before sleep. For instance, as a non-native English speaker, Anna uses her children's post-bedtime as "me-time," time for learning English and improving herself. As her four-year-

old child was afraid of falling asleep while alone, she had to stay in the room until the child was asleep, which disrupted her own sleep patterns.

Yeah, the most big problem is I cannot sleep for well, I mean, and when I try to let her sleep, let them sleep, I fall asleep.. maybe two or three hours later, I woke up suddenly and, "Oh, I didn't do anything at all." ... all the time [when I fall asleep with my daughters,] I want to wake up, so I cannot fell asleep until morning, because I feel I want to do something after they fell asleep so I always wake up about midnight… (Anna, 41 years old, mother of two children)

She mentioned that this happened on average four times a week, and said how tired this made her during the day. Lauren likewise pointed out how her son's bedtime influenced her own sleep: if his bedtime gets delayed, so does her own schedule, as she always has tasks remaining from her job, and cannot use her phone to unwind before bed.

Yeah. No, because I push off everything. I probably work until 11:00-ish, and I want some me time. Once they all sleep, I want to use my phone, I want some me time. Yeah. So a lot of time, I probably stay up until 12:00-ish, sometimes 1:00. So I know, I should actually go to bed, but no, for my sanity, I really need some me time. (Lauren, 41 years old, mother of two children)

Her one-year-old son requires constant attention and supervision, but her husband goes to work during the day and she works full-time from home. As such, her mental health had become a major issue, and could only be relieved by adequate self-care in the evening.

Participants discussed that as the two systems guided children to follow their regular bedtime and stay in bed, they were able to use their evening time satisfactorily.

Kim discussed how, thanks to System2, she was able to resume physical exercises: during the two-week test period, her child only called for her once, and so she was able to spend evenings using the climbing panel in her basement.

But in general, I think it really worked for our case, for my child. So after putting my child to the bed, I was able to have my personal time, doing some exercise, working out every night. That really enhanced ... It's been only two weeks, but I was able to have a regular working out time, some working out time and I could have more time to be with my husband, so I really liked it. And my husband was like, "It works." (Kim, 36 years old, mother of two children)

She expressed how satisfied she was with being able to return to regular exercise and have more time with her husband, both of which were hindered by her child needing attention during bedtime.

In line with Kim's experiences, other participants also described the importance of having time as a couple after children's bedtime for their family relationships and overall quality of life. Parents of young children rarely have time during the day to have a conversation, or even to just pause and de-stress, because their children require constant attention. For instance, Meghan and her husband usually watch television to wind down their long day with two children and work. If a child constantly comes down to the living room and interrupts nighttime relaxation, this becomes a significant mental stressor for the couple. System 1 enabled Julie and

her husband to put their children to bed on schedule and to have one-on-one time - with each child, and also with each other.

It [System 1] is a device that would help me achieve those things. Help me have good family time because that's important at that time. It's just like having good family time with each other and having a good one on one time… which can be hard when you have three kids…Because when our kids are in bed, my husband and I have quite a bit of time to ourselves and I think really important as parents to have time as a couple, just us. We have friends that their kids, they stay up until 10 o'clock at night, 11 o'clock at night and I'm like, when do you guys have time for yourself? (Julie, 38 years old, mother of three children)

The example shows two systems' possibility of strengthening family relationships by creating more time for them.

4.3.3.2 The necessity of guidance on parents' routine to make the system more effective

Although the two systems provided opportunities for parents to spend time doing exercises or engaging in hobbies , and can indirectly improve their overall satisfaction with life, they did not necessarily lead to the parents getting more sleep. Parents were aware of the negative consequences of their own delayed sleep if they spend too much time on other activities. Three participants discussed the necessity of guidance on their own routines to make the system more effective for parents' sleep. In particular, they suggested the potential benefits to having instructions for ideal sleep duration, and reminder systems that would tell them to end their non-sleep activities.

And so I mean, I still have the option to push a button and ignore it, but at least it's making it front of mind saying, "Hey, maybe you should turn this off." So that's kind of a strategy I've decided that I'm trying to get in place because that's what I've found is even when I'll go to bed to lay down at like ... I'll be like, "Okay, it's 9:30, I'm tired and got to get up really early. I'm going to go rest and get ready for bed now, and if I fall asleep by 10:00, it'll be great." Then I find myself pulling out my phone, going to charge it, and then just sitting there and just scrolling through. (Lindsay, 42 years old, mother of two children)

Lindsay mentioned that even though parents can more easily ignore those suggestions than children can, it is helpful to be presented with options that remind them of the ideal bedtime. Mary also made suggestions about how System 1 could quickly remind parents to keep to regular bedtime. She used to have a FitBit (wearable technology that reminded her of routine tasks), and mentioned that having intuitive ways (e.g., music) of prompting bedtime would be beneficial for parents.

...But every night at 10 o'clock it would vibrate on my wrist and it would tell me, "Time to go to bed." And so, I think the same concept, "Oh, if I hear this song, that means I should be going to bed." So, I do think even for adults, it could be helpful. (Mary, 33 years old, mother of two children)

This subsection shows the system's effectiveness for parents' extended self-care opportunities: engaging in activities for themselves and spending time with spouses. Also,

participants discussed the benefits of a robust behavior guidance system, which can provide appropriate prompts for adults at night to achieve improved sleep.

4.3.4 The system reminds parents of family routine and facilitates coordination

For families with young children between 2 and 7, coordinating the daily schedule is an important but challenging task that requires significant additional effort. During the interviews, participants expressed difficulties in keeping track of their schedules, including their children's extra-curricular activities and school, and their own work. To alleviate the issues, they used different tools to facilitate the coordination, including online calendar apps (e.g., Google Calendar), voice assistants (e.g., Alexa), or alarm systems (e.g., Fitbit or digital clocks). In line with their needs, they mentioned that System 1 allowed parents to 1) be aware of where they are at in each day's schedule so that they can prompt their children according to the music being played, and 2) coordinate multiple children's routines.

4.3.4.1 The system reminds parents to be aware of their family's daily schedule

As System 1 guided family members to perform tasks at specific times, parents mentioned that the system not only prompted children to follow their routines, but also reminded parents to keep up with those same routines.

Three participants mentioned that they often forgot to remind children to follow their bedtime routine; the system reminded them of which task should be performed at a given time of day. For example, Joyce how the system effectively reminded them to initiate the family's bedtime routine: cleaning up toys. She often forgets to tell the children to start their bedtime routine as she is occupied by other tasks. However, with the system, she was able to remember children's routines while she was doing other household chores, including washing dishes. Similarly, Meghan found the system to be a useful reminder for bath time, which is one

of her 5-year-old daughter's main bedtime tasks. The device enabled the family to keep to the schedule, including bath time. She said:

But, with the device, we know that the time is up, we have to take a bath and those kind of things…For me, it reminds its time. And then, when the bath time comes, [her daughter] really wants to listen the music and take a shower. So, that make me really easy to [engage her into the routine]. (Meghan, 37 years old, mother of two children)

Mary pointed out that when the music was on, her family was able to know they should have had dinner by that time as "dinner music" was played. Although the family had a relatively flexible routine and it was hard for them to do things at the exact same time every day, they were able to know what routine tasks should be done by the time they heard the music.

Participants also shared the perceived benefits of System 1 over other smart technologies they had used in their routine management. Lauren mentioned that although she frequently used Alexa to remind herself to prompt her son's bedtime routine, System 1 was convenient with its visual cues (e.g., icons on the screen). Similarly, Julie shared that the currently available smart technologies should be incorporated and targeted for children's improved routines as they had limited functions as background music player, white noise maker, or digital clock. Her family viewed System 1 as possibly an integrated smart device for children's routine management with its visual and audio cues and child-friendly appearance.

4.3.4.2 The system coordinates multiple children's routine

In case of families with more than one child, parents emphasized the importance of coordinating their schedule to have one-on-one bedtime routine with each of them. Meghan's family was busy with their one-year-old child during the day. As it was difficult for Meghan and her husband to spend time with their five-year-old daughter during the day, she had to make sure her daughter got adequate time with parents in the evening to feel secure. If her daughter did not receive quality time, this led to multiple post-bedtime requests. Similarly, the biggest challenge for Julie was managing the time expectations of her three children and getting them all into bed at roughly the same time and a reasonable hour. Julie and Ron discussed how System 1 created opportunities for them to put their children into bed around the same time. When their middle daughter, the one who most disregarded bedtime routine, followed the routine provided by the system, her parents were able to coordinate the other two children's bedtimes. Parents mentioned that the system allowed them to have one-on-one time with them, which can be hard with three children.

So then that way I could just... It kind of helped with managing, trying to get multiple kids down for bed at once. Having [their middle child] go through those tasks [suggested by the system] at the same time as her sister and then... So then I could say when she completed those things, okay, now you can go play or do what you want to do until it's time for you to go to bed a little later. (Julie, 38 years old, mother of three children)

The benefit was more salient when her husband was alone at home with three children during their bedtime routine.

And then there are times when [mother] has to go to work in the evening, and so [dad] would just be doing it on his own and it just would help him manage all three of them. [The system] would give a specific start and end time for [their middle child] stuff. That was like kind of separate from the other two, which helped [dad] manage all three of them when he was up here alone as well. So we are all about making our lives easier. (Julie, 38 years old, mother of three children)

Although the father was frequently in charge of assisting children during their bedtime routine, it was extremely difficult for him to manage three children (2, 4, and 6 years old) at the same time. With the system, parents were able to manage multiple children's routines without any major issues.

To make the system more useful as a reminder and coordinator, families also provided suggestions: 1) expanding the scope of the tasks, 2) having a greater flexibility in terms of adjusting the duration of separate components of the routine (System 1), and 2) simplifying reminder systems (System 1 and 2).

First, participants suggested that the system's scope could include the daytime routine as well as bedtime, with reminders like "leave for school by 8AM", "use the potty every two hours", or "take your medication." Lindsay mentioned the system's potential benefits for stay-at-home mothers who need to provide guidance for their children.

Second, participants also suggested adding a function to easily adjust the duration of each task (by, e.g., touching the screen), to accommodate children's differing abilities. They said that improving these aspects would be more convenient, and better enable them to coordinate their daily lives.

Finally, three families also mentioned difficulties in remembering to use the system at all. Lindsay shared that, although the system provided benefits in facilitating her son's bedtime routine, she had to set an external reminder for herself to initiate the system each night. Participants shared that addressing these aspects would increase the usefulness of the system.

Based on my participants' experiences, it appears that the system provides opportunities for the families to effectively coordinate their bedtime during their busy routine. Parents used the system to remind themselves to begin their children's bedtime routine and keep the attention of one child while working with the others.

In this results section, the participants' experiences showed how the implementation of two family-based sleep management systems influence families' overall sleep management practices and their existing social dynamics, and their perceptions in using two systems that intend to challenge existing social dynamics within the home context.

CHAPTER 5: DISCUSSION

5.1 Sleep as a complex and collaborative experience for the family

A major contribution of the current study is to investigate previously overlooked boundaries in understanding family sleep in HCI studies. In Study 1, by examining how families work towards establishing their sleep routine in everyday lives, and understanding facilitators and barriers of managing their sleep routine, the study showed that family sleep issues are collaborative experiences that are not limited by the three boundaries that have been frequently used within the existing discourse about sleep: 1) time, 2) space, and 3) unit of analysis. This study provides a valuable addition to the current literature on sleep-support technologies by suggesting the broadening of existing boundaries, which had not been considered critical to perspectives on family sleep.

In previous studies, sleep was considered solely as an activity that occurred at nighttime. Thus, with a few exceptions (Bauer et al., 2012; Cherenshchykova & Miller, 2019, 2020; Choe et al., 2015), researchers have focused on how nighttime routines are managed and how sleep is sustained until morning. Nighttime routines were important in our study; however, all-day routines were important as well. In Study 1, participants showed that coordination of their daily schedule, taking into account appropriate naptimes and children's school schedules, was critical for a stable sleep. They also shared how having guests in the home influences the sleep environment and routine (e.g., delays to dinner and bedtime). To establish an effective routine that sustained the family, they implemented various strategies (e.g., checklists for naps and bedtime), rules (e.g., token system), and motivation for children (e.g., reward). Study 1 showed that in order to properly understand family sleep, it is necessary to consider their daytime activities and evening routines; in line with this, in Study 2, participants shared how they used

the systems to implement a healthy routine, both in the afternoon (e.g., put away toys) and evening (e.g., brush teeth, take bath).

To understand complex issues related to family sleep, designers need to consider spaces beyond the bedroom. In previous studies, researchers investigated how technologies can create an improved sleep environment by providing better lighting, sounds, air quality, and humidity, and by detecting other family members' motions (Choe et al., 2010; Kay et al., 2012). When I permitted participants in Study 1 to freely explain their sleep issues without providing our conceptual boundary of what defines sleep, they explained issues both inside and outside the bedroom, including on the playground, where children can tire themselves out. For example, one of the most important sleep issues for my participants emerged when families are traveling. To alleviate the effect of sleep environment changes, families needed to have strategies. As these examples showed, the issues originate from the changed environment, which is not necessarily bounded to the bedroom or even to the house. Study 1 indicated that a proper critical perspective would include data from outside the home environment, due to the limited timeframe, Study 2 only examined the family behaviors while they use family-based sleep support systems within their home environment. Future studies should expand the scope of technology design to various contexts and situations, including when families are on trips or children are at school.

Lastly, the unit of analysis for my participants was not the individual but rather families as a whole. When medical studies investigated sleep, they focused on an individual's sleep quality. These subjects were examined in the lab, and their sleep behaviors were quantified (e.g., how many times they awakened at night, how long they slept). Because the unit of analysis was the individual sleeper, apps created as a result of medical studies suggested individual-focused solutions to improve sleep quality. In HCI, the unit of analysis has become the family

(Cherenshchykova & Miller, 2020; Pina et al., 2017; Pina et al., 2020). Because both family-centered and system perspectives have been critical lenses for understanding family health management in different contexts, including everyday wellness management (Li, Caldeira, Epstein, & Chen, 2020; Lukoff et al., 2018; Saksono et al., 2020; Sandbulte, Choe, & Carroll, 2020; Schaefbauer, Kahn, Le, Sczechowski, & Siek, 2015) and chronic illness contexts (Shin et al., 2018), studies have emphasized that collaborative effort in daily life can facilitate successful family sleep (Pina et al., 2020).

However, the importance of the family as a unit of analysis works only when the social dynamics among the family members are considered. For example, in both Study 1 and 2, participants often explained that their children's delayed bedtime and frequent waking up were important sleep issues. Those situations were problematic because when children could not have quality sleep, this led to tantrums and other behavior issues during the day. In many cases, this frequent waking up not only affected the children's behavior, but also the parents' mental and physical wellness. For my participants, this frequent waking up impinged on their own valuable self-care time. This was especially true for the mothers in our study. After spending a busy schedule supporting and managing families, the mothers wanted to focus on themselves. However, their children's unstable sleep was a major interruption for their self-care time. In addition, this issue reminded them to question why the frequent waking up should always be handled by the mothers rather than their partners. As the example shows, the sleep issue is not only an individual issue (child's sleep). The real issue emerged from the family's unbalanced role distributions or gendered roles. Although there are many sleep-information tracking and routine reminder apps that are commercially available through smartphones and wrist-worn devices, those solutions focus on tracking information among family members by motivating

each other to participate. They do not take into account the complex social dynamics among family members. Even when HCI researchers applied family-system perspectives, they focused on the benefits for families to collaboratively track and share health information, or parents to support tracking their children's information.

By implementing two family-based sleep support systems in the participants' homes, Study 2 examined the influences on existing social dynamics, and families' perceptions in using sleep management systems that intend to challenge existing social dynamics.

The systems appeared to support participants and their spouses in actively sharing household chores, and offered children chances to reflect upon their behavioral consequences within the family context. These practices created opportunities of self-care for parents. The results from Study 2 demonstrated the implication from Study 1: to improve the sleep of families with young children, technologies should take into account the family's interconnectedness.

When social problems are examined, evaluated, and addressed within a set of boundaries, there is always the possibility that the solution lies outside those boundaries. Thus, technologies that were designed within the constraints of these boundaries (time, space, and unit of analysis) were not able to properly assist my participants with their complex sleep issues that stemmed from family dynamics. The limits imposed by boundaries to understand complex social issues have been criticized in both HCI and STS (Cowan, 1983; Howard & Irani, 2019; Jenkins, 2017; Latour, 2005; H. R. Lee et al., 2017). For example, Cowan described how the boundary between workplace and home excludes home as part of a socioeconomic system, and how that exclusion devalued the labor at home (Cowan, 1983). Latour explained how sociology did not see the complex issues of society, because researchers tend to focus on predefined boundaries, such as geographically-bounded social actors (Latour, 2005). Jenkins discussed difficulties in

representing families' unique needs and cultures when designers focused on general, idealized home environments that were predicated on traditional boundaries (Jenkins, 2017). Although sensing technologies for sleep improved an understanding of individuals' sleep during the nighttime, they could focus on less visible factors (e.g., children's frequent requests after bedtime routine) that actually cause deeper issues regarding families' well-being (e.g., parents having less self-time, more daytime fatigue, and eventually worsened sleep quality). In my study, reconstructing the elements of family sleep led to a better understanding of sleep issues of families with young children, which were previously invisible due to widely accepted perspectives on sleep (Meltzer & Montgomery-Downs, 2011). By reconstructing the elements of family sleep and emphasizing interconnectedness, the two systems allowed families to discuss neglected but critical issues, thereby providing positive impact on their routine behaviors.

5.2 Towards sleep technologies that challenge an unbalanced division of labor

One of the major contributions of the current study is that it extends the previous discussion on division of labor in designing technologies for family-based technologies; as well, it broadens the scope of sleep-support technologies to consider social dynamics as a design theme. This study provides a meaningful addition to the existing body of HCI literature on family coordination and collaboration. By implementing two sleep routine support systems, the study showed how sleep and routine support technologies can intervene in the domestic environment: that is, by inviting other members to participate, rather than merely utilizing existing dynamics and family relationships. This critical view could help HCI researchers to enhance families' collaborative work regarding health issues, including sleep-related ones, by challenging their existing family dynamics rather than affirming them.

One of the most salient themes discussed in both Study 1 and 2 was how participants, especially mothers, want to share their heavy responsibility: they wanted to redistribute labor among family members. In my study, the parents of young children, particularly mothers, expressed burdens related to managing family life regardless of their occupations. For example, stay-at-home mothers said it is their responsibility to manage children's time for school, academics, and extracurricular activities while their husbands are at work, and working mothers also mentioned that children tend to ask for mothers' attention, especially around their bedtime. In Study 1, among the twenty parents who participated in my interviews, only two were male (fathers). Similarly, in Study 2, from twelve families, only six fathers agreed to participate in the follow-up interviews. I acknowledge that I did not have enough male participants to properly represent their view of family sleep. Although I intended to have a balanced gender ratio of participants to understand both sides of the view on family sleep, a limited number of male participants expressed their interest during the recruitment phases; this indicated that household tasks related to children's sleep are mainly considered a mother's duty.

In fact, mothers in the study believed that it was primarily their responsibility to create the necessary conditions for a family's sleep, particularly for family schedule management and coordination of work. They expressed that redistribution of their household responsibilities among other family members was essential not only for improving their sleep, but also for having appropriate self-care and well-being. For my participants, children's sleep meant not just time for children to rest, but securing self-care time and engaging in different activities (e.g., reading a book, hobbies) to unwind from the day's obligations. Unlike previous studies focusing on efficient collaboration among family members (Davidoff et al., 2010; Lukoff et al., 2018; Mennicken & Huang, 2012; Neustaedter & Bernheim Brush, 2006; Neustaedter, Brush, &

Greenberg, 2009; Plaisant et al., 2006; Schaefbauer et al., 2015), including health and wellness management (Binda et al., 2018; Eschler, 2015; Hong et al., 2020; Lukoff et al., 2018; Pina et al., 2017; Pina et al., 2020; Schaefbauer et al., 2015), the current study addresses the importance of challenging and intervening in the existing division of labor in home settings by reallocating labor (Rode, 2010) as a way to support quality sleep for the whole family.

In HCI, the division of labor has been a vital concept for investigating unbalanced labor distribution among family members (Bell & Dourish, 2007a; Borning & Muller, 2012; Lee & Šabanović, 2013; Rode, 2011). For example, Lee and Šabanović pointed out gendered roles as an essential but less highlighted concept of technology design in home settings (Lee & Šabanović, 2013). The study found that domestic technologies are used, adopted, and envisioned in the context of gendered social dynamics. A STS scholar, Cowan, showed how the unbalanced division of labor in home settings was reinforced by domestic technologies (Cowan, 1983). She explained how labor distribution is socially, politically, and economically constructed inside the home as part of a larger socioeconomic system and how domestic technologies reflect that division of labor. The early smart home studies were criticized due to its lack of understanding of gender dynamics and division of labor (Berg, 1995; Rode, Toye, & Blackwell, 2004), and studies addressing gender dynamics opened a new direction of home technology studies (Bell & Kaye, 2002; Rode, 2010). As gender dynamics gain more attention in HCI, researchers have adopted more feminist approaches in home technology design (Bardzell & Bardzell, 2011). Lukoff et al. used a feminist HCI lens to understand how design of technology can encourage fathers' involvement in childcare, and engagement with their identities as fathers (Lukoff, Moser, & Schoenebeck, 2017). D'Ignazio showed how breast pump design, an important technology for

motherhood was overlooked, and discussed emotional burdens and changes of the postpartum period for mothers (D'Ignazio, Hope, Michelson, Churchill, & Zuckerman, 2016).

By integrating the division of labor into the design of sleep-support technology, System 1 facilitated children's spontaneous participation in their bedtime routine and house chores—families were able to achieve more balanced role sharing. Similarly, System 2 showed family time and labor to be common resources by, to be specific, visually displaying how time-saving practices in one part of family life (e.g., children not making multiple requests after bedtime) can benefit other parts of their life (e.g., securing parents' self-care time). This effect eventually contributed to improved evening routine and sleep for the family. By revealing the nature of the family role and responsibilities in what would otherwise be invisible work (Star & Strauss, 1999), the system emphasizes the interconnectedness of the family; this motivates children. With this approach, social dynamics among family members so that parents — particularly mothers — can no longer be considered to have sole responsibility for managing the family's sleep and instead can secure their own time and sleep.

5.3 Engaging children in the family health behavior changes

Further, the current study investigated how health technologies designed for multiple users with discrepant motivations and needs can engage each user, including children, with increased motivation during their bedtime routines through gamification and humanlikeness cues. Although the study did not test direct influences of gamification or humanlikeness cues on children's improved motivations and cooperative behaviors, it suggests future pathways for technologies designed for multiple social actors in the home setting.

In particular, the current study expands the empirical knowledge on gamification as a family-centered goal-setting practice. Although goal-setting theory has been used to explain

individuals' improved performance with goal-setting and motivation, little has been done to explain how family goal-setting can be integrated with gamification principles (badges, social interaction) and eventually support a family's discrepant health and wellness needs. The findings from Study 2 suggest that both systems contributed to children's proactive behaviors in their bedtime routine, which also resulted in improvements to the family's lives. Parents witnessed that their children wanted to show that they could complete the bedtime routine in less time than recommended by System 1, and stayed in bed in order to achieve the goals suggested by System 2. This increase in the children's active engagement, and strong motivation at bedtime, can be explained by gamification. Gamification is the application of game elements in non-game contexts. It can enhance users' motivation to engage in different contexts, including education and healthcare (Sailer, Hense, Mandl, & Klevers, 2014). HCI studies often borrows game elements (e.g., characters, reward points, feedback, and game stories) for the technology design in broader healthcare contexts, and shows their value in terms of facilitating user engagement in an improved quality of life (Klasnja, Hekler, Korinek, Harlow, & Mishra, 2017). For example, Fish'n'Steps, a daily footsteps counter, shows users' daily steps through the growth of the game character and its emotional status in a virtual tank (Lin, Mamykina, Lindtner, Delajoux, & Strub, 2006). Similarly, a mobile-based system, UbiFit Garden, was developed to promote the user's physical activity, with a visual representation of activity data using a garden metaphor (Consolvo, McDonald, & Landay, 2009; Consolvo et al., 2008). Despite the theoretical foundation of goal-setting and gamification that explains the benefits of having concrete goals for individuals' improved performance, it is still a new concept in family sleep management. Therefore, many existing sleep or support systems mainly focused on goals related to data tracking (e.g., sleep duration), and were targeted for parent users. Only a few systems were

developed to involve children, but they also functioned as parental support tools that helped parents manage their children's routine, rather than support children's autonomous participation in their routine management. In line with gamification principles, in Study 2, children were able to receive visual feedback based on their performance during the bedtime routine (e.g., check mark displaying according to children's accomplishment on System 1, and brightness changes according to children's behaviors on System 2). Also, the reward system (e.g., the sticker chart) implemented in both systems may have had some effect on children's improved behaviors by itself. Parents witnessed that their children wanted to "beat" the system, and perceived it as a "game."

Another possible interpretation is that children perceived System 1 as a social agent which influences their socio-emotional behaviors. When technology has a humanlikeness, such as appearance or features (e.g., voice, motion), embodiment in physical interfaces, or even display in a virtual form, children are likely to engage in suggested behaviors. Social robot studies have discussed the positive influences of humanlikeness in different social contexts with children, including classroom settings (Kanda, Sato, Saiwaki, & Ishiguro, 2007; Tanaka & Ghosh, 2011) and healthcare (Feil-Seifer & Mataric', 2008; González-González, Violant-Holz, & Gil-Iranzo, 2021; Jeong, Dos Santos, et al., 2015; Jeong, Logan, et al., 2015; Wood, Zaraki, Robins, & Dautenhahn, 2021). For example, the social robot Huggable showed the benefits of companion-type technologies in children's health contexts (Jeong, Dos Santos, et al., 2015; Jeong, Logan, et al., 2015). Similarly, Looije et al. showed the positive influences of embodiment in educational robots for children, in that the robots drew attention and received positive feedback from them (Looije, van der Zalm, Neerincx, & Beun, 2012). Studies further discussed the optimal degree of traits (e.g., proactiveness, judgement) for better motivating

children's everyday tasks. For example, Fink et al. showed how different types of interaction (system-driven vs. user-driven) from the robotic platform Ranger influenced the way children put away their toys (Fink et al., 2014). Results showed that a user-driven robot, which reacted to users' behaviors rather than initiating interactions, was more effective for cleanup. Similarly, in the context of musical instrument learning, children showed higher motivation with a robot with nonevaluative traits, regardless of children's levels (Song, Barakova, Markopoulos, & Ham, 2021). These studies showed the benefits of embodied technologies and effective features in different everyday contexts, including health and education.

CHAPTER 6: DESIGN IMPLICATIONS

Based on results from the current study, I suggest three main design implications for family-based sleep support technologies: Facilitating both individual and shared goals to support discrepant motivations behind managing routines, technologies that support the creation of new family routines and roles, and social agency and humanlike cues of the social agent in a family-based sleep support system.

6.1 Technologies that understand the complex situation of family members with discrepant motivations behind managing routines

The findings from my study showed that family members' engagement in their bedtime routine mattered in successfully managing family's overall evening routines, reducing tension between parents and children, and improving parents' own health and wellness by securing their time and energy. Thus, to facilitate a family's bedtime routines, it is critical to support each family member's autonomous and active participation, including children's motivation and interests.

When people are given specific and achievable goals, they are likely to perform better (Locke & Latham, 2002; Lunenburg, 2011). This goal-setting principle is often applied to gamification, and often used with other components in technology design, such as feedback, rewards, or badges (Fortes Tondello, Premsukh, & Nacke, 2018). These principles provide useful lenses for future design implications of family-based sleep support systems. In particular, previous studies on goal-setting theory have shown that balancing group and individual goals is more effective than having individual or group goals alone (Lunenburg, 2011). They pointed out the positive effects of sharing goals between individuals in a group. Also, goal achievement has been shown to be more supported when users have difficult-but-attainable goals and receive

appropriate feedback on their performance (Lunenburg, 2011). When household members perceive that others share similar goals, they are more likely to be motivated. For example, previous HCI studies have used goal-setting with gamification (e.g., family exergame studies) (Katule, Rivett, & Densmore, 2016; Saksono et al., 2015; Schaefbauer et al., 2015). The study outcomes showed increased levels of motivation and healthy behaviors when family members shared a collective goal (Colineau & Paris, 2011). These studies showed that a collective goal as a family positively influenced each family member's contribution, and knowing other family member's status from appropriate feedback further increased the participation.

In addition to the importance of supporting shared goals, one of the critical considerations from Study 1 and 2 was the family's needs and motivations driving the bedtime routine, which are both invisible and discrepant. For many children in the current study, bedtime routine not only meant time to rest, it also meant completing a series of tasks within a given timeframe subject to parental guidance. These tasks and needs changed as children entered new developmental stages, and thus parents were expected to meet new requirements. For parents, children's sleep means time for caring for their own mental wellness, often resulting in sleep procrastination. As participants in Study 2 mentioned, these parents also need behavioral guidelines to improve their sleep quality. Despite complex needs and motivations related to sleep, existing sleep-support systems only provide one-dimensional goal support, including tracking sleep data as a family (Pina et al., 2017; Pina et al., 2020) and indicating wakeup time or bedtime (Ozenc et al., 2007).

Therefore, to design a family-based sleep management system that can engage family members, it is critical to support household members' discrepant needs related to their bedtime routine, and provide optimized guidelines. Based on these findings, I suggest a system that offers

both personalized routine goal-setting functions elicited from each family member's different needs related to sleep (e.g., cuddling with parents, more story time, self-focused time), and ways of showing shared goals as a family (e.g., going to bed on time and having enough sleep for the family). Supporting individual motivation and achieving shared goals would facilitate each family member's engagement in managing their routine.

For instance, System 1 could provide a way of supporting a family of children with age gaps. A family with three young children (ages 2, 5, and 7) can set a shared goal for all three to go to bed by 8pm after they follow their bedtime routine. However, these children may have discrepant needs and motivation related to sleep because of their different developmental stages. A new family-based sleep management system could visually show three different routines and goals that satisfy individual needs. By following each routine, the two younger siblings could spend more time for taking a bath with their father, while the older child could spend story time with their mother. Each child gets a reward once they achieve their goal, and once all three children have completed their tasks, they receive bonus points as a group.

In addition, goal-setting theory also explains the positive influence of having deadlines. In many cases, goals were shown to be more effective when there was a concrete deadline for task completion. When people know their deadline is approaching, they tend to invest more effort to achieve their goals, compared with when they perceive they have enough time (Lunenburg, 2011). The current design of System 1 used audio cues (music chosen by the users) to indicate rough deadlines. Families in my study showed how they reacted to the music and performed the tasks. In addition to the audio cue, it would be helpful to have a strong visual feedback (e.g., timer, hourglass) to indicate the remaining time for children and their progress in achieving the task throughout the day, week, or month. In this way, young children can engage in

their tasks easily even if they cannot read the clock. For parents, it might be useful to show a simple message or reminder to go to bed themselves after a reasonable interval past the children's bedtime; this way, parents can be aware that they have had enough self-focused time.

6.2 Technologies that support the creation of new family routines and roles

Previous HCI studies on division of labor have been limited to unbalanced gender roles; however, the current study, particularly System 1, prompted other types of role-sharing (e.g., parent/child). In Study 2, families who used System 1 expressed their greater satisfaction with children's active participation in their tasks, as well as in other household chores. Because of the spontaneous nature of the system's guidance, parents were able to give fewer verbal reminders to their children. In human development and family studies, researchers examined different types of domestic role sharing (e.g., siblings, homosexual parents) (Tornello et al., 2015; White & Brinkerhoff, 1981) and cultural influences (Blair & Johnson, 1992; Pinto & Coltrane, 2009).

As the current literature has not yet examined those aspects in the context of family health, future HCI studies will benefit from expanding definitions of division of labor to encompass various types of domestic role-sharing, and from examining influences on collaborative health management practices. To facilitate different types of role-sharing in the family, the system needs to actively intervene in the family's existing division of labor. In my study, participants were asked to negotiate their role and responsibilities between themselves while they used the system. However, these negotiations did not result in drastic changes of their existing domestic roles. This is probably related to the recruitment process of Study 2. In 11 of 12 households, the mother was the contact person and the main participant. Although 6 of 12 families had both parents participating in the post-study interview and sharing their insights, I was unable to conduct interviews with the other 5 fathers and 1 mother;

interestingly, these were the families where the interviewee reported a less balanced division of labor.

In particular, despite the family members' improved participation in their roles, all seven families who used System 1 shared that they implemented already-established roles and routines, rather than creating new ones. This suggests the need for stronger intervention. In future studies, systems should help families to find and develop a balanced division of labor rather than merely prompt them to engage in assigned roles.

For example, future designs for the system could include simple questionnaires for each family member during the initial setup, so as to better understand their perceptions on the current division of labor. The data thus collected can be used in a graphic which illustrates the current status of division of labor within the family -- information which is often invisible. The system can further suggest an ideal routine and/or division of labor, so that families can easily establish new goals rather than remaining with their existing practices. In this way, could provide more effective solutions for families with less effective bedtime routine, or unbalanced division of labor.

6.3 Technologies that utilize humanlikeness to enhance families' sleep management

In the current study, results showed that families perceived the social cues from the system; it also enabled them to better perform their bedtime routine. Families also shared how they perceived System 1 as a social agent providing care and guidance. When technologies presented humanlike cues, such as socio-emotional dialogues (e.g., greetings, everyday conversation), and embodiment, users were more likely to accept directions and suggestions from technologies (e.g., robot) (De Greeff & Belpaeme, 2015; Kraus et al., 2016; Lohani, Stokes, McCoy, Bailey, & Rivers, 2016). For example, when users taught a robot new knowledge, they

were likely to engage more with effective learning input if the robot displayed social cues, including showing visual images, expressing its preferences, and encouraging users (De Greeff & Belpaeme, 2015).

By using those cues as strategies, future systems can guide families in the creation of new routines, distribute their roles, and provide learning opportunities regarding care for family members. HCI/HRI studies discussed the use context of technology and users' situations as important determinants of their preferred degree of social cues for a technology. Rhue et al., observed that although there are characteristics that positively influence users' evaluation of technology (e.g., robots), those factors were conditional depending on various factors: the task context in which the technology is used, the specific role of the technology, and the user characteristics (Goetz, Kiesler, & Powers, 2003; Rheu, M., Shin, J., Peng, W., Huh-Yoo, 2020).

In this regard, technologies with the same degrees of humanlikeness and features could be perceived differently depending on their use contexts. For instance, while a robot designed for assisting exercise was expected to be more delicate, so as to display specific posture and touch that resembled those of a human (Fasola & Matarić, 2013), a robot designed for medical use was expected to show authority as an agent who provided medical assistance (Chita-Tegmark & Scheutz, 2021; Moharana, Panduro, Lee, & Riek, 2019; Utami & Bickmore, 2019). Future studies should investigate the effective social cues that facilitate role sharing among household members.

In Study 2, participants perceived System 1 to be a useful reminder for domestic routine management. Although participants had previously used other smart technologies, such as Alexa, one participant particularly noted that System 1 was better because it used a mounted screen to display visual content. Similarly, participants with System 2 also noted that providing children

with visual indicators (i.e., lighting systems) made it easier for them to follow the routine. This may suggest that, for families with young children, agreement among householders could be achieved by providing a reference (e.g., screen or tangible interface) which multiple family members could see, and which would help them pay attention while in the midst of other tasks. By applying the findings from the current study, these design components could be used to deliver humanlike cues, such as displaying feelings, emotional status, or short dialogue.

In the current study, I applied basic design components, such as ready-made stuffed animals, simple icons, and lighting systems, to visually display assigned tasks. As several participants mentioned, it would be necessary to diversify choices in the systems' appearance or the music being played (e.g., for boys or older children). In future studies, it would be useful to narrow down the user groups and identify context-, age-, or gender-specific features that can be useful for family's sleep management.

CHAPTER 7: LIMITATIONS AND FUTURE WORK

While the current study discusses families' experiences with sleep behaviors and perceptions towards the two systems, this study has several limitations that future studies should consider. In this section, I describe those limitations, and detail a future study plan to expand on my current findings.

7.1 Limitations

As the majority of participants were upper middle class mothers from the midwestern United States, the populations of both Study 1 and 2 were relatively homogeneous living in a single-family house and having a relatively affordable cost of living compared to those in cities. I also included only two single-parent families; the rest of the participants were heterosexual two-parent households with child(ren). Given that today's families are becoming more diverse, expanding study populations (e.g., single parents, same-sex parents, extended families) could help researchers be reflexive regarding the conventional definition of families. It would also be useful to compare groups of participants with specific characteristics, such as by family's marital status, employment status, culture, age, or number of children. For example, families from Asian culture could feel more comfortable about co-sleep with their children compared to those from the US (Owens, 2004). Future research should provide more comprehensive design concepts that facilitate family's health management practices depending on their unique characteristics.

Also, despite the effort to recruit both fathers and mothers in Study 1 and 2, the majority of participants who agreed to participate were mothers. To have a non-biased perspective on gendered family roles and the influence of technology on family dynamics, it would be necessary to recruit more male participants. Similarly, the study mainly included parents' voices, not children's. Although I collected children's perceptions toward my design through simple

drawing outcomes in Study 2, the outcomes were used as supplementary materials that prompted parents' answers regarding how family used and reacted to the system. Deeper insights from children's experiences with the system were not collected and identified in the current study. For future phases, it will be necessary to understand how children perceive their family's sleep management practices, and identify implications for the technology design through appropriate design methods, such as co-design approaches and techniques (e.g., workshop, storytelling).

When designing technologies targeted at multiple family members, one issue to consider is perceived invasion of privacy. If a family-centered technology —particularly one that is always on — is placed in a shared space (e.g., a living room), this can hinder active usage due to family members' privacy concerns (Shin et al., 2021). Other studies have particularly showed the concerns of teenage users, due to their increased need for privacy. These needs vary depending on family relationships and children's age (Racz, Johnson, Bradshaw, & Cheng, 2017; Shin et al., 2021; Yarosh, 2015). Given that many families in the current study had children of many ages (including teenagers), and placed the system in shared spaces (e.g., living room, kitchen, hallways), family members' feelings about privacy should be taken into account during the development phases of future studies.

Another limitation of the current study is the possibility of the novelty effect: factors such as trends and social pressures, which lead to initial high acceptability of the technology use, can wear off over time (Koch, von Luck, Schwarzer, & Draheim, 2018). Although the two-week length of the current study was within the normal range of many field deployment studies in HCI, this makes it difficult to determine whether the participants' positive appraisal of the two prototypes was primarily due to the prototypes' benefits, or simply to the novelty effect (Cho, Lee, & Lee, 2019). For example, studies showed that in the 3rd month, the usage of health

technology declines (G. Shin, Feng, Jarrahi, & Gafinowitz, 2019). Ultimately, many users do not continue regular usage of smart technologies (Cho et al., 2019). To properly understand user experiences, long-term observation is necessary: not only of how users adopt new technologies, but also of how they abandon them (Holtz et al., 2021). Given the importance of long-term observation, it is important that the prototypes remain in the participants' home environment, where their use - or non-use - can be observed, for at least 12 weeks.

Furthermore, as the main purpose of Study 2 was understanding feasibility of both systems in terms of the changes to the family's social dynamics, the results presented in this paper were acquired using working prototypes rather than finished products. Thus, participants' actual behaviors, including their current or ideal length of sleep, behavior changes after using the system, and quality improvement through the systems, were not quantitatively measured. Similarly, because the log data was not rigorously collected, the study results were based on participants' recollection and perceived behavior changes, rather than on objective measurement. For instance, when System 1 prompted Mary's spouse to help children change their clothes, the current system did not track whether he changed his behaviors due to the prompt. Similarly, although participants mentioned the positive influences of the systems on broad aspects of their life (including family relationships), correlation with their actual sleep quality was hard to determine. In future phases, users' preferred length of sleep should be determined, and more sophisticated system design with rigorous methods (e.g., log analysis, RCTs) would be necessary to assess the effect of each design component on user's improved sleep (Klasnja, Consolvo, & Pratt, 2011; Klasnja, Hekler, Korinek, Harlow, & Mishra, 2017).

More importantly, in both Study 1 and Study 2, parents expressed their dilemma of staying up late to relax regardless of their perceived tiredness and lack of sleep. Although they

mentioned that self-care time is necessary to maintain good levels of health and wellness, this correlation was difficult to determine with interview data. In this respect, each individual family member's sleep-related behavior should be measured, as should their different motivations that affect the quality of their sleep. Addressing such factors will contribute to knowledge of how family-centered sleep technologies can improve individual family members' sleep by considering specific factors of family sleep.

7.2 Future work

In the future phase, I will recruit families for co-design and follow-up interviews to elucidate the input of users, particularly children, whose insights will assist in the design of family-centered sleep management technologies. Activity-based co-design is helpful for drawing out children's ideas during the technology design phase (Hong et al., 2018; Poole & Peyton, 2013; Woodward et al., 2018).

Studies 1 and 2 revealed children's positive perceptions towards music, stuffed animals as attachment objects, and gamification of sleep-support systems (e.g., tokens). Children and parents will be provided a participatory design kit consisting of craft materials (construction paper, sewing kits, felt), and invited to create a tangible form of technology they desire to use in their bedtime routine. Children will be asked to reflect on meanings and stories of their objects (e.g., attachment toys or stuffed animals) used in the actual bedtime routine and apply them to the design activities. During the follow-up interviews, participants will be asked about their design concepts and intentions. Design outcomes will be transferred to refined products by trained designers and combined with the core design themes of the current studies (e.g., role assignment and brightness changes of the lighting systems).

With the refined outcomes from the co-design phase, I will conduct a long-term study to determine the proper length, the number of participants, and the measurement scales, before moving on to RCT (Randomized controlled trial). Given that the usage of many smart technologies declines after 12 weeks, and many users did not continue frequent usage of technologies (Cho et al., 2019; Shin et al., 2019), a refined product will be tested for at least 12 weeks to observe whether participants' usage patterns decline after a certain period and show any notable changes in their behaviors. During the study, participants will be given several questionnaires to measure their family bedtime routine and sleep quality (e.g., sleep hygiene index, parenting self-efficacy) (Coleman & Karraker, 2000; Mastin, Bryson, & Corwyn, 2006). Outcomes of this phase will be used to determine details of RCT, including the length, the number of families, and the measurement scales.

CHAPTER 8: CONCLUSION

In this dissertation, I conducted two studies (Study 1 and 2) with families of young children, and showed that sleep is a complex experience entangled with social dynamics between family members that should be understood outside of three boundaries that previous sleep studies often considered: individual-, bedroom-, and nighttime-focused. Sleep technologies have long been considered to be "good design" if they accurately capture sleep data while users sleep at night in their bedrooms. When I interviewed the families, however, the most salient and critical themes that emerged were parents' experiences that stem from the life changes of needing to provide constant attention and care to young children, and family members' discrepant needs and motivations behind managing their bedtime routines. My participants' experiences showed that good sleep could only be achieved when family members care for each other and work collaboratively throughout the day. This new perspective on good family sleep would expand the design possibilities for sleep technologies that actively intervene in the family's existing social dynamics, and support both individual and group motivations and goals. I hope my study provides families with opportunities to reflect on the meaning of care in their family, and to collaboratively improve their sleep routines as well as their broader health and wellness.

APPENDICES

APPENDIX A: INTERVIEW THEMES

STUDY 1

First Session

<Introduction>

Could you tell me about yourself?

- Probe: Your occupation, and number of years married
- Probe: Brief introduction of your family members (number/ age of children)

<Mapping activity>

Participants devised their own map about their sleep issues during map-making activities. At the beginning of the first Zoom session, participants were given three keywords: 'sleep,' 'family,' and 'me.' Using sticky notes, whiteboards, or virtual drawing tools, participants generated twenty words that were related to the initial three keywords, and explained how each of the twenty words was associated with their everyday life.

1. Do you mind sharing your cultural background? (particularly if participants moved from another country)
    - Probe: Could you tell me about division of labor in your household?
    - Probe: How does your cultural background affect manage household tasks, including raising children?

2. Could you describe overall family relationships in your household?
    - Probe: How often does the family get together and have conversations?
    - Probe: Who is your child's primary caregiver and how do you divide tasks and roles in terms of taking care of your child?

Second Session

< Routine >

1. Could you walk me through a normal day for you and your family, from morning to night?

2. What was the biggest change in how you manage your daily lives, since you had your child?
    a. Probe: For example, busy morning routine, time constraints

3. Could you describe your family's sleep routine, rules, or any collective efforts especially for your children?

4. What are the biggest benefits and challenges to implementing those rules in your sleep routine?

5. When your daily routine is disrupted, due to busy schedule (e.g., visitors to your home, business trip, night out), what are some challenges?

6. You shared your cultural background before, but are there any familial, cultural factors you think that influence your family's sleep routines?

<Sleep Environment>

1. Could you describe your family's sleep environment and your efforts to manage/ improve sleep environment, if any?

2. If one of your family members has a hard time keeping their normal sleep routine, how would that affect the routines of other family members, including you?

3. Do you have any special tools that adjust environmental factors for either adults and children?

<Sleep Behavior>

1. What is the biggest issue that you face in terms of your family's sleep behavior?

2. What would be the disruptive factors that interfere with your sleep, if any?

3. Do you perceive any barriers to your family member's (children's) sleep routines?

4. What strategies have you tried to alleviate those barriers?

5. Have you had any resources/strategies to help solve the problems related to your sleep routines?

<Family Technology Use>

1. What types of [information] technologies do you use for your daily activities, such as exercise, listening to music, playing games, etc.?

2. Have you used any sleep-related technologies?

3. If your household members use any [information] technologies (e.g., smart speakers, digital games, computer) collectively as a family, could you share how you use them?

STUDY 2

<General Questions>

1. Please introduce yourself. (If interviewee is new-- obtain demographic info, house configuration)
2. Could you briefly share any changes that you and your family have experienced (new member, life course changes) since we had our last interview a year ago?
3. What efforts have you made to establish or maintain your child's bedtime routine and stable sleep?
4. What have recently been the most challenging issues in parenting, including sleep routine management?
5. What have recently been the most rewarding parts in parenting, including sleep routine management?
6. You mentioned the importance of a bedtime routine and how you established it previously. Could you briefly share your children's current bedtime routine?
7. Tailored question based on the previous interview
    a. You mentioned role-exchange during the weekend. Do you still do this with your husband? Does your daughter still sleep with your husband?

<Family Role>

1. Have you considered how to teach your children their roles in the family, i.e., responsibilities, household chores?
2. Have you considered how to teach your child the concepts of care and empathy, particularly the impact of their behaviors on other family members?

<Prototypes >

1. Tailored question based on the previous interview
2. How would you use the systems in your daily routine? What roles did you assign to whom?
3. Could you walk me though how you used the system for the last two weeks?
    a. Did you name the system?
    b. When did you use it? What were your motivation and goals?

    c. How often did you use it? Were there any barriers to using it?
    d. Where did you place the device and why?
    e. Is there any place where you would prefer to place it?
4. Have you considered additional bedtime routine tasks that were not listed in the app?
5. Could you describe how each family member, including your children, reacted when you started to use it?
    a. What conversations have you had since you implemented it into your daily lives?
    b. What changes have you experienced? Any positive or negative effects?
6. When you assigned a task to a particular family member, how did you decide what task to assign? Did you simply assign them, or did you first discuss the issue and achieve agreement?
    a. Have you had conversations about the division of labor in your family?
7. When you explained to the children about responsibility and how to save the token lights, how did you do so?

Design Implications

1. Can you think of other design functions? Could you share your insights?
    a. What are the most positive aspects of this prototype?
    b. What were the most difficult aspects of using it? How could we improve the prototype?
2. If you were asked to redesign the prototype, how would you do so?

Drawing form

1. Have you asked your child to fill out the form? Could you walk me though the outcomes?

APPENDIX B: DRAWING FORMS

A. SYSTEM 1

Date: **Name:**

Draw pictures or write words to share your experiences with the system!

What do you think of when you see the word **"Sleep"**? Draw or write.

Draw your ideas of toys, tools, or people that **help you sleep well!**

B. SYSTEM 2

Date: **Name:**

<u>Draw pictures or write words</u> to share your experiences with the system!

What do you think of when you see the word **"Sleep"**? Draw or write.

Draw your ideas of toys, tools, or people that **help you sleep well!**

APPENDIX C: INSTRUCTIONS

SYSTEM 1

- The app allows you to set up a tailored routine for your child at a specific time.

- We have 11 different routines in the system: Clean up Toys, Bath Time, Use the Potty, Pajamas, Brush Teeth, Bedtime Story, Drink Water, Kiss, and Cuddle, Turn Off Lights, Go to Bed, Eat Dinner, and a blank that you can fill in with a task of your choice.

- Please choose up to 5 tasks that you want to include in your child's routine.

- Discuss the system with the rest of your family (spouse/partner, older children). Ask their opinions/preferences on sharing responsibilities, and get their agreement on who should be in charge of what.

- After discussion with your family members, use the app to assign particular routine tasks to specific household members.

- Assign a piece of instrumental music from the set of 20 different songs to reduce the level of stress before the bedtime routine. Feel free to ask about your child’s musical preferences.

- You can check the status through the app. If your child follows their routine, you can reward them.

- Please use at least five days a week for two weeks. Your active participation will be helpful during the follow-up interview.

SYSTEM 2

(1) Heart-shaped light

- The brightness of the heart light will depend on the number of light tokens the child has used: at zero, the light will be out, and at three, it will be fully lit

(2) Round-shaped lights (Light tokens)

- Each night after the bedtime routine, you will be asked to turn three light tokens on.

- The lights function as post-bedtime tokens, and children may "spend" them getting out of bed for any reason they want (e.g., a drink of water or another hug) at the cost of one token each time.

- Whenever your child calls you to make a request, you should turn off one light after responding to their needs. The brightness of the heart-shaped light changes with the number of round lights.

- Unfortunately, the device is a prototype and does not currently have a reset function. If you want to turn the lights back on, you will need to unplug the device and plug it in again.

- The remaining number of lights will be stored as rewards in your app.

- You can check the status of the lights through the app.

- If your child does well (e.g., saves more than one token), you can reward them using the sticker chart.

***** Because this prototype is an early-stage design, it is delicate and easily breakable. Please do not pull out the wires. Please leave them as they are now. Thank you!***

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