Routine as Resource for the Design of Learning Systems

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Keywords

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Abstract

By understanding how routines support people's everyday activities, we can uncover new subjects for sensing and machine learning. This new data creates new ways for end-user applications to support daily life. I demonstrate the value of this approach using dual-income families.

My studies of family logistics shows that family members sometimes need but do not have access to information about the plans and routines of other family members. Because family members do not document this information, they do not exist as resources family members can turn to when needed.

With only the GPS on commercial mobile phones, we can use machine learning and data mining to automatically document family logistical routines, and present that information to families to help them feel more in control of their lives.

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Chapter 1. Introduction

Through the repeated performance of a set of sequenced actions, groups and individuals construct routines. Routines allow people to complete their activities without having to constantly attend to the details of what they are doing, freeing attention to focus on more important tasks, issues, challenges, and pleasures. Without routines, individuals would have to invent new plans just to complete simple tasks like getting dressed in the morning, driving to work, and starting and ending conversations.

As sensing technologies trend towards ubiquity, a wider variety of human activities are becoming accessible to computational pattern recognition. The repetitive nature of routines, and their central importance to daily life, would seem to make them a natural subject for these growing computational capabilities. Knowing the routines of successful athletes could help create new ways to train current athletes. The routines of successful dieters could be used to help obese individuals with their weight loss. Knowing the routines of successful businesspeople could help aspiring managers to assess their skills. Knowing the routines of skilled mechanic could help train new mechanics when they encounter unfamiliar situations. Knowledge of routine could also be used to identify or predict when non-routine events are or might be occurring. Knowing the habits of successful students could help identify students who are on the cusp of having problems. Knowing the routines of healthy child development could help parents identify when their children are acting out above normal thresholds.

Despite this potential value, routine remains a largely unexplored computational abstraction. Routines have been used in a limited manner, to improve the classification of domestic activities (Huynh, Fritz & Schiele 2008) (Van Laerhoven, Kilian & Schiele 2008), to create opportunities for workplace communication (Begole, Tang & Hill 2003), and identify anomalous transportation patterns for the cognitively impaired (Liao et al. 2007). Routines serve as a unit of analysis for geographic mobility (González, Hidalgo & Barabási 2008) and social network analysis (Eagle & Pentland 2006).

This work looks to extend how the concept of how routine can be used by computer systems. If we could teach computers to learn specific human routines, computers could communicate that information back to people in ways that could improve the quality of their lives. This work looks to demonstrate and validate this concept.

For this purpose we turn to the dual-income family demographic. To many dual-income families, balancing the demands to transport children between home, school, and their enrichment activities, when faced with limited resources, often requires an extensive investment of energy and attention (Ling 2006). To support this complex task, dual-income families rely largely on routines (Wolin & Bennett 1984). Even with the most careful and attentive management by alert and responsible parents, however, plans do break down. These breakdowns take many forms. Some breakdowns are common. A child goes to soccer practice without their cleats. A parent forgets when it is their turn to bring snack for their child's class. Even these simple breakdowns can cause more complex problems. Single problems can easily disrupt other events, setting in motion a day of additional problems. Other events are rare but have severe consequences. For example, a parent forgets the day of a make-up soccer game, and does not go to pick up their child

When plans do break down, parents experience various forms and degrees of anxiety (Darrah & English-Lueck 2000). Anxious parents are often task-focused, and lose the pleasure of time spent with their children, or watching them play. Parents can become disconnected from the experience of being parents (Lee et al. 2008). This feeling can be compounded when a parent feels like they are not performing as good parents, or good exemplars of time and resource management. These forces exert a cumulative effect. Parents in dual-income families often feel like their lives are out of control (Davidoff et al. 2006).

Logistics – or the transportation of parents, children and their equipment when and where they need to be – is central to this family experience. Families rely on routines to help them reduce the effort required to support the transportation of their children. In this capacity, routines help reduce anxiety associated with getting people all the places they need to be. Routines can provide busy parents an experience of more confidence, competence, and control (Fiese et al. 2002).

Reliance on routines proves to be an effective logistics strategy when days unfold as planned. For the dual-income family, however, less than half of events unfold in a routine manner (Davidoff, Dey & Zimmerman 2010). When an activity does not happen in a routine manner, we label it a **deviation** from routine**. Scheduled deviations** from routine occur when the participants know before the event occurs that the event will not happen in a routine manner. Examples of scheduled deviations include make-up games (e.g., for when games are rained out), holidays, scheduled school closings and half-days, and doctor and dental checkups. Scheduled deviations provide families with time to plan a response to mitigate the disruption to routine, which can then be minimal (Wolin & Bennett 1984).

Even more disruptive are unanticipated, **unscheduled deviations**, which are non-routine occurrences that cannot be anticipated. Examples include rained-out sporting events, forgotten items, and sick children. Unscheduled deviations can create some of the most stressful and demanding situations for parents (Frissen 2000), and can degrade effective coordination practices (Wolin & Bennett 1984), which can trigger a cascade of coordination breakdowns (Davidoff et al. 2006).

In this work, we create a link between computational systems and family routines. We demonstrate that we can use techniques of sensing, machine learning, and data mining to model a subset of family routines. We develop a detailed understanding of family routine and demonstrate how and why this understanding can lead to tangible improvements in the quality of family life. Specifically, we aim to contain deviations' capacity to undermine the family's experience of control.

Since we recognize that no computer system will be able to prevent all deviations, we adopt another approach. Instead, we develop models and applications that can reduce parents' anxiety response to deviations. Our goal is to develop a system that helps non-routine days feel more like routine days. And knowing that non-routine days will be cause less negative affect and disruption, parents will experience less anxiety about deviations in general.

1.1 The Problem

Part of being a parent is taking responsibility for arranging and supplying transportation of children between various events. The detail and effort to arranging and coordinate the transportation of people and "equipment" related to school, work, family, and enrichment activities is a significant task for parents. Planning is constrained by younger children, who cannot be left alone. Parents must communicate across distance, and adapt plans in real time. Then parents actually have to execute their plans in a timely manner.

Dual-income families rely especially on routines to support the enactment of their dynamic schedules. As parents repeatedly perform similar sequences of actions around each pick-up and drop-off, a routine emerges, significantly reducing the attention required to complete the task. When tasks unfold in a routine fashion, coordination requires minimal attention to detail. However, when families must deviate from their routines – e.g., when one parent must travel for work, schedule an orthodontist appointment, execute a new carpool, or remain home with a sick child – the likelihood that some part of the plan will break down significantly increases. These deviations in routines, like when a child is unexpectedly ill, create some of the most stressful and demanding situations for parents, and can degrade effective logistical practices, requiring stressful re-planning and improvising. Because of the closely tied nature of family logistics, single points of failures can cascade into multiple event failures. A child wakes up late and misses the bus. When dad drives him to school, he encounters extra traffic and is late for work. Behind at work, dad asks mom to drive their son to soccer, a task he usually performs. Mom remembers to pick up their son. But mom does not know to remind him to bring his bag. They arrive at soccer without the cleats that were in the bag. The son cannot play, and the coach benches him for the next game. On days when one parent must travel for work, schedule an orthodontist appointment, plan a new carpool, or remain home with a sick child these problems are often exacerbated. Parents and children together feel angry, upset and anxious.

While simple, direct communication between family members can often derail potential communication breakdowns, any of a large number of possible issues can obstruct communication and send a day heading towards a coordination problem. For example, a person might be too busy to call, or outside of communication range, leave their phone at home or elsewhere. A person might be in meeting, or a location within a building where there is poor reception. They might leave their phone on vibrate, or another mode that makes it more difficult to detect calls in real time.

When obstacles prevent communication, family members can either choose to postpone communication, look for external resources like calendars that contain the needed information, or make plans using their knowledge of the routine location, availability and intentions of other family members. Despite their importance to many planning situations, family members rarely document routine events on their home calendars. In part this may be because routines are challenging to express in detail, and are frequently evolving, making them cumbersome to describe. Even when they are articulated, descriptions are often incomplete, missing key information like which parent will drive. Regardless of the cause, without some form of documentation, there is no resource that family members can turn to in order to access routine information.

Without an external resource to rely upon, family members must recall details of other members' routines. So when a parent cannot get in touch with a child, and believes it more reliable to make plans at that moment than to delay planning, the parent will make plans using information they believe to be true about their child, and here errors can take place. A parent might make plans for a family member at a time they are not available. They might make plans that require other people travel over distances that require significantly more time at one time of the day than another. A child might assume a parent will be available to drive them one place when they will not be.

Many coordination problems arise, therefore, when various normal life circumstances prevent normal communication, and lacking any external resources that contain the necessary information, family members make plans using what they recall to be the accurate information. When this information turns out to be incorrect, plans can be made that will contain internal inconsistencies or situations that will prevent them from being enacted in the real world. Often, these problematic conditions are not discovered until family members try to enact the plans. By the time the problematic assumptions are discovered, on-timer plan amendment is impossible, and the family must respond to the difficult and stressful circumstances described above.

1.2 A Solution

A lack of access to accurate information about the plans and routine of other family members, and the need to recall it while remotely distributed, lies at the core of the various coordination breakdowns that families experience. If a lack of accurate information can lead families to transportation breakdowns, the most direct solution is to find some way to make this information available to families. Because documentation is cumbersome if at event possible, alternative methods would be required.

Because plans elements – and even entire plans – are repeated across time, they lend themselves to being learned computationally. If plans and routines were made accessible to sensing systems, applications that employ machine learning and data mining could be used to automatically document them. The purpose of this work is to demonstrate that this is possible, and that the outcome is desirable to families.

Thesis Statement

We can learn a model of family logistical plans and routines, and present that information to families to help them feel more in control of their lives.

A computational approach to supporting family life would not claim to offer complete, blanket prevention of coordination problems. Instead, such a system would help families confront the near inevitable deviations from routine in a way that makes them more pedestrian. Given these capabilities, family members would not have to attend to deviations from routine with the same amount of attentional resources. Ultimately, this approach would help family members be more present to engage with one another as they perform their everyday tasks, instead of being distracted by the struggle to maintain control.

To demonstrate and validate this thesis statement requires three steps. First, we will need to investigate family coordination so that we can uncover how a technical system could support coordination breakdowns. The outcome of this section is a vision for a new kind of system that relies on sensing and machine learning to support family coordination. Second, to develop this system, we will need to show that we can sense and learn several new activities. Third, we will need to demonstrate that these models provide information that is desirable and valuable, and can help families solve some of the coordination problems that they face, and help them feel more in control of their lives in the face of those coordination breakdowns.

1.2.1 Routines can Provide a Novel Resource for Application Design

Whether input manually or as part of a learning system, routines can serve as a resource for the design of new kinds of applications. In other words, we can use knowledge of how routines function in the context of family coordination to transform the way we think about the design of family support applications. Because routines are not documented, they are not readily available to computational systems as input. Were they to be made available, then a new kind of information could be provided directly to end users, and could be used by learning and systems to make higher-level inferences about the state of family logistics.

This particular perspective views the routine as a design enabler. In this sense, routine can be provided to support applications as a novel kind of input that can then creates or augment the application’s capabilities. Using routine models, for example, calendaring systems like LINC (Neustaedter & Brush 2006) and DateLens (Plaisant et al. 2006) could display implicit routine events, event times, pick-ups and drop-offs that parents don’t document but are critical to making effective plans for and that affect others. Family members could see an entire day’s plan, helping make unresolved and conflicting responsibilities salient. In another example, models of routine could help location systems like Motion Presence (Bentley & Metcalf 2007) and the Whereabouts Clock (Brown et al. 2007) display where people are with implicit routine information like future pick-ups and drop-offs, helping remind family members what they need to do, and monitoring and peripherally updating an account of routines that happen as planned, and alerting others as days deviate from routine.

Models of routine could even help parents update plans in real-time, helping parents make more reliable decisions. As pick-ups happen, reminder systems like commotion (Marmasse & Schmandt 2000) and PlaceMail (Ludford et al. 2006) could suppress potentially annoying reminders to perform those pickups. Lastly, models of routine could help reminder systems infer that a required pick-up is not happening, and remind parents without an explicit creation of a reminder in advance, creating a new kind of safety net to guard families against this infrequent but stressful outcome.

To demonstrate the enabling power of routine models, we take the routine model (either documented in some way by users, or learned by learning systems) and add its capabilities to an end-user application that shows the overall state of the family logistical plan, in a new kind of visualization that could be displayed on, for example, an augmented calendar. The new resource contained in models of routine could create an additional resource that can be made available directly to end users as novel visualizations. This automated approach both lowers the burden of user input and introduces new capabilities that no manual system could possess. Transportation routines, for example, are often not listed on the family calendar. Access to the routines of other family members can make it much easier to predict where and when they might be, allowing one family member to plan for the near future participation of the others and to improvise even when the others are not available to coordinate with. By showing learned transport routines information, a learning system knows that the daughter, Jane, usually goes swimming, and that the parent with that usual responsibility has a scheduled conflict, then a mobile device application could, for example, make this unclaimed responsibility more salient.

1.2.2 Routines can Provide a Novel Resource for Technical Modeling

To provide applications with access to routine as an input source, the information needs to either be entered manually, or learned by a learning system. When actualized as part of a learning system, routines can serve as a resource for new kinds of technical modeling. We can use machine learning algorithms to extract valuable **but currently undocumented** information that would increase a family's ability to respond to coordination problems, creating a new resource that currently does not exist for them.

While researchers have detailed the importance routines play in how people live and work Winter 1964 (Zerubavel 1981) (Crabtree & Rodden 2004), many researchers in ubiquitous computing caution that systems designers will find significant challenge modeling the idiosyncratic behavior patterns that guide people's lives at the detailed level (Suchman 1983) (Tolmie et al. 2002) (Swan et. al 2006). Considering these caveats, to develop reliable models of routine, development should find a level of abstraction at which there is enough regularity to train statistical models.

Given our understanding of family logistics and the capabilities of modeling, many kinds of models of routine are possible. To demonstrate this concept, this thesis focuses on routines of when parents pick up and drop off their kids at their enrichment activities. We select these routines for two reasons. First, routines of the transportation for activities are a primary responsibility for parents in dual-income families, and so, to them, represent one of the main stressors in their lives, as well as one of the keys towards an improved sense of their own abilities as parents. Second, focusing on the routines of pick-ups and drop-offs allows technical models to be composed using a single sensor that exists on current, commercial-grade mobile phones. No special hardware is necessary.

Technical models of routine can provide the engine that drives new kinds of coordinating support applications envisioned from the study of routine. In other words, a system that has learned family routines based solely on the movements of individual family members can provide the information needed for support applications that make appropriate and valued interventions in family coordination. Such a system can accomplish this by performing three kinds of learning and inferences. First, the system will mine the dataset to determine logistical responsibilities, including activity time and location, and which parent is responsible for pickup and drop-off. Information like which parent makes a pick-up and which makes the drop-off, and at what time and specific location, are exactly the kind of information that would help with making plans, re-planning and improvising, but family members currently do not document.

Second, aggregations of sensed information can then be used to predict which parent should be making a pick-up for a particular activity at a particular time. These learned models of family routine expand the capabilities of current reminder systems. In their current manifestations, reminder systems suffer from two limitations. First, they can only remind their users about things they have specifically stated *a priori*, which is only a subset of all things that are forgotten. Second, current reminder systems deliver user-specified reminders even if their users' behavior demonstrates that they have not forgotten anything. If such a reminder is about a pick-up that the system reasons that a parent is on their way to do, this information could be passed to reminder systems to help them determine if a reminder about a pickup is actually warranted.

Third, such a system can combine these lower-level contextual details into higher-level predictions about states of family coordination, like detecting discrete pickup and drop-off events. This data can further be abstracted to generate a probabilistic model to determine if a parent is on their way to pick up a child, effectively developing a technique that can be used to monitor the coordination practice as it unfolds in real time, and assign a probability that a parent has forgotten to pick up a child.

1.3 Contributions

To prove this thesis, this work crosses the complete spectrum of research in Human-Computer Interaction (HCI). The work begins with fieldwork dual-income families that foreground the problems of the coordination of children's activities (Davidoff et al. 2006). Seeking to develop applications that help support families through the needs defined in the first part, the work then describes collaborative design with families to more concretely define the capabilities of a set of support applications (Davidoff et al. 2007). Having selected an application domain, the work then moves back to the homes of dual-income families, and takes detailed observations of the context in which routines participate, carefully allowing for both an understanding of how to specifically support routines, while at the same time allowing for the collection of a data set through which models of routine could be developed (Davidoff, Dey & Zimmerman 2010). With a rich data set in hand, the work then moves on to demonstrate and validate that the proposed models can in fact be developed without any supervision (Davidoff et al 2011). Lastly, the work explores the design of visualizations that use the learned routine information, and describes an evaluation of those visualizations using experience prototyping.

This process offers four main contributions around the use of routines as a resource for the design of novel interactive systems. First, it characterizes the logistics process in the life of the dual-income family. The examples explain how misunderstandings, miscommunications, and other trivial events can lead to non-trivial coordination breakdowns. It describes logistical breakdowns as a problem of information. In other words, if family members had the information they need, the problems would unfold in a manner of much less impact. This section also describes the social and moral consequences families experience when their logistical plans break down. This motivates the work, and helps guide the technical solution that is the subject of later chapters. This section also introduces and problematizes the central concept of control. Logistical breakdowns induce anxiety because they leave parents feeling at a loss of contrtol.

Second, the work turns the description of family life into a set of design opportunities. This catalog describes how technical interventions that use sensing, machine learning and data mining could help family members plan more effectively, more quickly detect plan breakdowns, and more effectively improvise solutions. This information could also be used to improve reminder systems, both in the dynamic construction of appropriate reminders and in the dynamic suppression of inappropriate ones. This section elaborates how these abilities could augment the capabilities of existing technical interventions to support family life.

Third, the work demonstrates the application of machine learning techniques towards the accomplishment of the agenda described above using only commercially available hardware. The proof-of-concept validates the thesis that the above-described applications are both possible and valuable. While this work describes a research agenda focused on dual-income families, and offers them practical and measurable benefits, this work also generalizes into other contexts, offering the potential for contributions in a larger scale. Because routines can be observed in many places – from the office, to the bathroom, to the health club, to the ball field, to the garage – an understanding of both their integration into daily life, and the development of algorithms that can capture and exploit their properties, promises to extend the same capabilities into these varied domains.

Lastly, the work conducts a laboratory study of a user interface that learned knowledge about routines can be communicated to parents in a consumable and useful manner. This section demonstrates the value of having information about routines, and validates the work to learn routines (or manually collect them)

Collectively these contributions support the main thesis, that routine presents a rich and enabling abstraction for the design, modeling, and application of learning systems. The ultimate outcome of this work is the foundation for a new kind of technology to support family coordination, and by providing them with more time to enhance the things that they value – their identity, their relationships, and their attention – and nurture family relationships as well.

1.4 Organization of this Document

The organization of the chapters in this document roughly corresponds to the contributions listed in the previous section.

Chapter two, Related Work, describes how this dissertation is situated within the histories of research across all the disciplines that it touches. The section links sociology of the family to product attachment theory, to machine learning, data mining and pattern recognition, to information visualization, and all within the context of human-computer interaction.

Chapter three, Investigating opportunities for Technology to Increase the Feeling of Control, draws on roughly three years of fieldwork with over fifty dual-income families to set the stage for the problem. It describes the underlying issues that contribute to problems of family logistics, and connects these coordination breakdowns to social problems of anxiety and, and the feeling of life out of control.

Chapter four, Routine as Resource for the Design of Learning Systems, defines how we can use observations of family routine to develop a design strategy, looking to guide the development of applications to support issues identified in the previous chapter. This chapter concludes that we can view breakdowns as a problem of undocumented information. This chapter then introduces how we can use sensing and machine learning to automatically document the missing information. It provides a plan through which family logistical routines could be learned using the GPS in commercial mobile phones. It also describes how the same approach could be used as a general purpose technology to augment the capabilities of existing coordination support systems.

Chapter five, Routine as Resource for Sensing and Modeling, provides technical verification of the thesis statement. It describes the collection of a massive data set of family coordination, and defines the techniques of sensing, data mining and machine learning that together generate the needed but undocumented information outlined in Chapter three. This chapter describes the gradual abstraction from low-level sensor data to higher-level inference about the family's context. An evaluation of each model is also presented.

Chapter six, Validation, describes two laboratory studies that evaluate the thesis. The studies examine if the information learned through the use of machine learning ultimately provide information that family members find useful. The experiments develop a novel visualization, the Family Time-Flow (FTF), that is used to encode the learned information. Through the use of experience prototyping, family members are asked to respond to common stressful situations using the information generated by the technical models, and visualized on the FTF. Semi-structured interviews and the TAM-3 scale provide supporting evidence.

Chapter 2. Related Work

2.1 The nature of routines

S.G. Winter first defined routine as a ‘pattern of behavior that is followed repeatedly, but is subject to change if conditions change’ (Winter 1964, p. 263). Arthur Koestler later described routines as ‘flexible patterns offering a variety of alternative choices’ (Koestler 1967, p. 44). Looking at organizational routines, these functional descriptions capture the practical behavioral outcomes of routines. Routines help people decide what to do. The definitions also capture that routines are not a policy or mandate, but are flexible heuristics. More recently, Nelson and Winter describe routines as a kind of social genetics (Winter 1994). They observe that routines serve the social function that DNA serves at the biological. From generation to generation, they observe, routines preserve an ordered sequence that serves as the template for future generations. Because this template is relatively stable, they compare this to the genetic property of inheritance. Routines also do develop and vary in ways that can be hard to predict, which they liken to mutation. Most tersely, Cohen and Bacdayan simply call routines ‘patterns of interaction’ (Cohen & Bacdayan 1994), emphasizing that they involve decision-making within an environment of expectation.

Some researchers have examined the flexibility of routines. Feldman compares routines to musical improvisation, where musicians listen to what others are playing, while attending to and responding to the actions of others, and to the situation (Feldman 2000). In this sense, a routine is not a scripted musical score. Like the jazz musician, a person performing a routine can maintain a fairly large space of autonomy while still acting within a set of acceptable conventions.

Pentland and Reuter examine how routines come to exist. They describe routines as “effortful accomplishments” created from an assortment of possible choices (Pentland & Reuter 1994). In this sense, the performance of each routine is explored against a background of rules and expectations, but the path a person chooses to follow is always in some way novel. Routines evolve from the repeated performance of an activity. People remember the successful performances of their activities. If the same behavior, when repeated, continues to deliver successful results, are it often grows to be a more reliable behavior. Much in the way people learn to drive, with each performance, individuals move from novice to expert. The behavior becomes requires less conscious deliberation, and becomes more incorporated as tacit and procedural.

This transformation makes them easier to perform but at the same time harder to explain (Cohen & Bacdayan 1994). Participants in routines can, for example, characterize their actions (e.g. driving to school, planning a ride for a child) but they struggle to describe how they perform those same actions. Individuals follow routines without deliberation, conscious or explicit attention (Pentland & Reuter 1994), making their performance 'uneventful' (Szulanski 1996) or 'unremarkable' (Tolmie et al. 2002). Routines in effect allow people to carry out their daily tasks without demanding their full attention. Because routines do not require attention, people are not usually aware of them as long as they run smoothly, and only become aware of them when they do not (Twomey 1998).

2.2 Families, Routines and Control

Routines of domestic life have been a subject of anthropological and sociological interest for some time. Ethnographic studies have describe a variety of routine on subjects, from household communication (Crabtree et al. 2003) and its relationship to locations (Crabtree & Rodden 2004), time management (Fleuriot 2001), communication technology (Frissen 2000), the meanings of calendars (Taylor & Swan 2005) and types of calendar use (Bernheim Brush & Combs Turner 2005), knowledge specialization (Rode, Toye & Blackwell 2005), and the role of routines (Tolmie et al. 2002). More comprehensive studies include a survey of technology use by form factor, and coordination with respect to the adoption of handheld computing (Beech et al. 2004).

Ethnographers have spent much attention examining daily life in dual-career families (Venkatesh et al. 2003), (Darrah & English-Lueck 2000), (Darrah, English-Lueck & Freeman 2001), (Darrah 2003), (Darrah, Freeman & English-Lueck 2007). One key concept that emerges from these studies is the notion of "busyness," which Darrah defines as "Increased obligations of daily life and the activities required to meet them." Parents survive their many obligations by blurring the home and work selves in an extended multi-tasking Darrah calls multi-contexting. Parents bring their home responsibilities to work, and work responsibilities seep into home life. The two lives interleave, and parents often need to manage activities for their professional and familial selves simultaneously. These parents don't just want to complete their myriad of responsibilities, but to complete them in a way that allows them to feel in control (Bandura 1997) – a situation Darrah describes as 'mastery' of busyness.

I chose the dual-income family for study for several reasons. First, dual-income families often rely on plans and routines to help them manage the busyness of their lives. Second, because the dual-income family is the fastest-growing family demographic in the United States (Unites States Census 2009), (Cherlin 1988), this work can potentially impact a large population. Third, unlike many audiences targeted by the ubicomp community (e.g. seniors), dual-income families are a good population to study because they already look to technology to help them manage their busyness and improve the quality of their lives (Frissen 2000). Fourth, families depend heavily on routines to help them navigate their many responsibilities. These parents face complex logistical challenges as they arrange the transportation and coordination of people and "equipment" related to school, work, family, and enrichment activities (Darrah, Freeman & English-Lueck 2007). And fifth, when coordination breakdowns occur, families experience heightened anxiety. Parents become so task-focused that they ignore or lose track of their children, and even leave them at events for extended periods of time. Even the idea that such an outcome could occur also causes parents to experience heightened anxiety.

Families use routines as one of their principle ways of maintaining a feeling of control over their lives and their environment. A form of habituated memory (Wakkary & Maestri 2007), routines liberate attention, helping people to feel more in control of their environment (Beech et al. 2004), and enabling the enjoyment of everyday experience (Tolmie et al. 2002). Parents often create routines intentionally, appropriating artifacts in their environment to do so (Crabtree & Rodden 2004) (Bernheim Brush & Combs Turner 2005) (Elliot, Neustaedter & Greenberg 2005). For example, in many families, when parents arrive home, they place mail, keys, wallets, mobile phones, and other small items by the door. This often becomes the routine location for these objects. Tables, staircases, coat racks, and other objects that are near the door are absorbed into these 'arrive home' activities, and also become part of the routine. When routines are used, parents generally feel more competent and children show improvements in their physical and mental health (Barnett 1994).

Parents often critique and evaluate their routines in an effort to optimize them for their particular needs (Wakkary & Maestri 2007). A parent might place a cell phone charger near the door so they can plug their phone in every day when they return home. Plugging in their phone becomes part of their routine, and the routine becomes more efficient. The parent is more likely to have a phone that is charged, and the routine location of the charger saves the need to locate the it every day.

However, even well-articulated, well-practiced and well-executed, plans and routines offer little protection against unexpected changes, such as when a child is sick and needs to stay home from school and other activities. These deviations in routines create some of the most stressful and demanding situations for parents. These coordination failures exert a strong influence on everyday family life. The failure of one part of a plan can lead to the successive failure of multiple parts of a plan, a phenomenon described by Frissen as a "house of cards" (Frissen 2000). For the Dutch families studied by Frissen, she observed that the feeling rarely subsides, leading to what she described as "the rush hour of life" (Frissen 2000), where lives come to be dominated by a feeling of being both in a hurry and out of control.

Parents employ a strategy of flexibility to help them manage busyness (Darrah & English-Lueck 2000) (Davidoff et al. 2006). Because routines can be susceptible to change, early planning investment can easily become wasted effort. When Dad gets the new soccer schedule, for example, he knows that he will establish a routine, and might agree to drive for the first game, but he often won't fix a time until game day. In this sense, plans acquire details when necessary, but not before. This strategy of incremental precision provides more flexibility when parents need to improvise.

2.3 Current approaches to family support systems

Many researchers have developed systems that support the domestic experience in a variety of ways. Each looks at a particular set of applications as a way to help families regain aspects of control over their lives. Applications developers often look to augment traditional logistical support systems, including calendaring systems, reminder systems, and location and awareness systems. Smart home researchers often look to support the domestic experience by creating end-user programming systems for the home.

2.3.1 Digital calendaring systems

Researchers augment family calendars as a way to increase what people can remember, especially appointment. Digitized calendars like LINC (see Figure 2.1) translate the traditional calendar into a digital form. Access to calendaring information, and the ability to record events are extended beyond the confines of the home, to locations like the ball field, the playground and the school yard, as well as to a variety of locations within the home (in addition to the central location of a large paper calendar) where planning is also likely to occur (Neustaedter & Brush 2006).

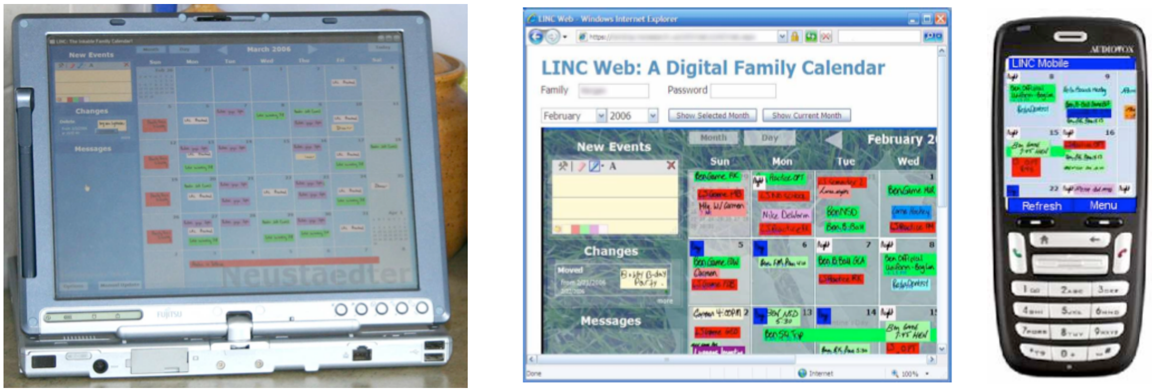


Figure 2.1. The LINC digital calendar (Neustaedter & Brush 2006) offered families three means to access – a tablet PC for the home (left), a web-based application (middle), and a mobile phone app (right). The application prioritized the expressive capabilities of inkable paper calendars.

Field trials of LINC expanded understanding of mobile planning. First, log analysis showed that the desktop web version of the calendar dominated the tally of entry modalities, reflecting that despite the number of tasks that occur when mobile, users were still often nearby desktop computers, and perhaps even preferred its easier input to the mobile device. Also, interviews showed that individuals expressed a desire to enter planning information from within multiple locations within the home(Neustaedter 2007). Despite the physical centrality of the calendar (Bernheim Brush & Combs Turner 2005) (Crabtree & Rodden 2004) (Davidoff, Dey & Zimmerman 2010), information about events could be triggered by any number of interactions throughout the home, and users desired the ability to input and access that information fluidly even while at home (Neustaedter, Brush & Greenberg 2006).

The capabilities of digital calendaring systems could be extended to meet the needs that recent field studies of family coordination have brought to light. First, digital calendars can only display information that is recorded on them. Various studies of calendaring applications show that calendars contain largely non-routine information (Zerubavel 1981) (Beech et al. 2004) (Davidoff, Dey & Zimmerman 2010) (Davidoff, Dey & Zimmerman 2010), but families often need the most support during days when they deviate from their routines (Frissen 2000) (Davidoff et al. 2007). In other words, calendars remind family members of non-routine events that are upcoming, but they do little to help family members as they make plans that require information that is not recorded on them, or when improvising new plans in response to external circumstances. For example, when mom goes out of town on business, dad assumes mom's usual job to drive their daughter from school to violin lessons. Mom might remind dad on the day of the pickup, and make sure he has the school's number just in case. However, on those routine days, mom also brings her daughter's violin music to work with her. Mom can go directly from school to violin with everything that her daughter needs. Because this behavior is routine, mom probably didn't write it on the calendar. Because it is so routine to mom, she might assume that everybody in the family knows that she takes the violin music with her to work, or assumes that it is obvious that one should do it. No digital calendar will help prevent a situation where there is no record of what needs to be done.

2.3.2 Digital reminder systems

Digital reminder systems can deliver pre-defined information to a variety of devices, including mobile phones and large displays. Sellen et al's Home Note System (Sellen et al. 2006), for example, provided a situated tablet display in a central area of the home (see Figure 2.2). The system provided a flexible way for users to enter reminders both directly on the device using a stylus, or remotely via SMS.

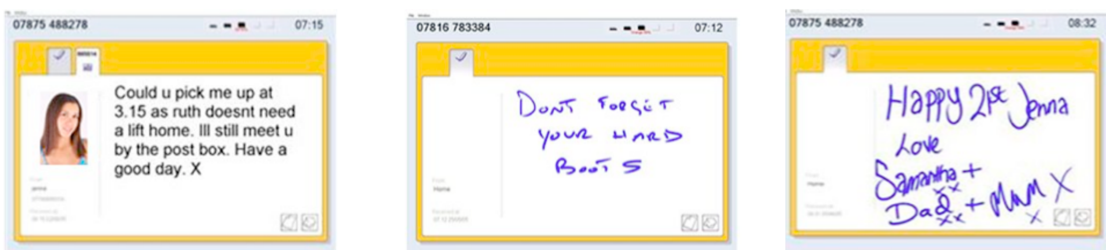


Figure 2.2. The HomeNote system (Sellen et al. 2006) allowed users to enter reminders directly on a tablet PC via stylus, or remotely via text message. The display was displayed centrally in the home. While messages often included functional tasks (above left, center), it also naturally supported social communication.

HomeNote, and reminder systems in general, prove to be a useful ways to send messages to yourself and others in a near-term future, containing specific information about a task or chore (see Figure 2.2 left, middle).

Context-aware reminder systems trigger alerts as people approach pre-specified places both inside (Kim et al. 2004) and outside the home (Marmasse & Schmandt 2000) (Ludford et al. 2006), or even when pre-specified situations unfold (Dey & Abowd 2000).

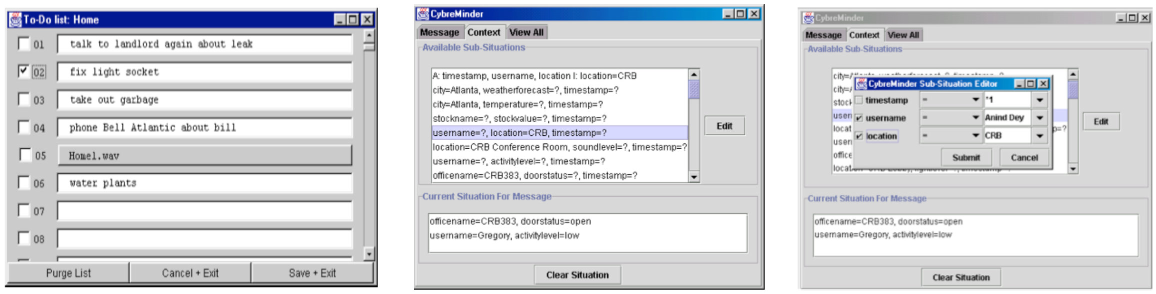


Figure 2.3. Left, the comMotion system (Marmasse & Schmandt 2000) links information from a list with a pre-defined location. The reminder is triggered when the user enters the pre-defined location. At center and right, the Cybreminder system (Dey & Abowd 2000) links information with a combination of contextual details that when combined by the specified logic, trigger the alarm.

Like digital calendars, digital reminder systems extend the capabilities of paper reminder systems to anywhere with network access and a display (Neustaedter 2007). When the needed information is known in advance, and a contextual trigger can be identified, this approach to memory support proves very effective. This approach proves less effective when less predictable information or situations lead to forgetting. A reminder system can only help remind family members of items they specifically create reminders for. Research on dual-income families, however, shows that many breakdowns can often be unanticipated (Frissen 2000) (Davidoff et al. 2006), or involve information that could have not been known beforehand (Colbert 2002) (Suchman 1987), making the task of manually creating an appropriate reminder in these situations impossible.

The alert time associated with a reminder is also a nuanced concept. For example, once a month parents of young children often need to bring snack in for their child's entire class. This event happens monthly, but often not on a predictable day, or even day of the week. A location-based system might trigger the a reminder when the parent is near a store that sells the snack, but the parent does not want to buy the snack so early that it goes stale. A time-based reminder might trigger an alarm on snack day morning. The parent needed the information, however, on the night before snack day, when they would have had sufficient time to purchase the snack in a way that was less hurried.

2.3.3 Digital location and awareness systems

To support various forms of coordination and awareness, people also share their geospatial position via location systems. Location information can be shared on mobile devices, or situated displays (Brown et al. 2007), and can provide literal place names, a limited subset of places (Brown et al. 2007), obfuscated places names (e.g. Carnegie Mellon, Newell-Simon Hall would read “work”), or even simply their status as ‘moving’ or ‘not moving’ (Bentley & Metcalf 2007).

Figure 2.4. The Whereabouts Clock (Brown et al. 2007) is a situated display that reduces location to ‘home,’ ‘work,’ ‘school’,’ and ‘other.’ Family members show an ability to read additional information from the message’s context.

The Whereabouts clock (see Figure 2.4) combines a situated display with a limited set of places, including one flexibly (re-)defined by user families (Brown et al. 2007). Family members demonstrate an ability to infer a great deal more information than is displayed. Relying on their rich knowledge of one another’s routines, family members interpret ‘travel’ at 9am to mean the person is going to work, and at 5pm that the person is on their home.

Displays of this nature can provide information, and through that information, an increase sense of connectedness (Brown et al. 2007). These displays include only a portion of the information that dual-income family members might need when trying to make or improvise plans. Also, since the display always shows the current location, no space is given to a location history. Even when a parent has made an important pick-up of a child, this information is not included on this display unless expressly communicated.

Location and awareness displays do show that they can increase perception of control by knowing here others are and sharing your own location. Remotely coordinating parents still have to maintain regular communication to make sure that everything is going according to plan. Similarly, information like travel does not indicate a destination, and so a parent will not feel in control if they know that their partner is traveling but they do not know if their partner is traveling to pick up their child. Similarly, early in the day, a location system does not declare which parent has responsibility for a pick-up later that day. Often miscommunications and misunderstandings are only discovered at events time. A display with a richer source of information would be able to help parents identify unclaimed responsibilities before task execution time.

2.3.4 End-user programming systems for smart homes

Another view we find in the research community is to give people more control of the devices in their home. End user programming comes through the ability to specify how to use your things. These end-user programming systems explore a creative a wide assortment of interfaces to provide end-users control of the devices in their homes, including natural language (Gajos, Fox & Shrobe 2002), Figure 2.5, interlocking puzzle pieces (Humble et al. 2003), visual programming (Jahnke, d'Entremont & Stier 2002), programming by demonstration (Dey et al. 2004), and magnetic refrigerator poetry (Truong, Huang & Abowd 2004).

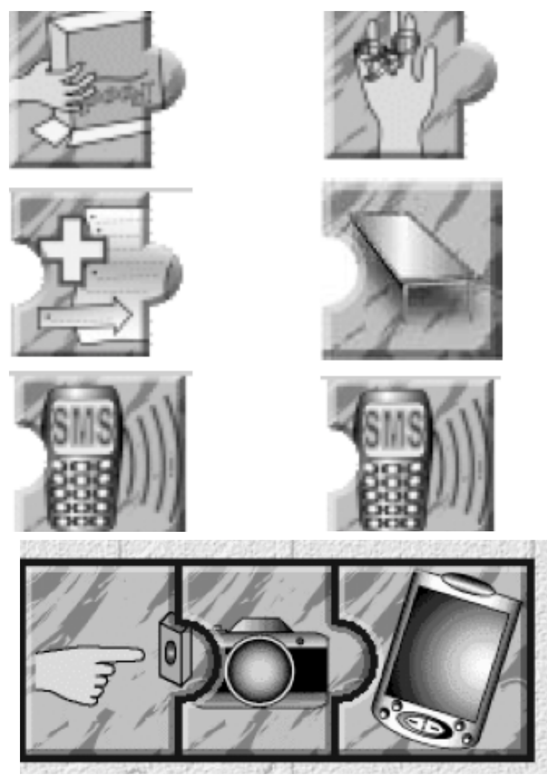


Figure 2.5. The Jigsaw end-user programming environment allows users to assemble new services using interlocking puzzle pieces. Services might include box is empty (top, left), add to shopping list (middle left), and send by SMS (bottom, left) to create a service that automagically adds empty food items to a shopping list, and then sends the list to the user by SMS.

The end-user programming approach offers home-dwellers several potential benefits. It provides users control over an unpredictable confederation of interoperating devices (Newman et al. 2002), and allows users to customize services as they might see fit (Humble et al. 2003), even inventing new services (Truong, Huang & Abowd 2004).

While end-user programming systems can potentially return a limited measure of control to users (Barkhuus & Dey 2003) (Dey & Newberger 2009), ultimately, framing the problem as end-user programming leads researchers to view the research and evaluation in terms of control of devices. Our fieldwork on dual-income families, however, shows that more than control of their devices, **families desire more control of their lives**.

To view family support systems as a problem for smart homes, then the notion of home control should be widened to include not just control of artifacts and tasks, but control of the things families most value – their time, their activities, and their relationships.

2.4 Returning control to the family

The historical record of domestic technology provides evidence for a cautious approach. Central heating, for example, advertised the gift of climate control. This comfort, however, destroyed time spent together surrounding the central hearth (Wyche, Sengers & Grinter 2006) As a historical pattern, this counsels that the promise of control does not guarantee its delivery (Cowan 1989).

This thesis offers not only a technical answer, but one that includes a learning system. The use of learning systems in the home has also received cautious attention. Ethnographers skeptically wonder if science will deliver models robust enough to interpret the deeply idiosyncratic human behavior (Suchman 1983) (Tolmie et al. 2002). And Taylor et al. argue that we should augment the intelligence of people, not houses (Taylor et al. 2008).

Our work builds upon these findings, extending them into the complex and highly nuanced context of family coordination. We model a family as a group of collaborating dependents, not independent individuals (e.g. (González, Hidalgo & Barabási 2008) (Brumitt et al. 2000) (Liao et al. 2007), (Marmasse & Schmandt 2000)), With multiple people, we can introduce models of collaborative family goals, like when parents pick up and drop off children, and whether a pick-up might be forgotten. Currently, the only extant notification mechanism we know for forgotten children arrives as phone calls from impatient day care managers (Gneezy & Rustichini 2000), embarrassed friends (Darrah, English-Lueck & Freeman 2001), or irritated spouses (Davidoff et al. 2006). Notification of this event in any form would present a significant contribution to family life, and create a new kind of safety net.

2.5 Modeling Routines

For families, routine information proves to be important but problematically undocumented. The central thesis of this work is that the very performance of routines by family members can be learned, creating a resource that helps family members feel more in control. In this section, we discuss previous work in learning and modeling routines, and conclude with prior work on applications of routine models.

Brdiczka, Su and Begole (Brdiczka, Makoto Su & Begole 2009) used temporal patterns (T-Patterns) to define characteristics of event routineness. Researchers have applied a variety of other technical approaches, each describing what could be described as a facet of routineness, or some of its key features. This long list includes Bayesian posteriors (Horvitz 2002) (Krumm & Horvitz 2006) and networks (Tullio 2002)Fogarty et al. 2005, Topic Models (Huynh, Fritz & Schiele 2008), Nearest Neighbors (Van Laerhoven, Kilian & Schiele 2008), Clustering (Begole, Tang & Hill 2003), Dynamic Bayesian Networks (Liao et al. 2007), Markov models (Marmasse & Schmandt 2000) and information entropy (Eagle & Pentland 2006) (Ziebart et al. 2008).

These technical models are then proving useful computational abstractions across a variety of domains. They have been used, for example, to improve the classification of domestic activities (Huynh, Fritz & Schiele 2008) (Van Laerhoven, Kilian & Schiele 2008) to create opportunities for workplace communication (Begole, Tang & Hill 2003) (Tullio 2002) Fogarty et al. 2005. GPS data has provided a gateway to many of those capabilities. The predestination algorithm (Krumm & Horvitz 2006) uses USGS survey data to define a prior on destination (Figure 2.6, left) and then can marginalize over destination for each individual using their destination history (Figure 2.6, right).

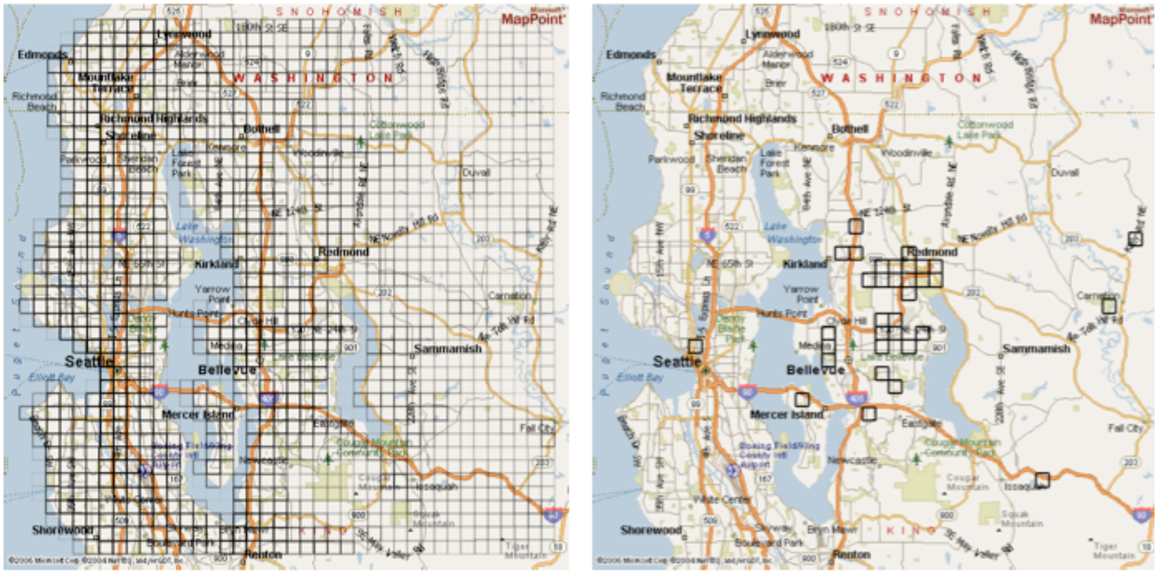


Figure 2.6. The predestination algorithm discretizes the city into a square-kilometer grid, and assigns a prior probability to each cell using USGS data (above, left). The algorithm then marginalizes over destination per individual, allowing for the computation of a Bayesian posterior on destination for each individual (above, right)

Researchers have used GPS data to model geographic mobility (González, Hidalgo & Barabási 2008), social networks (Eagle & Pentland 2006), and navigation for the cognitively impaired (Liao et al. 2007). Our technical work on routine models extends this work on GPS data streams into the context of the family, and builds upon this history of technical development in several ways. First, rather than modeling independent individuals e.g. (Van Laerhoven, Kilian & Schiele 2008) (Liao et al. 2007), family coordination involves multiple individuals that share dependencies on one another and external events. Second, our work is the first demonstration that we know of demonstrates the sensing of pick-ups and drop-offs. Third, our work is the first demonstration that we know of that demonstrates the prediction of which parent will make a pick-up or drop-off. And last, our is the first demonstration of the prediction of pick-up time by parents.

2.6 Visualizing Routines

To demonstrate the value of the routine models, we create an application that displays a family's plan for the day. This application develops a visual vocabulary that encodes place and time for various individuals, and overlays key events like pick-ups, drop-offs, and most importantly, unclaimed responsibilities.

This work builds upon research in information visualization and geography on the representation of time and place. Tufte (Tufte 1983) points to Marey's depiction of the Paris to Lyon train schedule as an early example of time-series data representation (Marey 1880). In this visualization (Figure 2.7) rows represent places, and columns represent time. Trains move in diagonal lines from top to bottom. The slope of the line corresponds to the speed of the train. Places are roughly spaced in proportion to their distance.

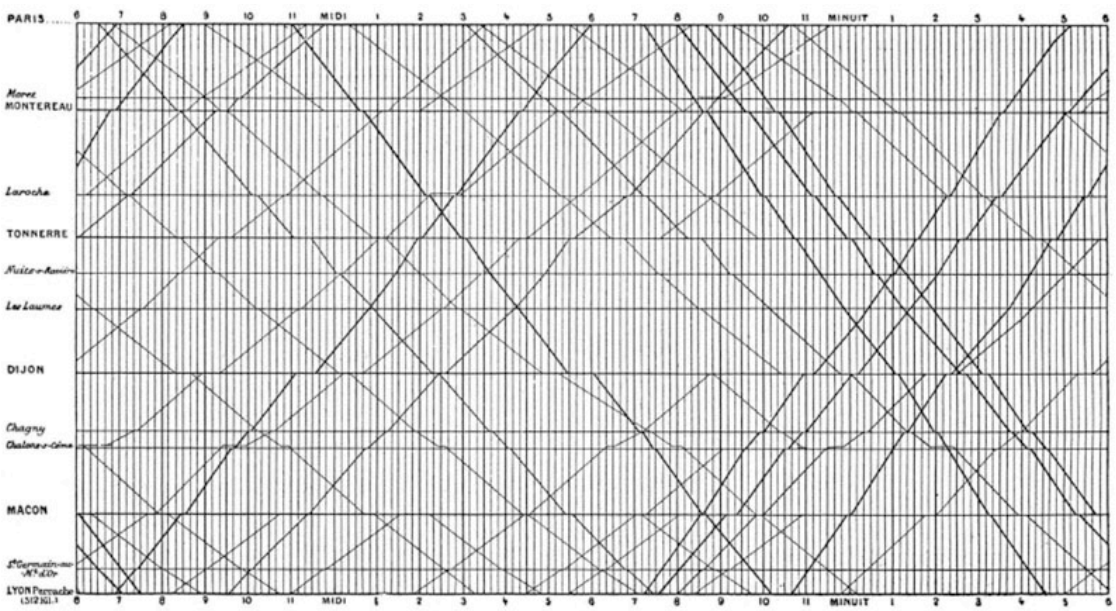


Figure 2.7 .Early work on time-space visualizations includes Marey's depiction of the Paris to Lyon train schedule.

These visual techniques enter the modern vocabulary through the work of Swedish Geographer Torsten Hägerstrand. He developed 'Time Geography' to investigate a spatial dimension to human behavioral rhythms (Hägerstrand 1969). Hägerstrand's version preserves the relationship of the two spatial axes (Figure 2.8), and adds a third dimension to represent time. Time spent at a location is drawn with a horizontal line. Travel between locations is drawn with a diagonal line. When flattened, the bottom plane of Hägerstrand's visualzation forms a map of all the places a person visits.

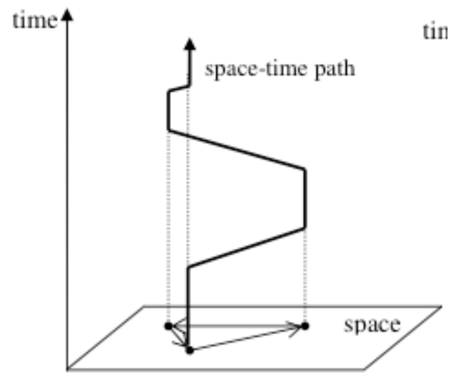
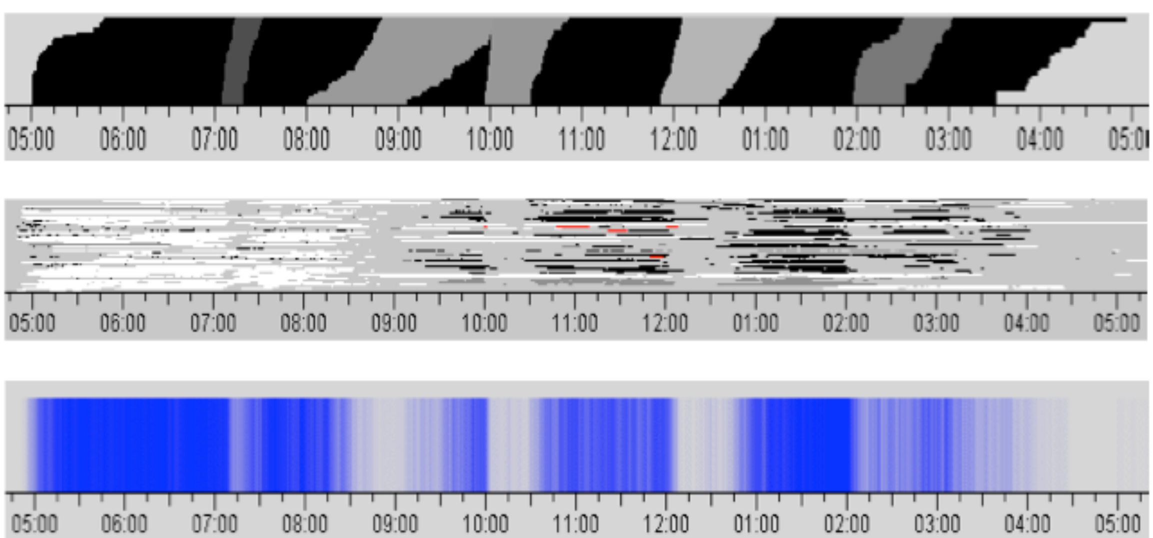


Figure 2.8. Early work on time-space visualizations includes Hägerstrand's time geography.

The emergence of scientific management (Taylor 1911) gave birth to what we now refer to as the Gantt chart (Gantt 1910), which decomposes a larger activity into various sub-activities, and displays them on parallel timelines. Critical to industrial planning, the Gantt chart adds the notion of the dependency to the previous works on temporal visualization.

Scientists turning their attention to routines then could begin with a firm foundation, but need to adapt extant visual forms to meet their particular needs. Begole et al. experiment with variations as they develop 'rhythm models' (Begole, Tang & Hill 2003) to represent an individual's aggregate computer activity (Figure 2.9).



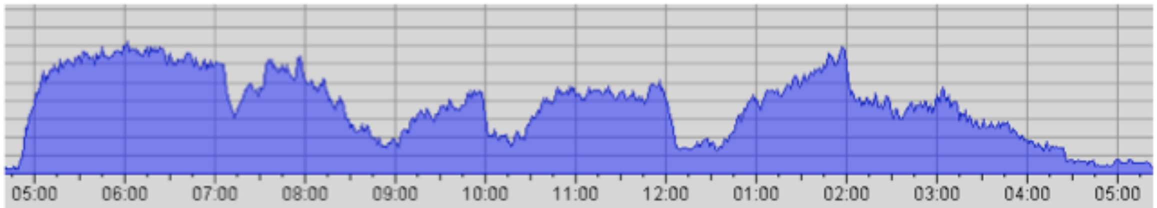


Figure 2.9. Various expression of computer activity routines take from Begole et al.'s study of workplace rhythms (Begole, Tang & Hill 2003). Activity is summed over time, and then represented various ways, include a heat map (second from top) linear heat map (third from top) and a line graph (bottom) line graph.

Eagle and Pentland Eagle & Pentland 2009 draw a timeline to represent time and location data for each person-day, group the data by day, and lay them in parallel creating a nominal heat map. Color represents a rough nominalization of the place data (Figure 2.10, left), and transformed into a binary matrix (Figure 2.10, right), a column of person-days for each place.

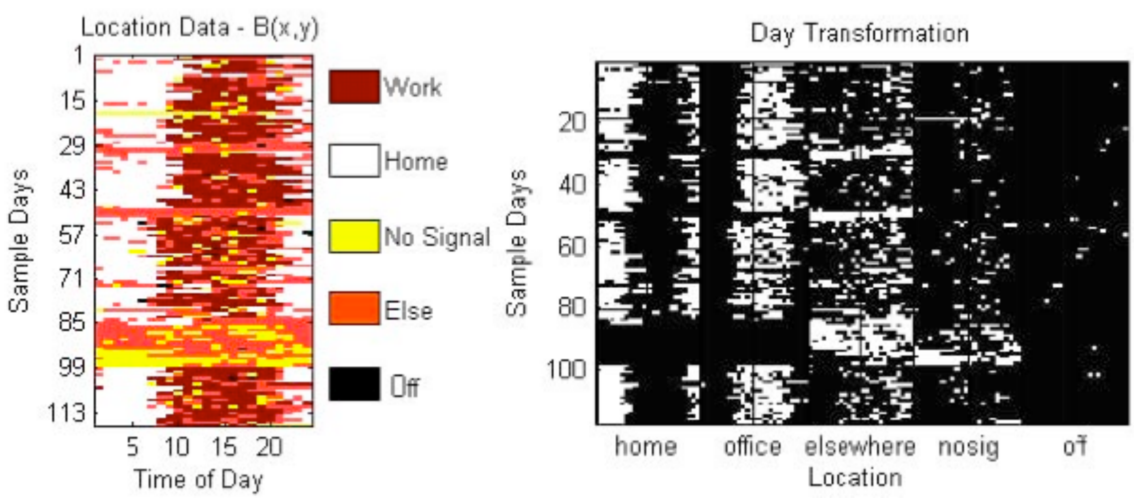


Figure 2.10. Eagle and Pentland Eagle & Pentland 2009 display routine locations as a heat map and binary matrix.

Because our work focuses on ways to develop a visualization to be used by families as a coordination tool, we add to previous work the ideas of multiple individuals, responsibilities, and various types of travel. Also, the graphics are meant to be interactive and not static representations, and exist in both large display and mobile phone forms.

Chapter 3. Investigating Opportunities for Technology to Increase the Feeling of Control

To define both the roles that routines play in family life, and to understand how technology based on routines can appropriately support families, I undertook extensive fieldwork and design exploration with over 50 dual-income families

First, we describe a yearlong field study of 24 dual-income families. The study included activities like semi-structured interviews, shadowing, artifact walkthrough and role-playing. A cultural probes package was also provided to families, to capture emotional qualities of parenting. Second, we condensed over 100 design concepts into 20 storyboards and again engaged 22 families in a needs validation study. The study quickly identified that transportation of children to and from their activities was both stressful, and an area in which families deeply desired support. Third, we engaged in user enactments of 27 application concepts with 22 dual-income families, to explore the many ways in which we might choose to support kids' activities.

From the first field study through user enactments, we evolved our perspective on how to help families feel in control by better supporting their logistics. It helped us realize that the work surrounding kids' activities actually sits within the much larger, principal task of the home – raising kids. Though our early applications focused largely on kids' activities, user enactments revealed that applications cannot decouple support for kids' activities from the fundamental act of parenting. In other words, parenting and kids' activities are contextually bound, and applications expecting to focus on one necessarily will need to be aware of the other in order to deliver appropriate assistance.

In this chapter, we describe each field study in more detail, describe the observations and findings, and ultimately link those together to point towards a new perspective on family support applications.

3.1 Field Study

3.1.1 Field Study Approach

Our study began with an exploration of the needs of 24 dual-income families with school age children. Fieldwork began with three-hour contextual interviews in the homes of the families. Time was organized to include directed storytelling, artifact walkthrough, and role-playing activities. The entire family was asked to participate in all the research activities.

Our families were solicited through bulletin board advertisement, and in person at shopping malls. We screened families in order to include a wide range of professions, ages of parents and children, and economic class. We required both parent works outside of the home, and that parents share responsibility for transporting their children (see Appendix A for demographic information on participating families.

Prior research identified the "wake up" and "arrive home" times as key opportunity areas for smart home assistance, so we focused our investigation on those time windows. During directed storytelling we solicited personal accounts of waking up or arriving home from particular family members. In addition, we asked them to act out the scenes so we could better understand the relationship between their routine and its context. During the artifact walkthrough, we asked families to demonstrate the use of their main coordination artifacts, often a large kitchen calendar, and their various personal calendars. During role-playing, we asked families to pretend to coordinate for a fictitious school field trip, for which we provided simulated school paperwork. The interviews covered both predictable days, like weekdays and weekends, schedule deviations like business trips and holidays, and unscheduled deviations such as sick days or miss-the-bus days.

To gain additional insight into the wake-up and arrive-home activities, we left families with a cultural probe package (Gaver, Dunne & Pacenti 1999). The package helped us identify emotional connections between families and their homes, and how families define themselves through their possessions and uses of their artifacts. The package explored the stressors and pleasures of waking up and arriving home, and the parts of their lives that make them feel like good moms and dads, in the form of several, freeform exercises. Parents were given packages, and asked to complete them over the course of two weeks. The package included a photography activity. Parents were given a book with stimulus questions, free response text space, and a camera to photograph ideas, insights and inspirations of vignettes related to the stimuli (see Appendix B for details on the probes package).

To ask parents to explore the concept of home automation without the implications of a computer, we created a storytelling exercise that asked parents to describe what they would want an omnipotent jinni to do for them in their homes. Finally, to capture specific stressors, or triggers to feeling out of control, we asked parents to log their wake-up and arrive home activities for a week. We captured their stress and hurriedness levels, principal activities, immediate needs and preoccupations. These logs provided a rich description of how families prioritize competing needs

3.1.1 Field Study Findings

Many of the logistical challenges that produce this feeling of "life out of control" can be traced to the enrichment activities of children. While work and school add to the complexity of daily living, they tend to present predictable logistical needs, many qualities of enrichment activities make them more difficult to convert into a routine.

Many enrichment activities present rapid seasonal changes. Most competitive sports, for example, have games that occur across seasons that last no more than ten weeks. They also require constantly evolving transportation needs. And they often present both scheduled and unscheduled attendant responsibilities. These factors make them much more resistant to the development of a consistent routine and much more likely to cause a breakdown requiring improvisation to the underlying logistical plan. Other sources of loss of control can be attributed to unscheduled events like sick children, or missing the school bus. Generally our families address this loss of control by increasing their flexibility. We consider this situation in more detail.

Dual-income families fill their children's lives with enrichment activities. These activities benefit the children in many ways such as teaching values, providing physical fitness, teaching competition and teamwork, supporting existing social structure and providing supplemental education. Families often select activities based on long-term goals such as preparing their kids for a successful career or increasing the chance of college admission to selective schools (Darrah, Freeman & English-Lueck 2007). In addition, the activities often serve as de facto "babysitting" to help cover the time parents are at work. Every child in every family we interviewed participated in at least one (and on average two) enrichment activities.

While children form the principal participants, enrichment activities affect every member of the household. In addition to the management of their households and the completion of whatever work they might have brought home, parents are charged with the successful logistical management of their children as they relate to these activities.

Family J's soccer practice shows the logistical complexity of a typical enrichment activity. For transportation, practices are held in one of two locations. Games are held in any number of locations. Locations are printed on the team schedule, which is kept on the family refrigerator. This sheet has no directions. Parents who carpool have to coordinate who picks up and who drops off. Practices start at consistent times, but games start at one of three times.

Children must come prepared. If the event is on turf, kids will need to bring their flat shoes. If the event is on grass, they will need to bring cleats. Children always need to bring their shin guards and kneepads. Games require either the home or away uniform. Practices require practice jerseys. All clothes need to be laundered, which often means washing them the night before so that they are clean for the day of use.

Three families bring refreshments to each game – juice for players during the game, juice for after the game, and oranges for halftime. This information is printed on the schedule on the fridge. Forgetting comes with a high social cost. Either the team goes thirsty, and the child is embarrassed, or the parent has to face the panic and stress of racing to get kids to the field on time while running to the store to buy drinks or fruit.

The act of leaving the house, is rarely "simple." To get the kids to school, parents need to make sure children are awake, washed, dressed, fed, and have transportation. They have to make sure children have lunches, homework, gym clothes, musical instruments, permission slips, and if young, are dressed appropriately. These activities depend on the (sometimes unwilling) participation of the child(ren), the coordinated use of (or competition for) scarce resources (e.g., bathroom time) with other family members, and the presence of these and other resources (e.g., school bag) along with the knowledge of their whereabouts. Our Family H's Dad described a successful morning as one where "we all get out the door, and there are no major disasters."

Routines allow families to function without having to carefully consider every option at every moment (Tolmie et al. 2002). Routines allow parents to walk out the door every day without having to create a new plan to dress themselves, get the kids ready, make breakfast, remember to take their keys, arrange for the carpool, and drive to work. However, routines for enrichment activities prove difficult to construct. And even when possible, these routines provide many opportunities to break down. Their high variability in both detail and responsibility make construction of a "normal" routine difficult. In addition, most of these activities do not run for an entire year. Instead they are "seasonal," forcing families to constantly re-adjust schedules as seasons end and new seasons begin.

Transportation to activities such as team sports regularly involves variability in the routine. Most dual-income parents needed to rely on others to provide some transportation due to other commitments in their complex schedules and due to the different locations and times of the events. In addition, many activities require sporadic use of special equipment such as the types of shoes and uniforms mentioned above.

Timing and order also play major roles in the capable execution of enrichment activities, adding further to their logistical complexity. Many activities, like musical groups, require special equipment. And since children often go to their activities directly from school, children must take this equipment with them in the morning, extending the time window of responsibility to the morning of the event. For Family H, washing soccer uniforms extended responsibility to the night before the event.

Responsibility can even extend significantly further than a single day. Family H, for example, has to bring in snacks for the entire class one day each month. Parents have to remember this day, and make sure to have enough snacks for the entire class in the house on the morning of the day on which the snack is their responsibility. This extends the time window for the event as far back as the weekend before the event, when Family H would go food shopping for the week.

Because children and parents are so interdependent, their schedules are united by a chain of dependency. Small failures that affect one individual can extend individual failures into multiple, shared coordination failures. We found this scenario to be common among our participant families: Mom might be running behind for a business meeting, so she needs the bathroom first. Her Son is forced to shower second, and misses his bus. Dad then has to drive him to school, which makes him late for his morning meeting.

The chain of dependency can also become more complex when parents, out of necessity, divide the jobs surrounding certain tasks. For example, in Family H, it is Dad's job to get their Daughter ready for ballet, and it is Mom's job to take their Daughter to ballet as part of a carpool. When Mom goes away on a business trip, and the carpool parent providing the ride calls with a cancellation, Dad lacks the resources to easily arrange a new ride. He does not know which other parents he can lean on, as this task is not part of his regular responsibilities.

Not enough gas in the car, traffic, a forgotten briefcase, an extra trip to the grocery store – all simple events that might delay one person – cascade into the schedules of other family members, who all depend on one another.

It would seem that if enrichment activities caused so much distress and made families feel "out of control," then a simple strategy to regain control would be to do less. However, this strategy is conspicuously absent in dual-income families. The parents in our ethnography value the enrichment their children receive through participation in these activities. In addition, participation allows them to demonstrate their mastery of "busyness," and the ability to master busyness is one of the values these families who have generally self-selected to be dual-income wish to pass on to their children.

Families exhibited many behaviors that allow them to manage this hyper-busyness. Some families imposed simple rules. Family L, for example, limited their four children to no more than three activities each. Many families assigned responsibilities for specific events to particular parents, liberating the other parent from dealing with those details. All our families leveraged some technological infrastructure (Frissen 2000) and had routines surrounding its use.

In general, we observed across almost all coping strategies, a quality of flexibility. One flexibility strategy involved incrementally adding details to plans as they became necessary. This means that a plan will have a general outline – include activities, tasks, and the places they occur – and can eve be partially ordered, but are not completely specified. By not specifying parts of plans that change often, parents save themselves from having to re-plan their day with every change to the volatile event. Instead, parents concretize the missing details of the plan at the last possible moment, allowing them to have a plan. This tendency causes long-term plans to differ substantially from short-term plans.

Long-term plans tend to resemble rough sketches. When Family H learns their day for snacks is weeks away, Mom puts the snack calendar on the fridge. She does not consider what snack to get at that time because what she buys will depend in part on what her daughter wants and what other families have provided that week. She doesn't know if she will purchase the snack when food shopping the weekend before or if Dad will have time to pick it up on his way home the night before. Only summary knowledge is either known or even possible to be known.

On the day of certain activities every logistical detail has to be covered. The night before a soccer game, just before dinner, for example, Family H consults the various media that include information relevant to that game: the location, home or away, who is dropping off, and who is picking up. Mom knows it is her job to pick up, so she confirms with her Daughter where to wait for her. Mom also confirms who else she will be taking in the carpool. Mom confirms all the details and places just to be sure that nothing had changed since its codification on the central artifacts.

Many events never acquire a priori detail . Sometimes, this was due to constraints of memory. Family H, for example, reported keeping "only two or three [plans] in our head at one time." And so on days when there were multiple events after school, Mom and Dad would speak on their cell phone multiple times and watch many plans evolve without preplanned conception of their ultimate order of operations. In fact, we observed that many plans started out as successful improvisations, and then were adopted as routines because of that success.

Frissen (Frissen 2000) and Darrah (Darrah, Freeman & English-Lueck 2007) also describe parents adopting new communication technology so that they could become more available and ultimately increase their flexibility. Because they could be reached by their families at a moment's notice, plans were able to evolve and be improvised even closer to their target times.

Mom and Dad also tend to bring their work life home, and arrange their home life at work (Nippert-Eng 1995). By bringing the two contexts together, parents don't have to constrain all their home planning to the house, or all their work planning to the office. This ability to seamlessly move between contexts allows for plans to dynamically evolve, and allows for more flexibility in how time is used. In Family F the Mother worked at home in the evenings close to her daughter to allow her to focus both on work and her family simultaneously.

This flexible changing between home and work also extends to artifacts. Parents would seamlessly shift between whatever media was most immediately available (Beech et al. 2004) (Crabtree & Rodden 2004) (Frissen 2000). We found that our families stored work information on their home calendar, and home information on their work calendar (Nippert-Eng 1995). This opportunistic use of media helps parents master their busyness while, at the same time, complicates their lives by requiring synchronization between the many artifacts that impact the different aspects of their lives.

We observed families making deliberate choices to increase their flexibility. Family J chose to live close to Dad's work so that Dad could be available in emergencies. In (Darrah, English-Lueck & Freeman 2001), Darrah found families who would consolidate their children into one school so as to simplify logistics. Family L staggered their work schedules so that one parent could be more available for unexpected events, like children being sick.

3.1.2 Field Study Discussion

Our exploration evolved our understanding of what families are, what families do, what families want, and how to support them. At the highest level, we observed that parents' desire to give their children rich lives, their desire to be good parents, and their need to feel in control of their lives interact in a circular way that illustrates the tensions of modern family life, and why they can be so difficult to reconcile. We can summarize this understanding in a conceptual model of the experience of the dual-income parent (Figure 3.1).

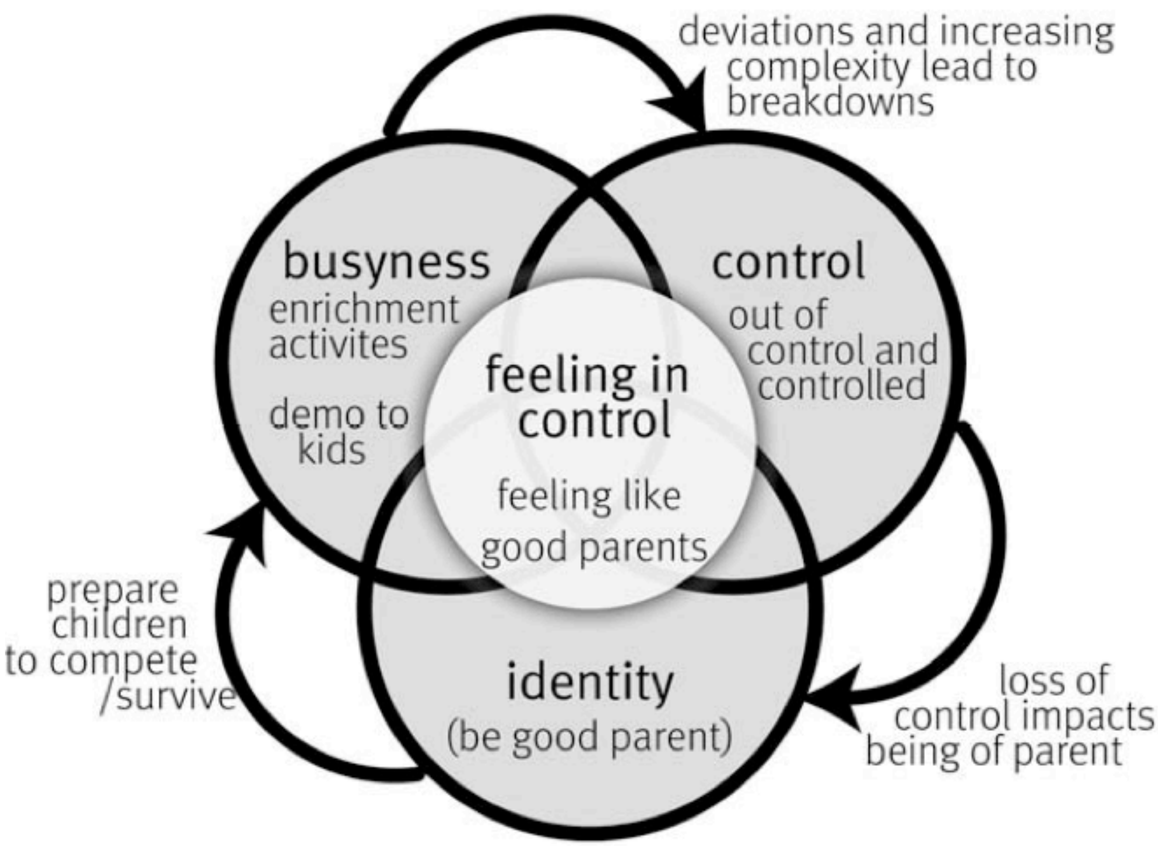


Figure 3.1. A conceptual model demonstrating the complex forces that shape the experience of the dual-income parent. Busyness both erodes the experience of control, but its presence (mastery) is also paradoxically important to parents' identity.

Parents desire to feel in control of their lives and to effortlessly demonstrate for their children a mastery of the busyness that comes with participation in many activities. Following this model, parents attempt to be good parents by enrolling their children in enrichment activities such as soccer, piano, Chinese lessons, or Sunday School to help them gain the skills they will need to compete and the knowledge to continue the family culture and traditions. The addition of new activities leads to increased busyness: more responsibilities to transport children and equipment and to address conflicting activities and commitments. The increase in busyness makes parents feel completely controlled by their schedules that allow for very little free time. Parents find themselves constantly scrambling to stay on top of things, but when deviations in the normal routine occur, they experience a cascading set of failures, and feel their lives have become out of control. The very action they have taken to feel like a good parent–enrolling their children in activities–has now become the source of their feeling like a bad parent.

This model allows us to specify important characteristics of a coordination support system for dual-income families. Because control forms a central role to families, any coordination support system also need pay attention to this dynamic. Busy families experience both a life out of control, and a life that is highly-controlled by the needs of their children's activities. Families find both ends of this spectrum to be dissatisfying, and challenge not only their physical levels of anxiety, but their sense of identity as good parents. This helps systems designers focus on a critical middle section, that supports parents by helping them maintain control during time that it slips from them, but maintains whatever autonomy they require to feel like good parents as part of a satisfying life.

Finding this spot is problematic. Woodruff et al. show that certain groups, like orthodox Jews during the Sabbath, will allow for technologies to effectively run their homes without their participation (Woodruff et al. 2007). They value the outcome that is provided by the control more than they feel undermined or stigmatized by its presence. This argues that a support system could play an important role in transitioning families from feeling out of control to feeling in control.

How? First, a support system could provide this service by helping families avoid breakdowns caused by deviations in daily routines. Second, a coordination support system can help make dual-income families feel they have mastered the complexity of their lives. Here, the smart home can provide opportunities for family members to give "gifts of time and attention" to one another around activities that support the construction of a family identity. These gifts make family members feel better about themselves and the roles they play, and potentially increase the emotional connection between family members.

3.2 Speed Dating

3.2.1 Approach: Needs Validation

In need validation, we presented a variety of paper storyboards to families to synchronize the needs we observed with the needs users perceive (Davidoff et al. 2007). These storyboards help designers prioritize user needs, more clearly map spaces for innovation, and use that focus to narrow the design space for potential applications.

Need validation intends to synchronize observed needs with perceived needs, helping teams focus technical innovation on areas where users both have a need and are aware of that need. Storyboard presentation helps redefine the opportunities for technical interventions.

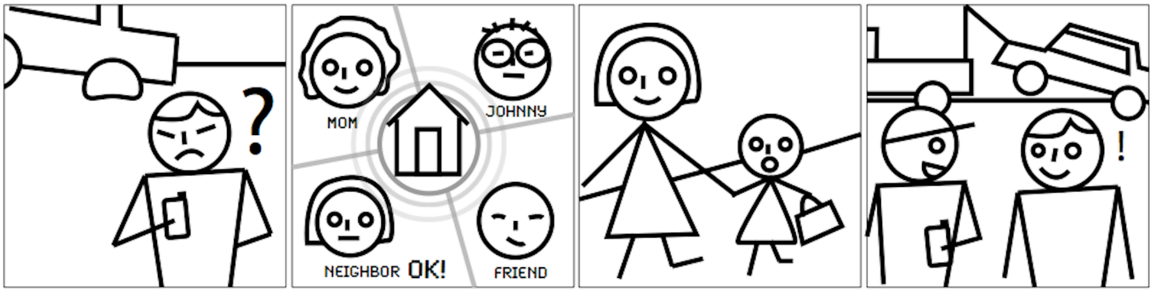
We used affinity diagrams to group more than 100 design concepts (Lee et al. 2008) produced through a process of brainstorming, bodystorming (Buchenau & Suri 2000), and a review of our fieldwork (Davidoff et al. 2006). These clustered into 21 categories. We then created storyboards for each category that described a need found in our fieldwork and a technical intervention that addressed the need.

Storyboards document how each need arises in daily life, and then show how the design concept intervenes to improve the quality of life. The scenarios focus on situations where it is easy for participants to imagine themselves. In order to increase the empathic connection between participants and our scenarios we developed a fictional, persona-like family consisting of two parents and two children – Johnny, 13 and Annie, 7 – in many enrichment activities. Storyboards show people in specific contexts interacting with the proposed system; however, the storyboards downplay specific technical solutions that distract users from the focus on the need and unintentionally dominate conversations.

The storyboards are also designed to probe social boundaries. Rather than have participants speculate on the social mores of imagined future situations and how technology could modify them – which often challenges users – we instead created scenarios that fall on both sides of boundaries we identified. After Garfinkel (Garfinkel 1967), we call these *future breaching experiments*. For example, one scenario focuses on the anxiety parents experience when, for some reason, they are unable to pick up their children.

In this scenario, Dad is stranded and cannot pick up his daughter (Figure 3.2). The storyboard shows that the smart home arranges to have her picked up. We observed many times when events outside of one parents' control prevented their being able to complete a responsibility.

We explored the location of the social boundary by investing the smart home with decision-making authority. Instead of including Dad in the decision-making process, the smart home communicates directly with people outside of the family, asking them for favors.



" I feel so helpless."

The smart home senses that Dad's going to miss Annie, and pings the people the Millers count on in a pinch.

The neighbor's not far from Annie. She agrees to get her.

The tow truck that comes for Dad tells him that Annie is safe and sound.

Figure 3.2. The 'Safety Net' storyboard. Dad is stranded and cannot pick up his daughter.

We conducted a series of 2-hour sessions with dual-income parents, where we presented our storyboards. After each storyboard is presented, interviews were prompted with a *lead question*, directing conversation towards if participants perceived the need in their lives, and if they desired the kind of intervention that we envision in response to the need.

3.2.2 Approach: User Enactments

Needs validation made it clear that we would develop an application to help families manage how they transport their children. Even within this domain, however, the potential design space was unmanageably vast. To further explore a critical set of design issues within this domain, we chose to conduct user enactments.

Like experience prototyping (Buchenau & Suri 2000), by engaging users as they carry out tasks, enactments bypass opinions based on the imagined fiction of storyboards and instead activate response to real-time engagements. User enactments helped explore the social mores surrounding children's transportation in two ways. First, they provide a setting for users to experience future breaching experiments. And second, by combining wide exploration via multiple structured engagements, user enactments provide a broad perspective to analyze the impact of risk factors.

To conduct user enactments, we created a matrix of critical design issues and wrote short dramatic scenarios that address the permutations of these issues (see Appendix C). We then asked participants to enact a specific role they regularly play (like mother or father) as they walk through the scenarios, within an inexpensive, low-fidelity simulation of the target environment.

Our fieldwork and storyboard sessions identified three principal dimensions of family activity management to explore: activity lifecycle, activity type, and system proactivity.

Family needs vary as activities evolve through their lifecycle. The first day of hockey practice presents different needs from the middle of the season, when families have established successful routines. Days when kids forget their skates and force deviations from a routine also present very different needs. Different activities also provide families with varied needs. The first day of school suggests a more permanent schedule change and ritual shopping, while soccer practice requires more episodic requirements and special equipment. We selected the type of activity as an axis to vary (e.g., soccer, ballet, school). System proactivity is also an important dimension to explore. By proactivity we mean the degree of initiative that an intelligent system might take based on its understanding of the needs of the family. We recognize that different levels of proactivity might be appropriate for different kinds of activities or different kinds of needs, among other factors.

To conduct our user enactments, we again leveraged a fictional family and asked participants to enact the role of the mom or dad. Sixteen individual dual-income parents participated. Each parent "play acted" 9 user enactments over the course of two hours. Parents walked through three scenes for each activity (Soccer, Ballet, School) with different combinations of proactivity and at different points in the lifecycle for each. In all, each user enactment was performed by at least 5 participants.

We asked parents to walk through simulated daily routines (e.g., dressing and feeding children), and each user enactment required them to complete additional tasks. The Soccer (activity) Beginning (lifecycle) enactments, for example, situate parents before soccer season begins, and asks them to arrange a carpool. The smart home either: (1) entirely automates the setup (High Proactive); (2) polls candidate driver families and informs parents who might be available, automatically confirming with the family of their choice (Medium Proactive); or (3) simply informs the family who might be available. To simulate extreme time pressure we asked participants to complete these tasks within a short time window. When actual routines deviated from scripted scenes, parents were afforded an opportunity to draw on their real experiences and engage with the scenario.

We used highly disposable creations to support these user enactments. We simulated our smart house (see Figure 3.3) out of 6'x4' white foam-core, drew appliances on a wall of a whiteboard, and filled the environment with enough physical trappings to suggest a home: magazines on a den table, coffee pot on the kitchen table, and a laundry basket partially blocks a hallway. After each enactment we probed participant reactions, digging past observed behavior towards its root cause. We conducted semi-structured interviews after participants completed 3 enactments for each activity (exploring one dimension fully), and a more elaborate interview after completing all 9 enactments.

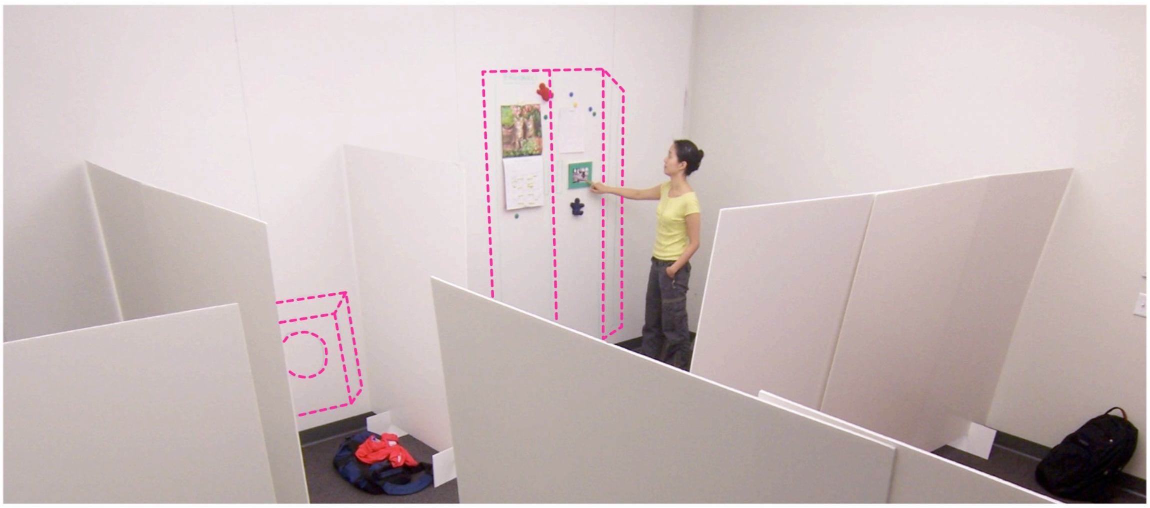


Figure 3.3. Our simulated smart home for Speed Dating. Foam core walls organize the "smart home" prototype into rooms. The refrigerator and washer-dryer are drawn on a wall of whiteboard (emphasis added for photo). A confederate is shown interacting with the fridge.

Participants then enacted the task as described by the moderator. Because the space of possible participant responses is vast, the moderator and confederates are required to improvise responses choices the participant makes, and collaboratively follow the sketch until it reaches its useful end. For example, in one scenario, the participant is brought outside the "home" and given many shopping bags (Figure 3.4, left). The moderator asks them to pretend they are returning home with groceries. Meanwhile, confederates arrange the scene so that Mom will walk by her Son's soccer uniform, which is on the floor (Figure 3.4, middle). Depending on the instructions from the moderator, and the parameters of the variation (like the level of proactivity of the home), Mom might then go create a reminder using a simulated smart calendar (Figure 3.4, right).

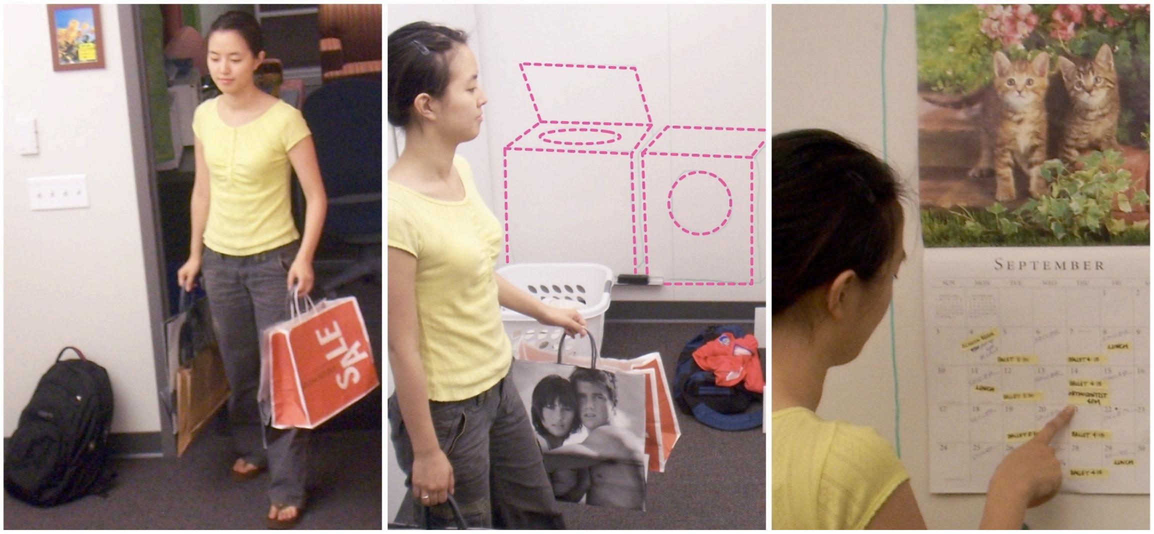


Figure 3.4. In one scenario, Mom arrives home with many groceries (left) and walks by her son's soccer uniform, which is on the floor (middle). Mom can then respond to the scenario in a variety of ways, depending on the moderator's instructions, and the conditions of the scenario (like the level of proactivity of the house). In this scenario, Mom goes to the simulated smart calendar on the refrigerator and makes a reminder for her Son's soccer game.

Because participants are asked to draw on their own felt experiences to respond to the situation, and that experience can vary dramatically, participants often respond in ways that required the moderator and confederates to improvise responses. During the post-enactment interview, the research team has an opportunity to interview the participant, often focusing the interview around the particular behavior, drawing out the reasons why.

3.2.3 Speed Dating Findings

Needs validation evolved our understanding of both the needs of dual-income families and how smart homes might help them in important ways. First, needs validation helped identify that supporting kids' activities presents a major opportunity for ubicomp to positively influence home life. Second, needs validation helped point that role shifting can trigger coordination problems. Third, needs validation helped identify a tension between efficiency and parenting.

To form the basis for more objective comparison between opportunities, we asked participants to rank our depictions of their needs, and the potential interventions depicted. Our top-ranked storyboard depicted the 'Snack Day at School' opportunity (Figure 3.5). The scenario depicts days when parents need to provide a snack for their child's class. Parents reacted strongly to the story of this responsibility, which because of its infrequency, falls outside of the daily routine, increasing the chances for breakdowns. One mother commented, "It is very hard to keep track of future events and their impact." A father shared that failure has very high costs in disappointing his children; "It's devastating to the kids when we forget."

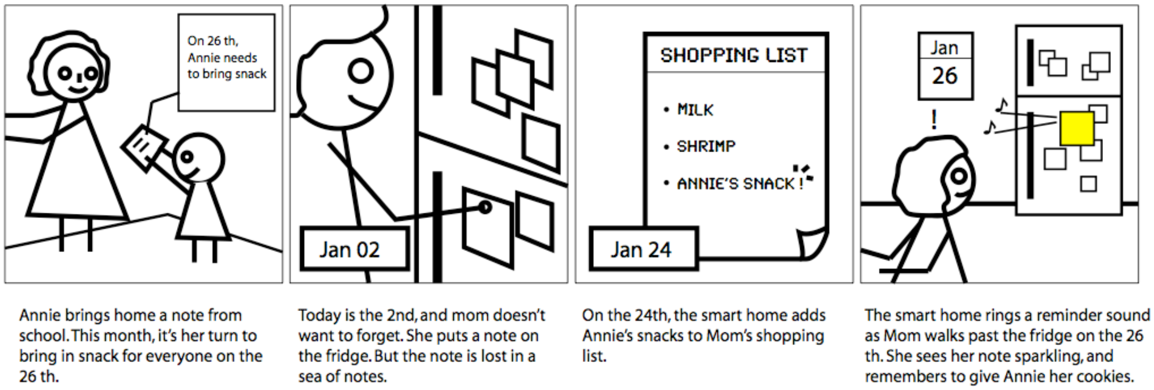


Figure 3.5. Parents strongly identified with the 'Snack Day at School' concept.

Several storyboards presented parents with scenes depicting recurring deviations from routines and the need for parental role shift, two problems that our fieldwork brought to light many times. One storyboard depicting 'Where are the Ballet Shoes' (Figure 3.6) explores both of these issues through a particularly stressful example of kids' activity management.

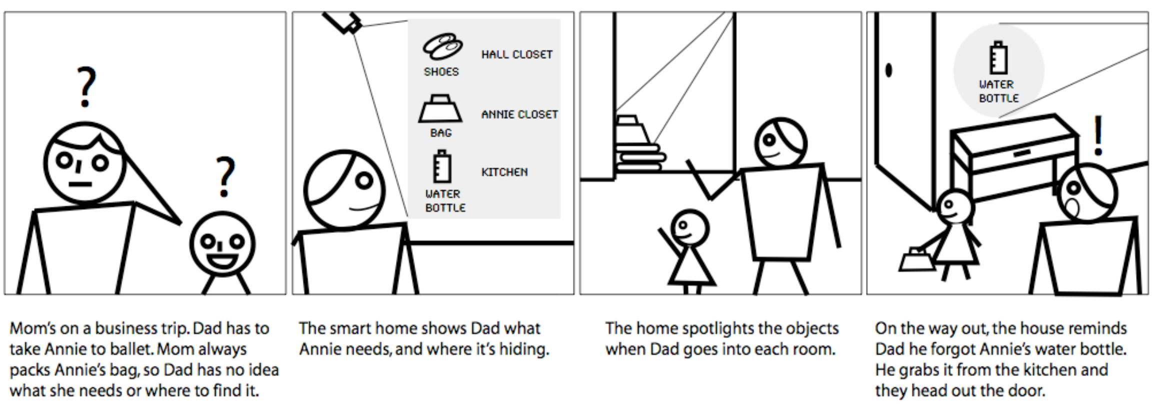


Figure 3.6. Where are the ballet shoes? This scenario depicts problems that can occur when parents switch roles. In this storyboard, Dad is responsible to drive his daughter to ballet. Because transportation to ballet is usually Mom's job, Dad does not know where the daughter keeps her equipment.

When Mom, who normally manages the responsibilities surrounding ballet lessons, is away on business, Dad assumes Mom's responsibilities. Dad has no idea what gear his Daughter needs or where they put these things in their house. One mother observed, "My husband would love this. He never knows how to dress our daughter." The storyboard also helped elaborate the consequences of failure to meet even these seemingly simple needs. One father described "it's very stressful for me. I feel like I failed as a parent when I forget what my kids need.

While storyboards such as this showed much potential in supporting kids' activities, other storyboards brought to light critical considerations that would impact how a smart home might support these activities. During fieldwork, many parents frustratingly described the stress of the morning rush. Part of that morning stress involved parents having to constantly persuade or nag younger kids to get them to comply with the parents' wishes. In "Annie Dresses Herself" (see Figure 3.7), the smart home limits Annie's TV consumption, and then helps her pick clothes on her own.

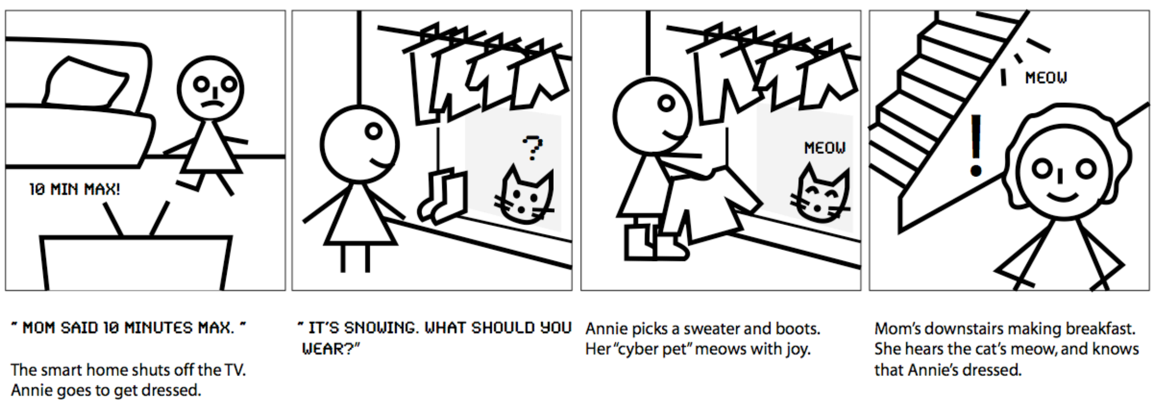


Figure 3.7. Parents reported that dressing younger children often injected stress into the morning. To alleviate stress and encourage independence, the smart home helps the daughter choose her own clothes. Parents resisted this system, suggesting that, while challenging, dressing children also forms a pleasurable part of their morning and helps them feel like good parents.

Though designed to help Annie feel more independent, and offload some of the morning struggle onto the smart home, the storyboard also revealed contextual factors: some more complex and subtle dimensions of the morning struggle that were less visible during our earlier fieldwork. For example, one mother asked "What's the parents' job, and what's the house's job? Is Annie going to listen to her Mom, or to the house?" This concept surfaced the fact that while dressing children creates stress for parents, it also creates opportunities for parents to act like parents – to teach their children how to select a wardrobe for the day, to be independent, and provides moments for meaningful interaction – and through these activities, to experience the rewards of being a good parent. Through concepts like this, we recognized that we should focus our attention on how to support the work of parenting, but also saw early evidence that we had to be careful not to reduce opportunities for meaningful interaction that occur through that work.

User enactments evolved our perspective of how to address the opportunity of managing kids' activities. It helped us realize that the work surrounding kids' activities actually sits within the much larger, principal task of the home – raising kids. Though our early applications focused largely on kids' activities, enactments revealed that applications cannot decouple support for kids' activities from the fundamental act of parenting. In other words, parenting and kids' activities are contextually bound, and applications expecting to focus on one necessarily will need to be aware of the other in order to deliver appropriate assistance.

User enactments also helped us realize that we could not support communication to facilitate the work of the home without considering communication's other roles. It revealed that communication plays an important social role when it occurs between members of different households, and that it can play a more utilitarian role when it occurs between members of the same household. Any application that supports communication within and between homes, will have to balance a desire for utilitarianism with the need for maintaining social protocol. In this section, we discuss these issues in greater detail.

Through the use of user enactments, we were able to witness richer evidence of the contextual factors found in need validation. Here, we describe three factors relating to our emerging view of the complexity between kids' activities and parenting.

One enactment explored potential emotional support from the smart home. The smart home interrupts a busy parent during the dinnertime rush, and presents them with a naked compliment, "You're very very busy. But no matter how busy you are, you always do everything you have to." We expected distracted parents to dismiss this empty sentiment. But interestingly, over three quarters of parents responded positively, saying "thank you." Half stopped their activity to express an almost shocked gratitude.

As part of the user enactments, fictional Son Johnny keeps all his soccer gear in a dedicated bag to avoid having to remember each needed item individually. Johnny's strategy breaks down whenever an item is separated from the bag. Muddy cleats that stay outside or a clean uniform in the dryer breaks this system down. These kinds of breakdowns can impact both kids, who need the gear to participate, and parents, who feel the stress when their kids can't participate in their activities, and sometimes rescue them with emergency deliveries.

The Soccer Routine Enactment explores an opportunity to avoid this potential disaster. As a parent passes a dryer containing a forgotten uniform, the smart home tells the parent about the dryer contents. Interestingly, parents strongly objected to this system. One father said that this felt “weird that the smart home is telling me something that I don’t have to do. It should be telling Johnny directly.” Another even said “I don’t want to do it for Johnny

Other user enactments went on to add further layers of nuance to this contextual risk factor. For example, parents strongly favored having the smart home tell them to deliver their daughter’s forgotten lunch to school, as part of the School Routine Enactment. Through this comparison, we see the same didactic needs of parenting now strongly interacting with parents’ desire to protect their child. A forgotten uniform presents modest consequences when compared to a hungry child. One parent noted, “Vital stuff. No problem. Without lunch...kids don't eat. It's reassuring. I wouldn't be as worried and stressful knowing somebody is watching.”

In the Soccer Deviation Enactment, a last-minute meeting traps a participant at work unable to complete her responsibility to transport her Son to his impending soccer game. With her husband also unavailable, the smart home: (High Proactive) automatically arranges a new ride; (Medium Proactive) communicates directly with candidate drivers on parents’ behalf; or (Low Proactive) presents mom with a list of candidate drivers and availability.

Despite the stress and work dictated by the situation, and the convenience automated support could provide, many parents placed social factors above convenience. “I would want to talk to the parents [asked] and see how they feel. I would have to connect and talk to people. I want there to be a person behind the name and to make sure they'd be comfortable when my kids are involved.” Parents described that automated communication simply smothers critical highly-social characteristics of human expression. One parent notes, "I would never say no to my friends without personal contact.” Automation would smother explanation or opportunities for coercion. "I would want to know why [he said no]. I might try to push if he could go,” says one mother.

Coordination within the home reflects a different standard for utility than external coordination. Here, the primacy of efficiency prevails. In the School Routine Enactment, a parent is asked to negotiate with their spouse about who will pick up their daughter. The smart home either: (1) assigns the task to them; (2) passes them the task from their spouse; or (3) relays them a voice message from the spouse.

Parents realized that they appreciated the expediency afforded by the smart home, and gave little consideration to the same requisite subtlety they rallied for when communicating outside the home. One father prefers automatic coordination when in his busy office environment. "I don't like to be called at work during the day. It's better to be like a quick message. It normally takes a lot to get somebody on the phone but this is more thoughtless." Some parents wanted even more automation: one wants "[the] smart home to make the call on my behalf. It's better for the system to automatically tell me to pick up [my daughter] so I don't have to make a call. I would feel comfortable with smart home automatically determining who has more time."

Fieldwork and need validation both provided evidence that kids' activities impose heavy communication costs on families. But user enactments showed us that families feel uncomfortable mapping the binary nature of automated communication with the social factors embedded in human contact, and that the work saved would not outweigh the potential risks of handling social needs without their requisite subtlety. In this way, user enactments helped us refocus our efforts on the work of supporting communication within the home.

3.2.4 Speed Dating Discussion

User enactments illustrated that a smart home cannot simply view its mission as one to prevent errors. Errors form part of the critical pedagogical mission of parents to raise kids who understand the consequences of their actions. And to raise kids to be responsible, successful adults, parents do not want to prevent their kids from making every mistake, or doing any work. In fact, doing work and making mistakes are important parts of being a child. The smart home has to approach support for these situations not just as failures but as important didactic opportunities.

Essentially, user enactments foregrounded contextual factors that the storyboard under-emphasized, forcing us to redefine our understanding of what we saw as similar situations, and by extension, applications we could design to address them, and ultimately helped to expand our understanding of the role of the smart home. Where we could have interpreted parents' responses to the earlier "Ballet Shoes" storyboard to mean that we should build applications that support "gathering items for activities," the first user enactments actually demonstrate that unconditionally supporting this need interferes with another equally compelling need to teach responsibility to children. But, by comparing the results from these user enactments to the user enactment on lunch delivery (School-Routine), we realized that this particular issue of parenting was much more nuanced than we first expected. Without user enactments and without the structured comparison that they offer, these nuances would not have been evident.

Communication proved to be another contextual risk factor that offered a layer of nuance affecting application development. Parents were very uncomfortable when automated support messages from the smart home sought help outside the family. In contrast, parents tolerated the efficiency of extremely abrupt, bordering on rude communication from the smart home when seen as coming from their spouse.

Both our research and the findings from the other ethnographies reveal that breakdowns caused by the need to deviate from daily routines are one of the major stressors that make families feel a loss of control. A seemingly small deviation caused by a predictable event can lead to breakdowns in daily routines and cause emotional damage to families. Even the possibility of a breakdown can cause families a great deal of anxiety.

The manner of this approach, however, need be carefully approached and understood. Our early research, for example, interpreted kids' activity-related failures as stressful problems to be solved by delivering the right information at the right time. But user enactments showed us that, while stressful, these problems are literally necessary parts of raising responsible kids. A smart home that removed these didactic opportunities in the name of "fixing problems" would also interfere with an important aspect of parental responsibility, and by showing an insensitivity to an important aspect of family life, risk rejection by parents.

This added nuance presents important implications as we move forward with our current research agenda, and shows how careful exploration of contextual risk factors can help effectively reformulate application design, opening previously overlooked opportunities. Instead of delivering information to parents to help them prevent mistakes their kids might make, we could instead create systems that give parents a choice about when to get involved, and that gives kids the tools to learn good decision-making without replacing their existing responsibilities. This would mean creating moments for kids to learn responsibility, and to involve parents in that dialog.

Even successfully managing their routines was not sufficient for families to have a feeling of control over their lives. They desire to carry out their routines in the way they want to and to achieve an expected quality of life through that action. Let us say, for example, that a parent manages to leave the house on time in the morning, but ends up rushing their children, or even yelling at them in the process. This results in making them feel like poor parents because they have started both their children's and their own day on the wrong foot. The required end is achieved, but the manner of its completion contributes to a feeling of lack of control.

The stress of the everyday work to support activity often leaves parents starving for gratitude. The smart home cannot simply focus on making the home more efficient by taking over appropriate parenting responsibilities. Instead, it should play an active role in helping parents feel like good parents. Supporting the transportation of children would need to be accomplished in such a way that it helps parents feel that they are mastering the busyness and in control themselves. This would mean transforming non-routine circumstances that cause the most disarray into situations that feel more like routine situations, where parents can smoothly carry out their tasks. By providing support for day-to-day chores, a smart home could help parents focus on the larger perspective of raising healthy children, providing opportunities for family members to give their time and attention to each other, especially for activities that support the construction of a family identity. Here, a smart home could provide families with opportunities to regain that control over these circumstances by providing them with more time to enhance the things that they value–their identity, their time, and their relationships.

Chapter 4. Routine as Resource for the Design of Learning Systems

4.1 Introduction

Previous chapters identify that the transportation of children to and from all the places they need to be is one of the major contributors to the busy family's feeling of life out of control. It uses these discoveries to generate guidelines for systems designers interested in supporting family coordination. This chapter then is the embodiment of the ideas that emerge from the previous chapter. Combining the observations that deviations in routine lead to the most challenging days for families, as well as our interest in learning systems, we set out to build a learning system that can represent and act on routines.

The goal of this chapter is to articulate a vision for how a learning system can support family coordination by acting on routines. This required the collection of a data set of family coordination that serves several purposes. First, the data set makes building statistical models possible. But to accomplish any learning also requires the collection of ground truth labels that can be used for evaluation. The labels also describes family coordination with exquisite detail, allowing us to examine their meaning, and look for ways to apply learning systems that could help families feel more in control of their lives.

This chapter describes the collection of that data set, and uses it to elaborate concrete opportunities where designed interventions would be appropriate. Similarly, it sets the stage for the following chapter, which describes the implementation of the models envisioned in this chapter.

4.2 Approach

We collected family data in order to reveal the underlying causes of coordination breakdowns that a routine learning system might be able to address. Methods employed included the following:

1. Nightly or bi-nightly interviews to capture the locations, plans, and activities of all family members

2. Weekly photo documentation of family calendars
3. Bi-weekly, in house Activity Interviews to capture more detail about observed issues
4. GPS sampling for every family member (including children) at one-minute intervals.
5. Evaluation of the knowledge of family members' routines
6. Identification of all calendar events as routine or non-routine

We selected families where both parents work full-time outside of their homes, and where children depend on their parents for transportation. We also sought families with no children over the age of 16. Within this demographic, we made an effort to recruit a wide cross-section, selecting families from a variety of ethnic and economic backgrounds, and where both parents participate in the transportation of their kids (see Appendix A for an overview of the six families that participated in our data collection.

Most nights during the study, a member of the research team would call the families, and interview each parent about that day's management of their kids' activities. In preparation for the interviews, family members were asked to input their daily activities into a web-based survey. Researchers then used the survey to scaffold the phone interview, probing and documenting the overall family logistical plan at each point throughout the day. Interviews lasted between fifteen and forty-five minutes, depending on the complexity of the day, the number of people available to speak, and the number of days of history to discuss. Coordination issues meant that interviews did not occur every single night, allowing researchers to use subsequent interviews to collect data on the missed time.

Logistical challenges at the arrival of summer (3 months into the study) forced two families to be dropped, but four families completed all six months of data collection. Over the course of the entire six-month observation period 528 unique interview sessions were completed, cataloging the location, activity, and plans of family members across 2112 person-days, or 5.78 person-years.

In addition to providing an empirical lens into family coordination practice, moving forward, these data can serve as ground truth for routine learners. We elected to capture aspects of family routine that could be sensed using only location. Location has already been shown to be a valid proxy for activity (Bentley & Metcalf 2007) (Brown et al. 2007) (Ludford et al. 2006), near-term-trajectory (Marmasse & Schmandt 2000) (Brumitt et al. 2000), and individual routines (Liao et al. 2007) can all be harvested from GPS traces alone. The sensing problem required to develop the routine models to support our vision of routine learners can be reduced to a technology readily available in commercial mobile phones.

To better understand the relationship between plans, routines and the main coordination artifacts, we asked families to take a digital photograph of their shared calendar once a week. Participants emailed us these photos and we entered the information into a digital calendar to speed the process of analysis. This documentation enabled an analysis of which events for a family were included on the calendar, and the frequency of new additions and updates. Over the course of the study, we created 91 unique family calendar models, each showing from three to six months of time, depending on the time of its construction

By further probing the form and triggers of coordination breakdowns, we address the types of breakdowns that a learning system that only has access to family member locations over time (from our expected GPS resources, for example), could reasonably solve.

We created a series of activity interviews to probe family members on different aspects of routines. These were conducted as a series of biweekly interviews in family homes. All family members were asked to be present. Researchers would conduct one of the activities listed below with a single participant while other family members observed. Following each activity, the observing family members would comment on the participant's output, filling in any information gaps, and explaining the details behind exceptions, and revealing inconsistencies. Activity-interviews lasted between 90 minutes and two hours. Over the course of the study, we conducted 102 such home visits.

In early activity-interviews, we asked each family member to describe their everyday routines; probing to learn individual roles and responsibilities. We then had participants walk us through reenactments of how they created plans and performed routines for various days of the week.

One activity asked members to specify the routines for every other member for the coming calendar week, including event start and end times, and travel times (see Table 4.1). Another activity asked family members to list all the steps required to complete an important task another family member regularly performs. This included the start, end and travel times as well as any equipment and any dependencies or constraints involved in the task, such as remembering to wash a uniform before it is needed for a game. We asked family members to pretend that other family members were to take over tasks they usually do, and to write notes to each other, explaining how to perform those tasks.

Other activities focused around the calendar. To understand both what activities families considered to be routine versus deviations in routine, and to understand the role of the calendar in managing routines and deviations, we examined a subset of calendar snapshots with each family. Family members walked us through each event listed on their calendars. We coded each entry for level of detail (time, place, name, transportation), and asked family members to classify each event as either “routine” or “non-routine.”

4.3 Findings

In this section, we draw representative narratives from our observations of family life to illustrate the ways in which a number of stressful coordination issues are introduced to family life. First, we find evidence of information gaps in family awareness of routine. Even though family members depend on accurate knowledge of one another’s routines, this knowledge often proves incomplete or inaccurate. Second, we find that the calendar is largely used to document deviations from routine. Despite its central role in family coordination, families encounter situations where the calendar does not contain information central to successfully making and executing some plans. Finally, we provide examples from family life where gaps in awareness of routines influenced and even caused coordination failures. In the absence of complete routine knowledge, family members show that they rely on what they believe to be accurate routine information. When these assumptions prove incomplete or inaccurate, even small inaccuracies can lead to coordination failures.

These narratives provide clarity on the structure of coordination breakdowns influenced in part or whole by deviations in routines, leading us to identify how a system that understands routine could intervene. We begin with some background on how routines fit into a family’s life. Though our data describe characteristics shared across participating families, to simplify the myriad details behind a comprehensive accounting, we focus on the life of family E.

4.3.1 Routines and Family Life

A middle class family of Italian descent, Family E lives in the suburbs around Pittsburgh. PA, USA, and reports an income in the $60k-$80k range, the median income range for the dual-income family (Unites States Census 2009). Dad is a medical technician at a nearby hospital. He works 10-hour days Monday through Thursday, and spends Friday working on community projects. Mom is a charge nurse at another nearby hospital. Her 5-day workweek changes every month, when she is assigned to a new rotation. She is also on call one night per month. Both parents drive about 30 minutes to work.

Family E has two children: S15 (son) and D10 (daughter). At school, S15 runs track and is in the band. Outside of school, he is in the Boy Scouts and takes lessons on both piano and trumpet. D10 is a flag-bearer in her school’s award-winning color guard, which travels to competitions across the country. Both children take a 10-minute bus ride to school every day, and after school head directly to track and color guard. Dad usually picks the kids up from color guard and track. The parents provide S15 transportation to and from music lessons, and they also regularly transport their children to and from friends' homes.

Our data collection allows us to empirically examine the impact participation in activities exerts on family life. GPS traces allow us to identify every activity occurrence by its location. Figure 4.1 summarizes these collected observations for family E. Each dot represents a unique occurrence of an activity, ordered chronologically from left to right. Survey, interview and calendar data enable the comparison of the actual outcome of the day to the family's stated plan, allowing us to classify each activity instance as routine (grey), scheduled (light blue) or unscheduled deviation (dark blue). Proportion bars to the right of each activity show the distribution of event types. Across the top is the number of unique plans made by the family during the course of each day. Numbers greater than one indicate that plans changed at least one time.

By cataloging the rides that parents give, our dataset allows us to characterize the time required to move kids to and from their activities. In family E, Mom and Dad provided 347 rides across the 146 days according to both GPS and interviews. On average, Mom and Dad provide 2.37 rides per day. Looking at the distribution of routine events, we see that of the 634 observed activity instances for family E, 41.8% occurred in a routine fashion, 34.4% as scheduled deviations, and 23.8% as unscheduled deviations. These findings are consistent with findings across all families, where we observe 37.6% routine activities, 20.8% scheduled, and 39.6% unscheduled deviations. These numbers suggest that by simply following their routines, our families can smoothly plan and execute around 40% of their kids' activities.

In the next section we examine the remaining nearly 60% of non-routine activity instances, where we discuss the ways that routine information can still play an influential role even during non-routine happenings.

Family E Routine and Non-Routine Activities, and Number of Plans

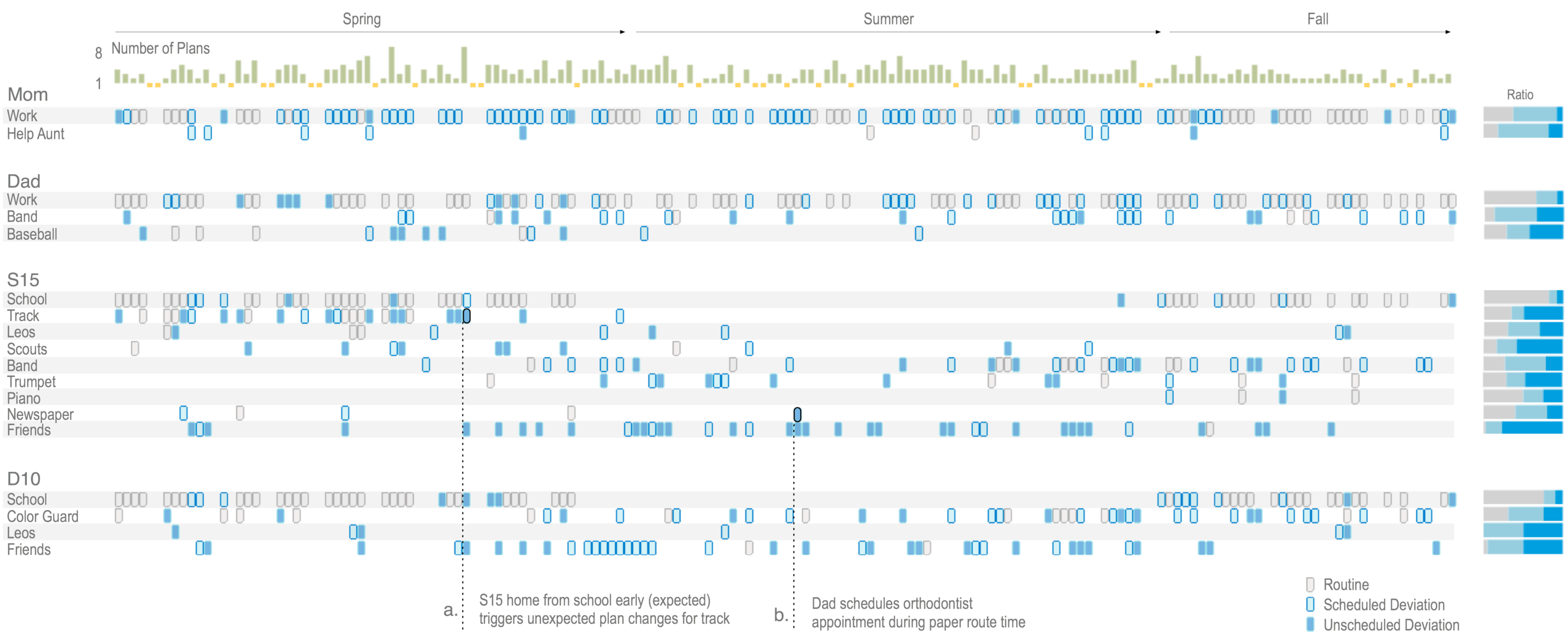


Figure 4.1. Six months of Family E's activities. Each dot represents an activity instance, ordered chronologically left to right, and classified as either routine, or scheduled or unscheduled deviation. Proportion bars to the right of each activity show the distribution of event types. Across the top is the number of plans created that day. Days with no plan changes are colored orange, and days with plan changes in green. Gaps in the dataset (caused by family or research team unavailability) have been condensed to accommodate publication space constraints.

4.3.2 Routine knowledge can be incomplete and/or inaccurate

Family members often make plans and decisions that affect one another. In the absence of contrary information, family members often choose to make plans based on their beliefs of one another's routines. If those beliefs are inaccurate or incomplete, they can make plans that rely on incorrect assumptions of the availability of people, and/or their time and resources, leading to stressful coordination breakdowns.

As part of the ongoing Activity Interview process, we asked every member of every family to specify all the routine activities for every other family member for the coming week, with approximate start and end times. In almost all cases, family members descriptions are largely complete and accurate. Family E's aggregated descriptions of S15's Wednesday routine (see Table 4.1) shows this disagreement and its potential consequences. On Wednesdays, S15 goes from school, to track practice, and in the coming week, conducts his monthly paper route. Mom and Dad accurately report many details, including the appropriate ordering of activities, and the precise definition of track's end. More notable, however, is the disagreement around the inclusion of Boy Scouts and the paper route.

The inaccuracy around the Boy Scouts shows how seasonal changes, can induce asymmetric information awareness. As the end of Boy Scouts approaches, S15 has stopped attending and plans to miss his last few meetings. Considering Boy Scouts over, S15 does not include the activity on his list. Mom and Dad, however, believe the activity to be ongoing, and both include it in their lists.

Activity		*S15*	*Mom*	*Dad*
School	*Start*	6:35 am	6:40 am	7:00 am
	End	2:25 pm	2:45 pm	3:00 pm
Track	*Start*	2:25 pm	2:30 pm	3:00 pm
	End	5:00 pm	5:00 pm	5:00 pm
Paper Route	*Start*	5:30 pm	5:30 pm	
	End	6:30 pm	6:00 pm	
Boy Scouts	*Start*		7:00 pm	7:00 pm
	End		8:30 pm	9:00 pm

Table 4.1. Wednesday routine as described by Family E. Dad excludes S15's paper route, an oversight magnified when he schedules a conflicting orthodontist appointment not discovered until the appointment day. The small information gap leads S15 to conduct a stressful last-minute search for a trustworthy replacement.

The problem around the paper route shows how information gaps can lead directly to coordination breakdowns. Dad does not recall, and so does not include S15's regular though infrequent paper route (happens once a month) in his accounting. An information gap of this magnitude might not by itself seem problematic. Later that month, however, we observed Dad schedule an orthodontist appointment that conflicts with S15's paper route. Even after adding the appointment to the calendar, the conflict is not detected until the afternoon of the appointment because the routine of delivering the papers is not on the calendar. Creating an alternate plan creates a stressful series of communications between Dad and the orthodontist, Mom and Dad, and S15 and his friends. Ultimately, S15 is able to find a substitute paperboy, and heads to the orthodontist (Figure 4.1, callout B) The dynamics of busy family life dictate that people depend not only on the efficacy of any given routine, but on the accuracy of their knowledge of the routines of one another.

Without accurate recall of routine information, coordination artifacts might help family members recognize and use routine information, helping them make and execute more successful plans. To evaluate this claim, we turn our attention to an exploration of calendar content.

4.3.3 Calendars Hold Deviations Not Routines

The family calendar helps provide information that family members need as they make and execute their plans. We observe that calendars suffer an information deficit when it comes to routine. Examination of the written contents of calendars shows that they largely hold deviations from routine.

Our Activity Interviews study repeatedly engaged families in discussion around and about their calendars. The six participating families showed variation in their use of calendars, consistent with previous research (Ashbrook & Starner 2000) (Neustaedter 2007) (Taylor & Swan 2005) (Wakkary & Maestri 2007), with three relying exclusively on paper calendars, one mixing digital with paper, one using exclusively digital, and one with no shared calendar. Part of our ongoing interviews asked each family as a group to classify every event listed on their shared calendar as either routine or non-routine. While the definition of routine varies, across all families, about 90% of the items on the 22 calendar months (4 months into the study) were classified as non-routine.

Across families we consistently found events that occur regularly but infrequently (e.g., school half-days), frequently but irregularly (e.g., school snack days), or both infrequently and irregularly (e.g., unexpected doctor visits). From the perspective of the calendar, however, routine events appear to be largely undocumented.

The effects of this lack of documentation become clearer when revisiting Dad's orthodontist double booking. Even without accurate routine information when he made the appointment, if routine information was visible on the calendar, Dad could have had another opportunity to check his assumptions and catch his mistake before the day of the event. Lacking documentation, however, it falls on each family member to accurately recall any needed details, to survey the calendar's listing of deviations and determine if there is a conflict with a regularly scheduled activity.

Later, we propose different ways that computational knowledge of routine information might have been automatically delivered to Dad, or placed on the calendar, creating multiple opportunities to avoid this mishap.

4.3.4 Small Information Gaps can Lead to Stressful Situations

As we have seen, the successful creation and execution of family plans requires accurate knowledge of the location and availability of various people and resources. In the absence of this knowledge, family members often fall back on their knowledge of one another's routines, which can be inaccurate. In this section we draw a connection between these seemingly small information gaps and the breakdowns that they influence and even trigger.

In family F, Mom regularly calls the gymnastics carpoolers early on event days to confirm that D10 will attend gymnastics. When out of town, Mom instructs Dad to make the call. However, she does not tell him that part of the call's routine is to discuss the pickup location. The carpoolers interpret no discussion of location to mean "the pickup will take place at school." Unaware his non-action has communicated meaning to the other carpoolers, Dad picks D10 up from school, and she waits at home for the carpool, which is sitting in the school parking lot waiting for her.

The gap in information represents only a small part of the communication content. Dad knows the date and time of gymnastics, and knows to make the phone call. All that is required to derail the carpool is an implied location. Considering that the key information is outside Dad's awareness, it would have been challenging for Dad to probe Mom in advance about this particular detail.

The same small information gaps that appear during planning can appear during execution. For example, in family E, Dad usually arrives home from work at 2:30pm. As baseball season approaches, however, Dad works on league organization and begins returning home closer to 5pm on Fridays. During track season, S15 practices with the team every afternoon at 3pm. Unaware of Dad's routine change, S15 returns home at noon on a school half day, assuming Dad will be home at 2:30pm and can drive him back to school for track (Figure 4.1, callout A). Without Dad to provide transportation, S15 misses track and is forced to sit out a track meet because of his truancy.

S15's awareness of Dad's routines becomes inaccurate as seasons change. He is still correct about Dad's schedule on four of five weekdays, but incorrect about the one day he needs a ride. Lacking any advanced knowledge of S15's intended behavior, Dad does not express his change in schedule to S15 until S15 had already made plans that depended on that knowledge. And while the school half day was on the calendar, the more routine track practice was not.

For another example of role switching leading to coordination breakdown, we turn to family A. Mom usually picks up D4 from day care on her way home from work. When Mom attends an out-of-town funeral, Dad agrees to take over Mom's day care pickup. On her first day away, about 30 minutes after the usual pickup time, Mom receives a call from the headmaster, who politely inquires when Mom was intending to pick up D4. Dad forgot that he was expected to handle this scheduled deviation and pickup his daughter, and, instead, carried out his normal routine, and simply drove home after work.

4.4 Vision for Systems that can Learn Routines

In the most basic way, these data serve to identify an important lack of logistics resources. Information about the routines of others is useful to many situations when parents make plans for and that affect other family members. Our data reveal, however, that only about 40% of events unfold in a routine manner. When deviations do occur, family members often need but do not have access to accurate information about their routines. Calendars can provide some of that information, but can provide only very little needed routine information. In the absence of that informational resource, parents are left to recall the routines themselves. Since family members do not have complete and accurate information on the plans of other family members, this often leads to the creation of plans that are logistically impossible. A parent signs their partner up for a pick-up that they will not be able to make. A parent assumes that a pick-up is at one location when it is at another. In the worst case, children are even left at their activities.

If lacking an information resource can lead to logistical problems, then the main strategy behind this thesis is to find a way to create that needed resource. The creation of a resource to provide routine information to family members leads to the generation of many new kinds of application designs. The routine can be used both to present information directly to end users, and as an enabling technology to create new capabilities in current family support applications

These breakdowns cut across families, parents, and economic class. For example, we saw parents commit their spouse to tasks that were impossible given the spouse's current routines. Even on days parents had a scheduled deviation, we saw them go to their routine pick-up location. We saw routines change and family members neglect to inform one another. Finally, on multiple occasions, we witnessed parents forget to pick-up their children, leaving them for as long as 40 minutes.

If a lack of accurate routine information can lead families to coordination breakdowns, we contend that one solution is to generate the missing routine information. The remainder of this work considers the capabilities computational systems can gain if provided with some form of documentation of routine information. This information could be input directly by users, learned using sensing systems or some combination of the two. We describe how the presentation of these new information resources can ultimately enhance the efficacy and experience of family coordination, and minimize unnecessary stress.

These observations lead us to develop a vision for how learned models of routine could support family coordination (Davidoff, Dey & Zimmerman 2010). We frame the discussion around the ways in which coordination systems and technologies support the problematic examples observed during our data collection study, and explore how models of routine would provide these capabilities.

In the following discussion of routine, we limit the scope of sensing and reasoning to the activities people engage in and where they occur as a function of time and location. Researchers have already shown that commercially available location sensing can be used to learn individual patterns of routine movement across an urban setting, e.g (Brumitt et al. 2000), (Liao et al. 2007), (Ziebart et al. 2008).

We use these examples to argue that documentation of routine can a powerful enabling technology, building a case for its exploration by the research community.

1. **Planning** – Using our models, calendaring systems like LINC (Neustaedter & Brush 2006) and DateLens (Plaisant et al. 2006) could display implicit routine events, event times, pick-ups and drop-offs that parents don't document but are critical to making effective plans for and that affect others. Family members could see an entire day's plan, helping make unresolved and conflicting responsibilities salient.
2. **Coordinating** – Using our models, location systems like Motion Presence (Bentley & Metcalf 2007) and the Whereabouts Clock (Brown et al. 2007) could display where people are with implicit routine information like future pick-ups and drop-offs, helping remind family members what they need to do, and alerting others as days happen as planned.
3. **Improvising** – Using our models, applications could update plans in real-time, helping parents make more reliable decisions. As pick-ups happen, reminder systems like comMotion (Marmasse & Schmandt 2000) and PlaceMail (Ludford et al. 2006) could suppress potentially annoying reminders.
4. **Protecting** – Using our models, reminder systems could infer that a required pick-up is not happening, and remind parents without their explicit creation of a reminder, creating a new kind of safety net to guard families against this uncommon but stressful outcome.

4.4.1 A Calendar with Knowledge of Routines

Digital calendars give remote access to events entered on the home calendar. However, this capability could in and of itself have helped family E's Dad avoid situations like the orthodontist mishap. Like many other routine events, S15's paper route is not listed on the calendar (see Figure 4.2, left). Without evidence to inform him otherwise, these digital calendars could not have prevented Dad from the scheduling conflict because it is simply not visible. The burden instead lies entirely on Dad's recall of S15's paper route.

Given computational access to S15's routines, the same digital calendar could overlay S15's routines (see Figure 4.2, center), providing Dad with a more accurate picture of S15's likely activities.

Documentation of routine can help calendaring applications assist S15 to avoid missing track on his school half day. Even though he might not know Dad's current routines, S15 could look to the calendar to display them. A conceptual prototype is shown in Figure 4.3, which shows how learned routine information could be overlaid on top of regular calendar information, providing information that an individual might not have immediate access to, in a way that provides room for its probabilistic nature, gaining overall access to information that current paper and digital calendars do not otherwise have. Adding a layer of intelligence to these applications takes another step towards avoiding these stressful situations that current calendars cannot achieve.

Given their current and past locations for a given day, for example, models of routine could be used to predict the family's goals (Simpson et al. 2006). Predicting, for example, that S15 needs to be at track at 3pm, and that Dad will arrive home at 5pm, planning algorithms like partially-observable markov decision processes (POMDP's) (Kaelbling, Littman & Cassandra 1998) could then be used to detect mutually exclusive conditions (Blum & Furst 1997) like the fact that S15 will not have transportation to track by 3pm. When the calendaring system anticipates the coordination breakdown with reasonable certainty, it can alert S15, giving him the flexibility to respond to the situation earlier and not miss practice.

Sketch of Calendaring System with More Complete Routine Documentation

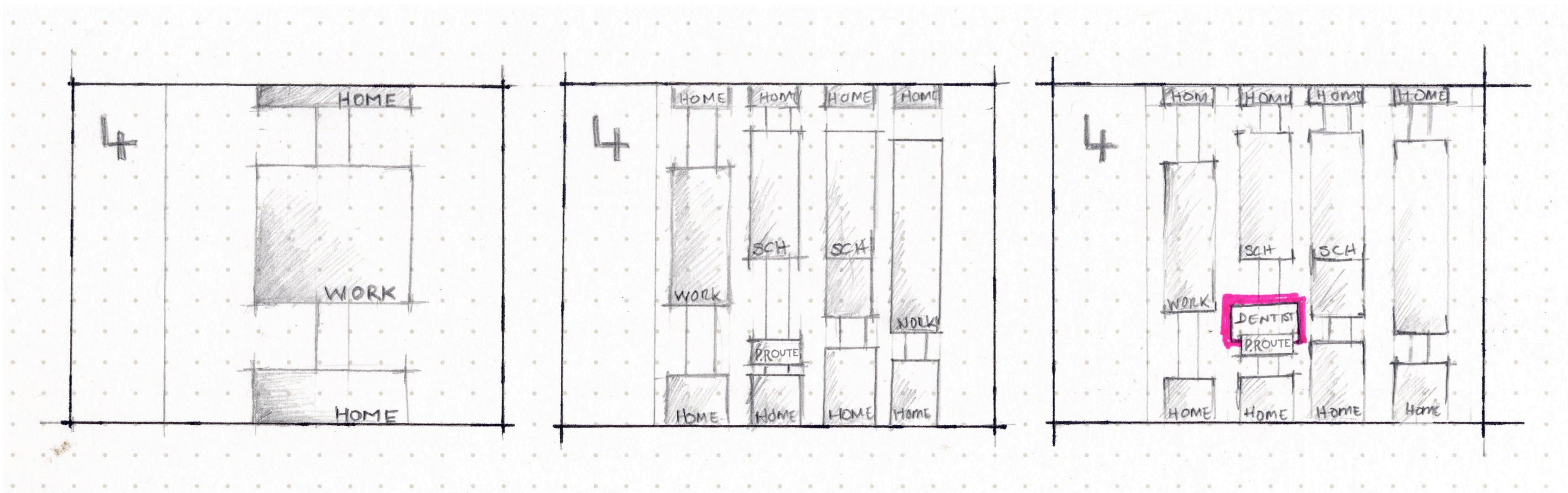


Figure 4.2. Rough sketch showing family E's calendar augmented with family routine information. At left, like with current calendars, Dad sees an overview of his day. In the center panel, to avoid a double booking, he compares his day with S15's expected routine. At right, the calendar highlights a possible conflict with S15's expected paper route.

Sketch of Calendaring System Showing Probabilistic Routine Information

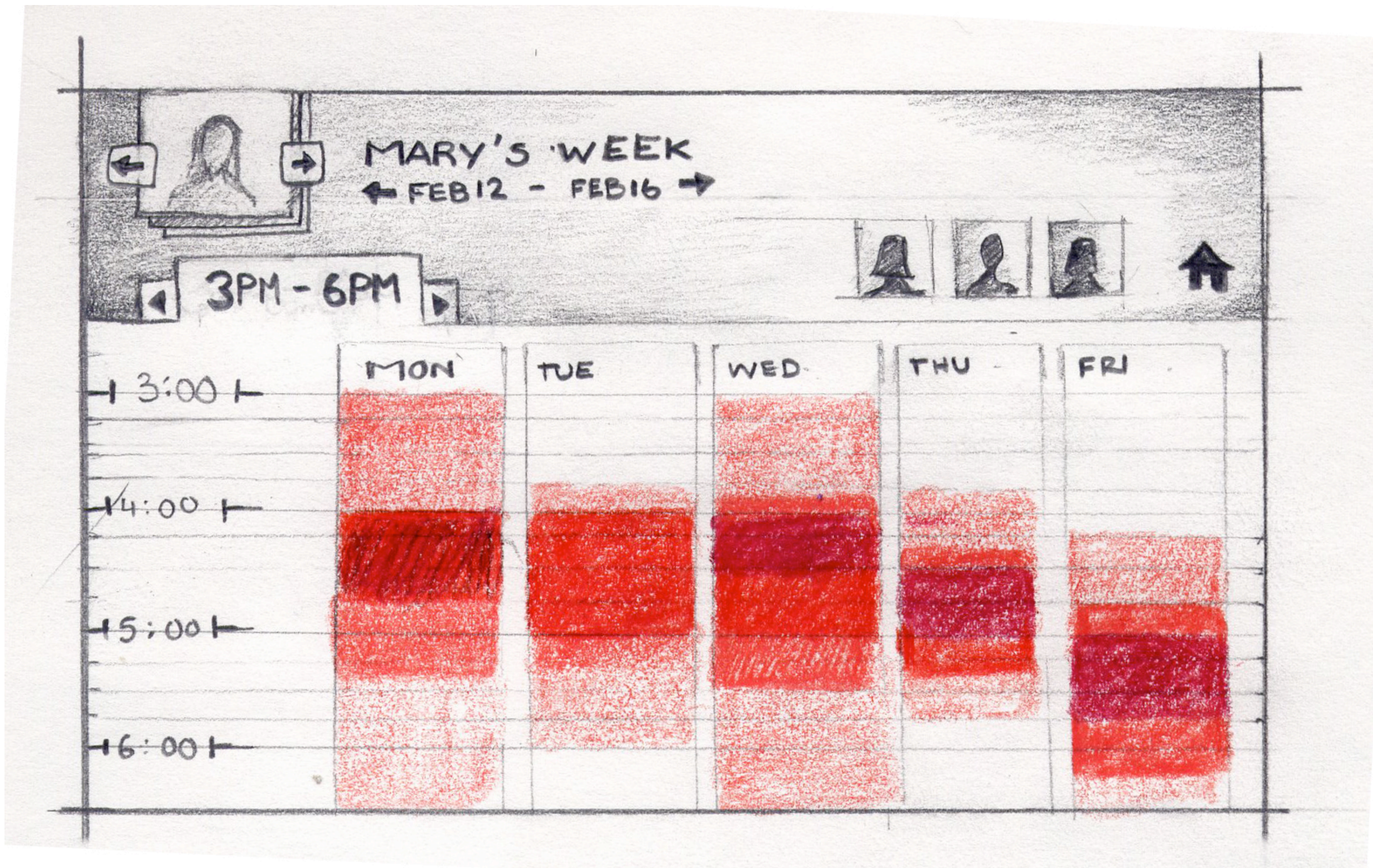


Figure 4.3. A calendar concept that displays information from learned models of routine. A person's movements will gradually be learned by the model using GPS, and, when queried, a calendar can display this as an additional layer of information to help during planning situations.

4.4.2 A reminder system with knowledge of routines

All reminder systems require that users know beforehand what they might forget. The examples taken from our data collection illustrate an important breakdown with reminder systems. Families cannot know in advance what information will not be known at the time of task execution.

In the example where family A's Mom is out of town, leaving it to Dad to pick up D4 from day care, a layer of learning on top of a model of routines might have helped to avoid forgetting D4 at day care. A display that lists the pick-up and drop-off responsibilities for a family, could then display when pick-ups appear to be unresolved, and bring it to the attention of family members, as displayed in the concept sketch in Figure 4.4.

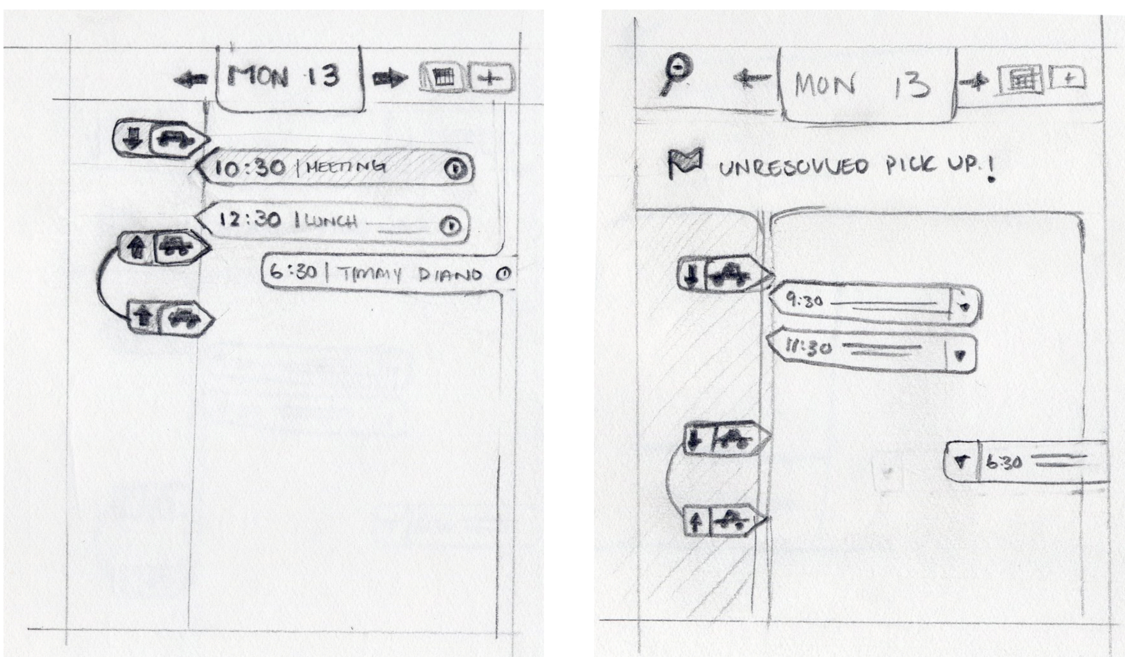


Figure 4.4. Concept sketch showing pick-up and drop-off responsibilities for a family (left), and how an unresolved pick-up could be displayed.

Whether by providing an ambient display to indicate perceived anomalies, or with more intrusive interruption, system designers can choose how applications will leverage this information. However utilized, a model of routine provides the underpinnings for the creation of an automatic reminder, where the system observes that certain routine (or non-routine) tasks are being overlooked.

The system might also be able to detect when the routine at a high level is being carried out, but certain aspects of it are being completed in a non-routine fashion. In the example where family F's Dad and D10 are waiting at home for the gymnastics carpool, a routine learning system could learn the destinations of each family member, and display them, allowing family members to view how the actual events of the day are following what they believe to be the plans (see Figure 4.5, left). Another approach would be to compare the model of how the routine is performed with its current state and determine that because the carpool and D10 are not co-located and are not moving towards each other, an anomaly is occurring (see Figure 4.5, right).

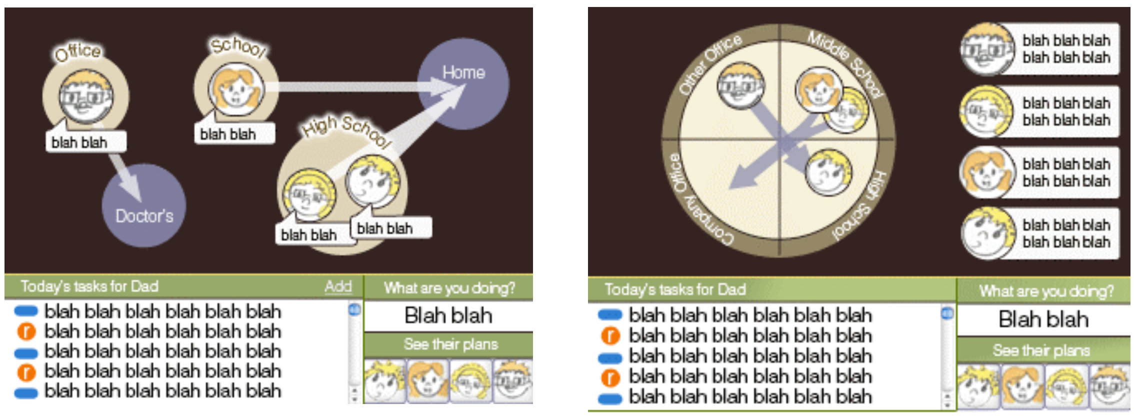


Figure 4.5. Concept sketches for a device that could add learned routine information to a location display. The image at left shows how learned models of destination could be laid over current locations. The image at right shows how learned routine information could be used to display that a pick-up or drop-off responsibility is not occurring.

A long-term consideration of system designers is how to avoid "nagware," or reminder systems that remind users based on conditions they configure, but are no longer needed because the users are currently performing the task the reminder was created for. By observing a situation as it unfolds, and comparing a user's stated reminding goals with the state of their current activities and location, a routine learning system could infer that a reminder is not necessary and pass that information along to reminding applications. Applications could dampen the intrusiveness of the reminder notification or suppress it altogether.

4.5 Summary

We find that busy families lead lives where more than half of all activities unfold as non-routine at the time of their execution. We also find that family members do not have perfect knowledge of each other's routines. Finally, we find that support tools like calendars support planning around scheduled deviations in routine better than they support the planning of routines themselves.

In this chapter we have proposed that there is a large opportunity for simple ubicomp systems to support dual-income families by learning their routines and then leveraging this knowledge to improve their lives. To investigate this opportunity, we performed a data collection study involving daily interviews with dual-income families. These examples argue that routine can be leveraged as a powerful enabling technology. By illustrating how this simple concept can extend and enhance current systems, we hope to stimulate continued interest in the development of robust routine sensing, as well the application of routine models to a variety of other domains to help solve observed, real world problems.

Chapter 5. Routine as Resource for Sensing and Modeling

Parents are often responsible for planning, coordinating, and executing the transportation of their children to and from their many activities. One coping strategy dual-income parents employ is to develop routines. As parents repeatedly perform similar sequences of actions around each pick-up and drop-off, a routine emerges, significantly reducing the attention required to complete the task.

When tasks unfold in a routine fashion, coordination requires minimal attention to detail. However, when families must deviate from their routines – e.g. when one parent must travel for work, schedule an orthodontist appointment, plan a new carpool, or remain home with a sick child – the likelihood that some part of their plan will break down significantly increases.

One these days, effective logistics can often depend on knowledge of the routine location, availability and intentions of other family members. Interestingly, families rarely document routine events on their home calendars (Davidoff, Dey & Zimmerman 2010). Even when they do, descriptions are incomplete, missing key information, like which parent will drive. Without a resource to provide needed information on routines, family members must recall details of other members' routines (or their own), and here errors can take place. Plans for new events or reactions to unanticipated situations can result in double-booked schedules, missed events, and even children being left at events (Darrah, Freeman & English-Lueck 2007), (Davidoff et al. 2006), and, or course, stress and anxiety for parents (Gneezy & Rustichini 2000) (Wolin & Bennett 1984).

This paper explores how sensing and modeling can provide computational access to family transportation routines, and how these learned models function as an enabling technology. Many ubicomp researchers have detailed the importance of routines in how people live and work, cautioning that system designers need to be aware of the importance of people's idiosyncratic behaviors (Beech et al. 2004) (Davidoff et al. 2006) (Frissen 2000) (Wakkary & Maestri 2007) (Wolin & Bennett 1984) and their incompatibility with the techniques of artificial intelligence (Suchman 1983) (Tolmie et al. 2002) (Taylor et al. 2008). We wish to take up this challenge. Specifically, we demonstrate how the historical accumulation of GPS trace data from standard mobile phones, without the need for any supervision, can be used to reliably perform the following precitions:

1. Detect if a pick-up or drop-off has occurred
2. Predict which parent has responsibility for a future pick-up or drop-off
3. Infer if a child will forgotten at an event

We also discuss how these learned models can create new resources that enable end-user applications, for example:

1. Awareness systems can know when pick-ups occur
2. Calendars can display implicit routine data like where and when pick-ups and drop-offs will occur
3. Location systems can show what pick-up and drop-off responsibilities family members have
4. Reminder systems can alert parents about children left at activities without explicit reminder creation

In this chapter, we describe the design and evaluation of our learned models of family routine. Our goal is to develop a proof-of-concept while providing insights on how to improve technical performance. We provide an overview of our previous research and situate our contribution within the field; we describe the design and performance of our learning systems; and we discuss how learned models can enable end-user applications, and ultimately, families.

5.1 Approach

The goal of this chapter is to provide an initial demonstration of the feasibility of our underlying technical approach in a realistic setting. It is also important to note that we in no way claim that our approach is optimal. Instead, the reader should consider the approach in this paper a demonstration of what is possible, and food for thought about other capabilities that knowledge of routines can offer.

First, to operate with a shared vocabulary, we offer a set of definitions. Since we are relying on GPS as our primary sensor for learning routines, we developed a place-centric view of coordination. A person's day can be described as an ordered list of the places they go. We call the transition between each place a ride. In our families, each ride has a driver (the parent) and possibly a passenger (the child). A drop-off is a ride given to a place, and a pick-up is a ride given from a place. A plan is an ordered list of pick-ups and drop-offs, each with an ideal time, when the parent intends it to occur, and an actual time, when it actually does occur. As a plan unfolds, the family coordinates, acknowledging completed rides, and reflecting on the need to modify their current plan for future rides. Families improvise; they dynamically modify and even generate new plans based on unanticipated situations that challenge the current plan. Collectively, we refer to planning, coordinating and improvising as family logistics (also known as coordination in other literature). Children participate in activities like violin and swimming lessons Parents give children rides to events, which are instances of the activities.

With this shared vocabulary, the remainder of this section describes the construction of three models of routine, their relationships, and how they can help families plan, coordinate and improvise; creating a new kind of protection against logistical breakdowns. Figure 1 depicts our modeling approach graphically, with arrows indicating the flow of data and inference. Models are constructed from two data sources: interviews, and GPS (Figure 5.1, top). Our GPS data set, captured during the same field deployment describe in the previous chapter, follows the movements of 23 people in 5 dual-income families across approximately six months, and is labeled with data collected from nearly 1,000 surveys, over 500 phone interviews, and over 100 home visits (collection reported in (Davidoff, Dey & Zimmerman 2010). Leveraging previous work on automated place discovery (Ashbrook & Starner 2000) (Marmasse & Schmandt 2000), we assume that all models include a set of known locations (taken from our interviews). Interviews provide a ground truth about which activities occur each day, and the ideal pick-up and drop-off times. We combined this information with GPS, and designed a series of three models, each recombining and building on the output of the previous model, and each supporting family logistics in different ways.

First, we apply a temporal logic to our GPS data streams, and compare the location and driving state of separate individuals to recognize when rides occur and who participated in the rides. Participation allows us infer which parent drives which kid to which activity. In the most basic sense, this is part of the routine that families almost never record on their calendar. The output from this model can begin to fill in the empty calendar spaces for the things people do every day.

Hierarchical Model Depicting Movement From Low-Level Sensor Data to High-Level Context About Family Coordination

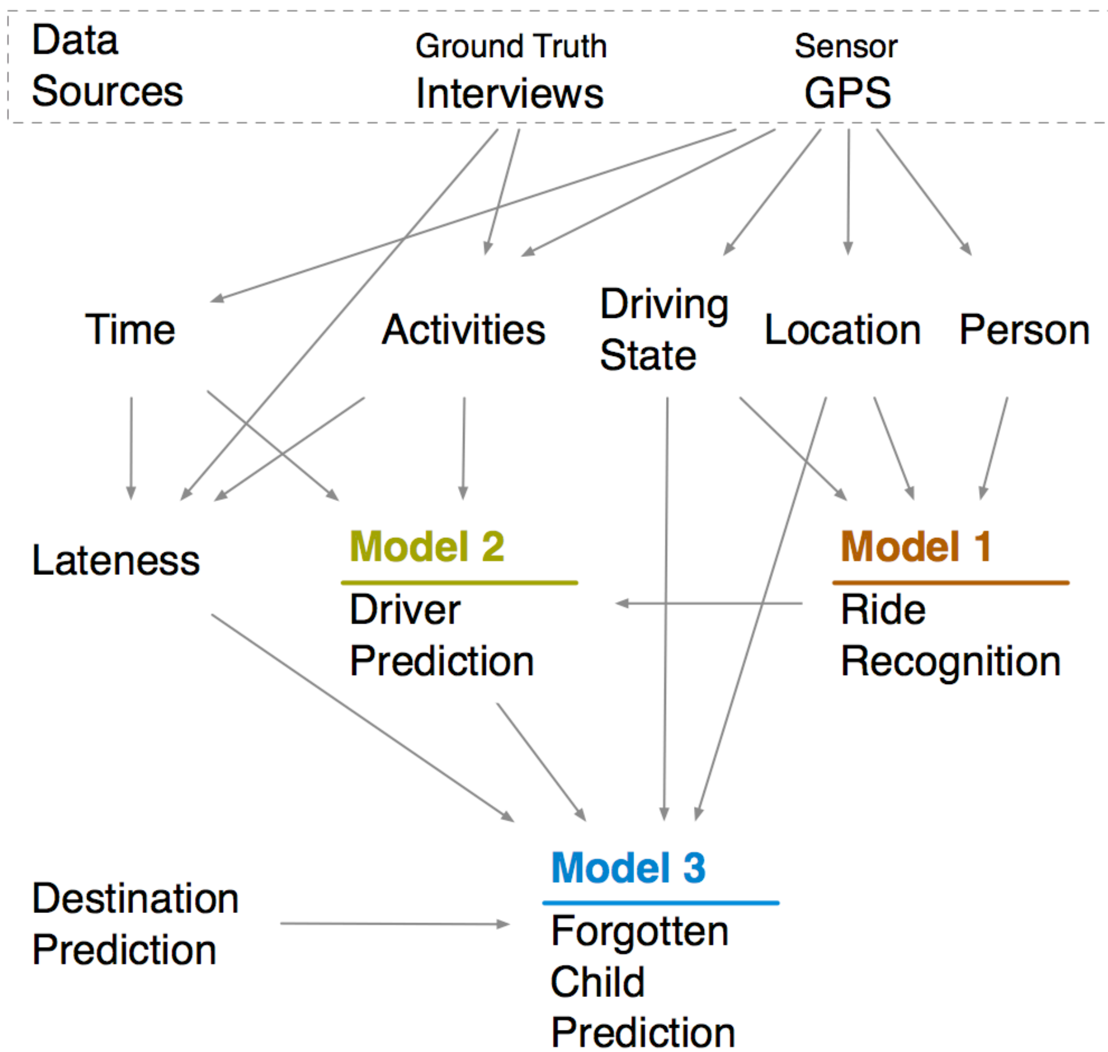


Figure 5.1. Interviews provide each activity's location and each event's intended pick-up time. All other knowledge is inferred from low-level GPS, creating unsupervised models that (1) sense rides; (2) predict the driver for the next event; and (3) predict if parents will arrive late for pick-ups. End-user coordination applications can use any model's output as a new data source to help families plan, coordinate and improvise. Model 3 can work with reminder systems to create a new kind of safety net.

Second, the ride recognition model provides seed data to learn the probability distribution that each parent will be driving a child to an activity (Figure 5.1, Model 2). We can use this distribution to predict future drivers, which, when compared with observations in real time, can offer an indicator of when events are happening in non-routine ways (Simpson et al. 2006). Because non-routine events are those most likely to lead to logistical breakdowns, early detection of non-routine rides can help propagate that information to coordinating family members, and, when appropriate, allow them to respond earlier, and to make plans in response to these situations with a more complete overall picture.

Third, the driver prediction model, along with real-time location and driving state, a learned distribution on lateness, and a driver destination model, feeds into a higher-level inference machine to detect when parents forget a child at an activity (Figure 5.1, Model 3).

We demonstrate that our approach is practical by conducting this work under legitimate sensor and modeling constraints. Since families literally rely on their phones, battery-heavy GPS sampling is limited to once per minute instead of the more common rates upwards of once per second. Models are then trained using an online approach, meaning we use only the data that would be available at any given point in time, and not the entire data set.

5.2 Model 1: Recognizing Rides

The routine rides family members take every day represent one of the basic units of undocumented family logistics. Without some form of documentation, a computational support system can neither provide routine information to families, nor use it as part of an inference system. The automatic capture of rides introduces the possibility of computational support while requiring minimal behavioral changes. Each sensed ride includes a driver, a passenger, a place and a time, providing information that can be immediately shared with awareness systems, as well as creating a source of labeled data with which computing systems can perform further reasoning. In this section, we describe a method for recognizing rides (from which we extract their drivers, passengers, and times), and examine its performance.

5.2.1 How are rides recognized?

To recognize when rides occur, we apply a simple temporal logic to the synchronized, discretized GPS data. We define three states for a person (see Eq. 5.1). A person is always either at a location, Ln, or traveling, T, which we define as the unique location occupying the space between all known places. Two family members are said to be co-traveling, CoT, if during the same time, ti they are both traveling and at a Euclidian distance of less than 500 meters. Any remaining states (e.g., no sample, outliers) are collectively labeled else.

$$States = \left\{L_n, T \mid CoT, else\right\} \qquad 5.1$$

We examine each parent-child combination separately, and refer to parent as P, and child as C (see Eq. 5.2)

$$People = \left\{P, C\right\} \qquad 5.2$$

We define a pick-up as the conjunction of states of a parent, P, and a child, C, over time (See Eq. 5.3). At time t1, the child is at location Ln. At time t2 both parent and child are at location Ln. Lastly, at time t3, both parent and child are co-traveling, CoT. This definition is broad enough to cover two cases of pick-ups. In the majority of cases, a parent comes from a different location to the child's location and they drive off together. We also consider a pick-up in the case where a parent is already at the child's location, and they depart together. Drop-offs are the inverse of the sequence for pick-ups (see Eq. 5.4).

$$\left.\begin{array}{l} (t_1,P,\neg CoT) \wedge (t_1,C,L_n) \wedge \\ (t_2,P,L_n) \wedge (t_2,C,L_n) \wedge \\ (t_3,P,CoT) \wedge (t_3,C,CoT) \end{array}\right\} \quad \text{Pick-up} \qquad 5.3 \quad \begin{array}{l} a \\ b \\ c \end{array}$$

$$\left.\begin{array}{l} (t_1,P,CoT) \wedge (t_1,C,CoT) \wedge \\ (t_2,P,L_n) \wedge (t_2,C,L_n) \wedge \\ (t_3,P,\neg CoT) \wedge (t_1,C,L_n) \end{array}\right\} \quad \text{Drop-off} \qquad 5.4 \quad \begin{array}{l} a \\ b \\ c \end{array}$$

Our method to detect rides is based directly on the definitions. We parse the GPS streams from all members of a family and predict that a ride is occurring for each example that meets all three requirements of our definition.

5.2.2 Accuracy of Ride Sensing

To evaluate the performance of our ride-sensing method, we compare its predictions with the ground truth taken from our interviews.

Aggregate interviews report 3283 rides, or roughly one ride per day per family. Because interview and sensor data in a longitudinal study of this magnitude do not always align perfectly, several additional evaluation conditions must be defined. We refer to moments with sensor data but no corresponding ground truth as sensor-only conditions (see Table 5.1), and moments with interview but no sensor data as interview-only conditions. Sensor data was not available when people had their phones turned off (e.g., when working in a hospital, or attending school) or when they were in locations where the phone could not detect the GPS satellites. Neither condition is included in the evaluation. As true negatives (accurate non-rides) constitute the vast majority of the dataset, they are conservatively excluded so as not to bias the evaluation in favor of our model. These real-world constraints place 1721 rides beyond the reach of sensor data collection. We report on the 1562 rides accessible to sensing.

		Ground Truth Interviews		
		Null	*True*	*False*
GPS Data	*Null*		Interview Positive	Interview Negative
	True	Sensor Positive	True Positive	False Positive
	False	Sensor Negative	False Negative	True Negative

Table 5.1. Expanded confusion matrix as defined by the longitudinal data format. Ground truth is defined by nightly family interviews, and the ride model makes predictions using only GPS sensor data. Shaded cells excluded from the evaluation.

Across all families, for both pick-ups and drop-offs, our simple temporal model performs well. 90.1% of the events the model identified were in fact rides (see Table 5.2, Precision), and 95.5% of all rides were sensed (see Table 5.2, Recall). Precision and recall measures between families are also consistent, with a variance of 0.072. This variance measure is dominated by the precision value of 0.684 for family E drop-offs, the only value below .80.

Family	*Precision*		*Recall*	
	How many of the sensed rides are right?		*How many of the total rides are sensed?*	
	Pick-up	*Drop-off*	*Pick-up*	*Drop-off*
A	.991	.987	.912	.910
B	.966	.962	.979	.981
C	.913	.824	.971	.921
D	.878	.873	.980	.944
E	.931	.684	.959	.985
Average	.936	.866	.960	.950
	.901		.955	

Table 5.2 Evaluation of our temporal logic model for sensing when children are picked up and dropped off.

A variety of factors can be responsible for these errors. (see Figure 5.2). Narratives from our interviews help explain the meaning behind these numbers. In family E, D10 walks to and from school. Family E's Mom, a doctor, arrives home from some hospital shifts at around the same time as D10 arrives home from school. Our temporal logic correctly identifies that parent and child are at the same location (Eq. 5.4.b), and not co-traveling (Eq. 5.4.c). Our temporal logic, however, mistakes arrival at home within the same minute for co-travel (Eq. 5.4.a). Both Mom and D10 are correctly labeled as traveling, and are within 500 meters of one another, but are not traveling together, causing the false positive errors. Another cause could be the distribution of journey distances (see Figure 5.3)

Family C GPS Traces, including Sensed Pick-Ups and Drop-Offs

Figure 5.2.One day's movements for Family C, overlaid with the output of the ride-sensing model. Each row represents one place the family visits. A uniquely colored line traces each family member's path. Horizontal lines indicate a person is at a location. Diagonal lines mean travel between places. A full circle shows a correctly sensed ride. An X represents a false positive, and an empty circle a false negative. False negatives are caused by gaps in the data.

Distribution of Journeys by Family and Journey Time in Minutes

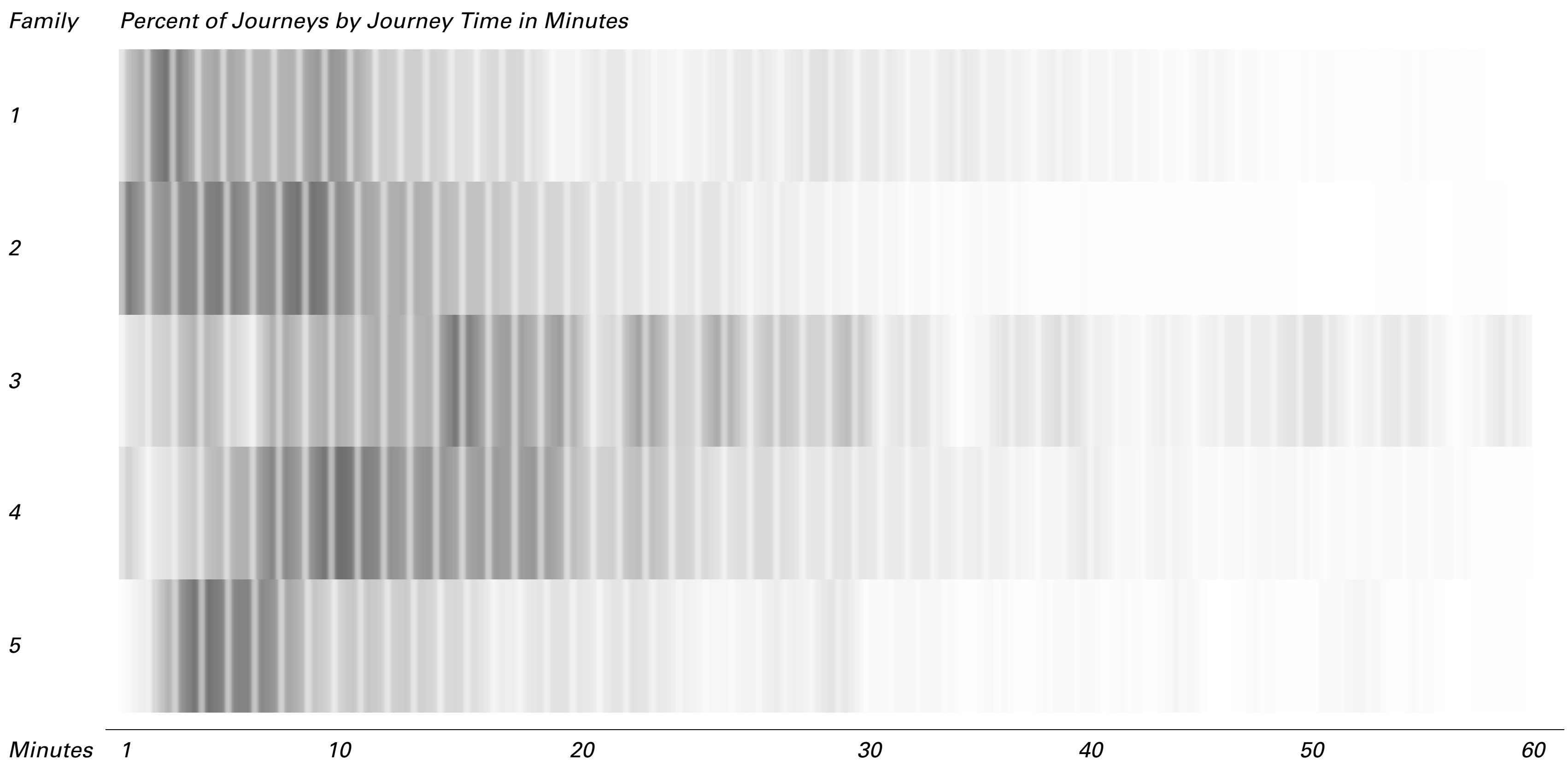


Figure 5.3. Distribution of family journeys displayed as a function of their journey length (in minutes). While we can see distinct patterns, two main classes emerge – a more Poisson-like distribution, and a skewed Gaussian.

5.3 Model 2: Predicting Drivers

With a capable ride recognition model providing reliable information on the driver, passenger, place and time of each ride, we can combine this information gleaned from sensed rides with low-level GPS data, derive a set of features, and use this to train a model of driver prediction.

5.3.1 Modeling which parent drives

To model the probability distribution of which parent drives, we first create a labeled set of rides in an unsupervised way using the predicted rides from Model 1. For each row, or prediction example, we build a feature vector, f, containing:

Name	*Meaning*	*Values*
L_n	Location of pick-up or drop-off	Place ID
RType	Ride type	Pick-up, Drop-off
DoW	Day of week	0,1,2,3,4,5,6
ToD	Discretized time of day (15 min)	1,2,3…96
$driver_{t-j}$	Driver for the last 5 rides to L_n	Mom, Dad
ϕ	Driver distribution model	[0,1]

Table 5.3. Feature vector for predicted rides.

We define the driver distribution for rides of type *RType*, on day *DoW*, at location L_n, to be the following:

$$\phi = \frac{\sum_{L_n, Rtype, DoW} driver = P_1}{\sum_{L_n, Rtype, DoW} driver = P_1 + \sum_{L_n, Rtype, DoW} driver = P_2} \qquad 5.5$$

For each example, we assign the label, y, as -1 if Dad was detected as the driver, and +1 if Mom was detected. Our goal is to create a classifier to determine who should be driving (or the probability that each parent is driving). We use a decision tree classifier because the shape of the decision boundary is unknown and trees perform well under both linear and non-linear boundaries. Because previous research on family routines observes frequent deviations from the intended family schedule (Darrah, English-Lueck & Freeman 2001) (Fiese et al. 2002), before classification we chose to use local weighting to reduce the impact of these non-routine outliers (Atkeson, Moore & Schaal 1997). For each labeled example q, we calculate a new label d(y) as a function of the old label y and the features f:

$$d(y)_{LW}^{q} = \frac{\sum\limits_{i \in labeled\ data, i \neq q} y_i e^{-\sqrt{\sum_j^i \left(x_i^j - q^j\right)^2}}}{\sum_{i=q} e^{-\sqrt{\sum_j^i \left(x_i^j - q^j\right)^2}}} \tag{5.6}$$

This transformation has the effect that deviation examples have labels closer to 0 and non-deviation examples have labels closer to the original -1 or 1. The closer the label to 0, the less impact it has on the accuracy of the classifier.

The overall classification process combines local weighting with a binary decision tree, creating a locally weighted decision tree (LWDT) to predict which parent drives for each ride.

5.3.2 Driver Prediction Accuracy

The ride model's treatment of the output class (Mom or Dad) as a nominal variable leaves only two cases for evaluation: (1) a prediction of Mom when Mom drives or Dad when Dad drives is correct; and (2) a prediction of Mom when Dad drives or Dad when Mom drives is incorrect. With no case that can lead to false positive or false negative, we cannot evaluate using precision or recall. Instead, we look at accuracy: how many times out of the total did the classifier predict mom or dad correctly.

We then train the model using a sliding window, and test on the week immediately following the training period, a common technique used with time-series data (Roberts 1959. Searching for an optimal window size, we vary the size of the sliding window from one to 24 weeks, and analyze the results. Across all families, when the model is trained using only one week of training data (Figure 5.4, top left), the model correctly predicts the driver 72.1% of the time, showing that a deployed system might be able to provide useable data after just a single week in the field. The optimal window size is four weeks, which predicts the driver correctly 87.7% of the time.

At test weeks twelve (June 1) and eighteen (July 13), nearly every graph in Figure 5.4 shows a steep drop in performance, correctly predicting the driver only marginally better than chance. These dips correspond to significant changes in family routines at test week eleven (May 25), when all our families transitioned from school to a new summer schedule, and at test week seventeen (July 6), when camps ended (families D, E), families vacationed (Families A, C), and summer sports ended (family B). Poor performance during each of these weeks is consistent with previous findings that routines are the least stable during times of transition (Davidoff, Dey & Zimmerman 2010) (Zerubavel 1981).

Evaluation of Unsupervised Driver Prediction Model Varying Amount of Training Data

Figure 5.4. Accuracy (vertical axis) of our driver prediction model across all families, plotted by test week number (horizontal axis), varying the amount of training data provided to the model from one (left) to fourteen (right) weeks. No matter how much training data is used, accuracy drops at weeks 12 and 18 (vertical lines).

Changes in routine that occurred in weeks eleven and seventeen would not appear in the training data until weeks twelve and eighteen, which exactly overlap the drops in performance. Looking more closely, the changes in routine at weeks eleven and seventeen also influence the outcome of our driver model optimization. Figure 5.5 shows the relationship between the size of the training data sets, and the number of times they include an aberrant week. Since five weeks separate the routine changes, training data sets that include five weeks of data or more will include one of these aberrant weeks more often than not, providing them with noisier training data, and lowering their accuracy. In fact, four weeks of training data marks the turning point, when training data sets do not include aberrant weeks more often than they do, explaining why it is the optimal number of weeks of training data to use in the driver prediction model.

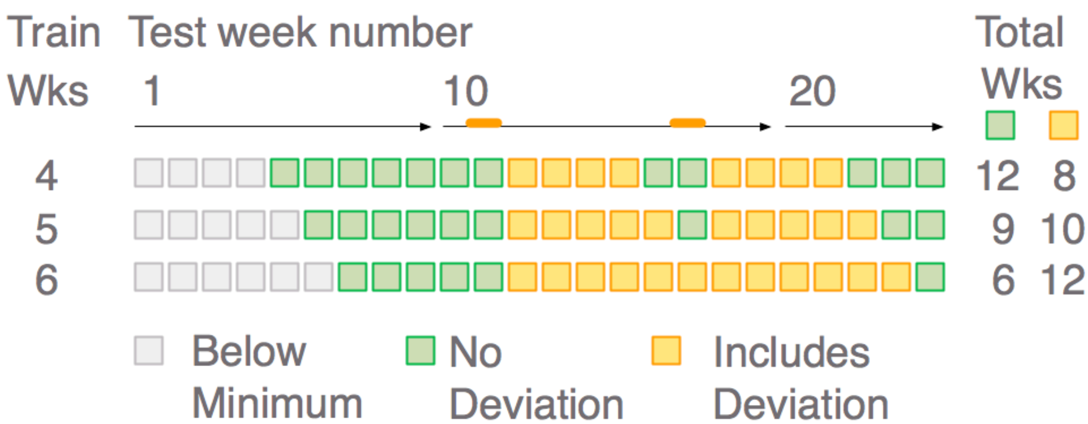


Figure 5.5. Performance drops of the driver prediction model at weeks 12 and 18 occur as transitions from the routines of school to into summer (week 11), and from the routines of camp to back-to-school prep (week 18) first appear in training data. Because these changepoints are separated by five weeks, models using five weeks or more of training data will include one of these aberrant weeks.

Lastly, despite poor performance at test weeks twelve and eighteen across the variations in size of the sliding window, performance makes a sharp turnaround in weeks thirteen and nineteen. This suggests that the model is able to make correct predictions with only one week’s data from the new routine, adding support to the belief that a deployed model could recover quickly and again provide useful data even after facing changes in routine.

5.4 Model 3: Forgetting Children

In this section, we explore the feasibility of a system that can predict when a parent will forget to pick a child up from an activity at an agreed-upon time, using only GPS trace information for family members. The fear of being late and forgetting a child is a constant source of stress and anxiety for dual-income families (Beech et al. 2004) (Davidoff et al. 2006) (Frissen 2000). Such a prediction system could create a new kind of safety net, reducing anxiety and increasing feelings of safety.

5.4.1 Modeling Forgotten Children

Forgetting is an ambiguous term. It can mean that a parent never goes to get a child, or that a parent failed to remember at the appropriate time and thus began the pick-up task later than expected. Relying on GPS for all our information, we develop a time- and place-centric definition of forgetting. We say that a parent wants to arrive at an ideal time, tideal. We say a parent forgets a pick-up when their actual arrival time, t0, is more than ten minutes after tideal (we defer the explanation for the choice of the 10 minute threshold to the discussion). From within the set of 1562 sensed rides, we apply this rule to the 813 pick-ups, and identify 83 instances of parents forgetting pick-ups.

Building upon our earlier driver prediction model, and relying on our GPS data set, we designate the following features to help us detect these incidents of forgetting:

Name	*Meaning*	*Values*
R	Whether the parent remembers	True, False
J	Driver prediction model	Mom, Dad
T	If the parent is traveling	True, False
λ	Empirical cumulative distribution(ecdf) of on-time arrivals to L_{child} at time $T_{now}T_{ideal}$	[0,1]
L_{child}	Location of the child	Place ID
L_{start}	Starting location of a parent	Place ID
L_{curr}	Ending location of a parent	Place ID
D	Destination of a parent	Place ID

Table 5.4. Feature vector for forgetting rides.

We assemble these features into a Bayesian Network (see Figure 5.6). The Bayesian network captures the complex dependencies shared by coordinating parents. Here, we use the term dependency as used in probability theory to mean the outcome of an event makes its dependent event more or less likely. It can be read as influences. Each side of the symmetrical model represents the state of one parent (Mom on the left, Dad on the right). Mutual dependencies are represented at the crossover nodes in the graph's center. For example, the location of each parent depends on (is influenced by) the location of the child, Lchild, and whose job the pick-up is, J.

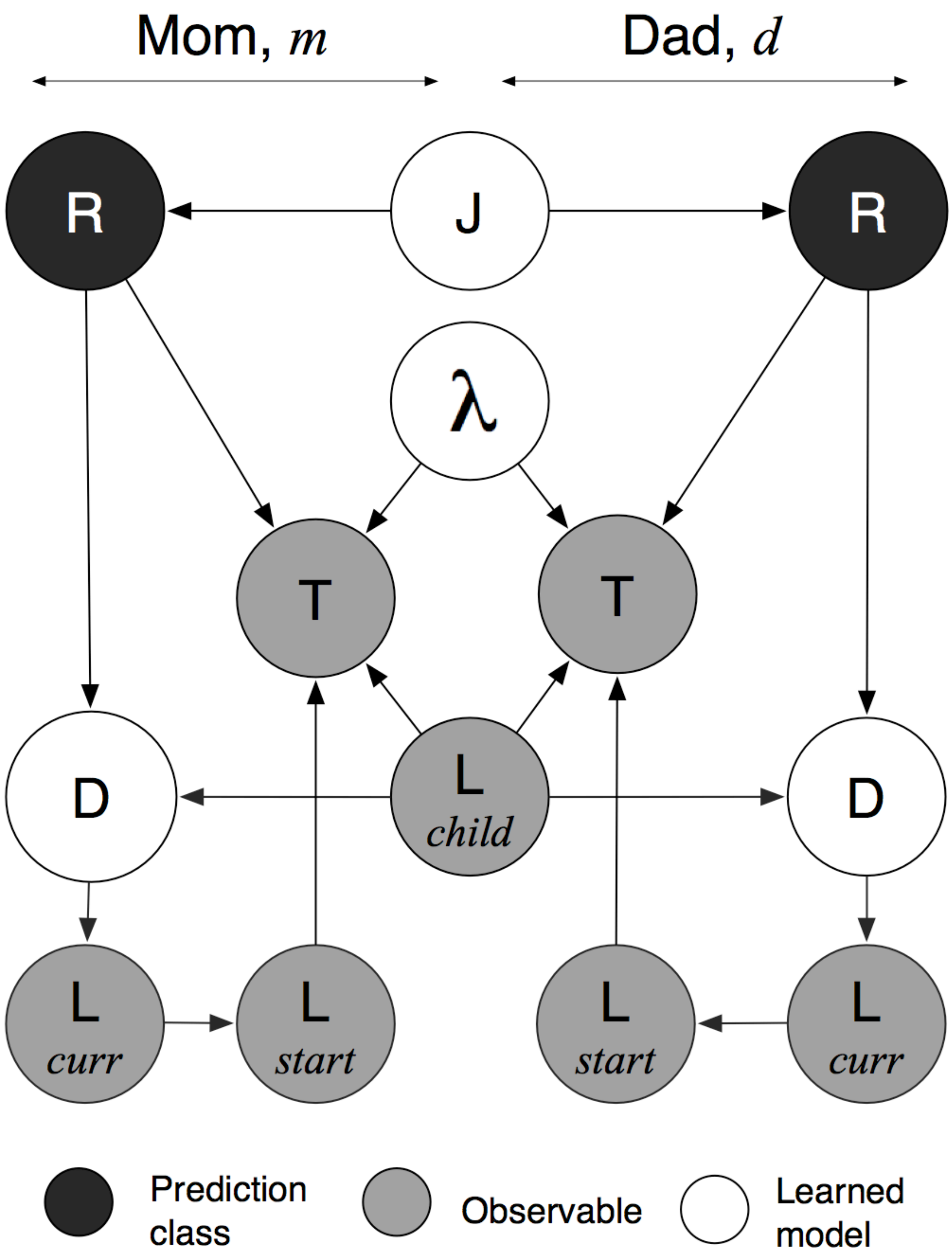


Figure 5.6. A Bayesian Network used to predict if a parent remembers to make a pick-up. Each side of the symmetrical model represents the state of one parent. At each point in time the model makes two predictions: (1) does the parent who drives remember the pick-up; and (2) does the other parent not remember the pick-up.

Other dependencies are mirrored for each parent. For example, according to the model, whether or not a parent is traveling, T, depends on their location, Lstart, the location of the child, Lchild, how often they have been late in the past, λ, and if they remember the pick-up, R. The model also shows that a parent's destination, D, depends on the location of their child, Lchild, their current location, Lcurrent, and if they remember the pick-up, R. The driver prediction model appears in the network as node J, predicting which parent has the job to make the pick-up. We can see that according to the network, if a parent remembers the pick-up, R depends on whether or not the pick-up is their job, J.

Starting 30 minutes before every late pick-up, we ask the network to make two predictions. First, we see if the non-driver is not going to be late. Second, we look to see if the driver is going to be late. We repeat these calculations at each minute until the actual time of the late pick-up, and see how early we can make the correct predictions.

We use the properties of the network structure to derive the formulas that will provide us the prediction values. To see if Dad remembers, we calculate the posterior probability Rdad, and then repeat the calculation for Mom.

$$P(R_d \mid L^d_{start}, L^m_{start}, L^d_{curr}, L^m_{curr}, L_{child}, T_d, T_m, \phi) \qquad 5.7$$

5.4.2 Performance of the Forgotten Child Model

Using four weeks of training data for the driver prediction model, J, we first determine that the optimal amount of training data for the remaining learned nodes – λ, and D – is ten weeks. We use the Maximum Entropy Inverse Optimal Control algorithm (Ziebart et al. 2008) to compute D, destination, and starting thirty minutes before each forgotten pick-up, compute values for Rmom and Rdad at one-minute intervals, until we arrive at tideal+10, ten minutes after the ideal pick-up time, when the parent is late (by our definition).

Given the unequal distribution of forgotten pick-ups (83 examples of forgotten children out of 1562 sensed rides – majority of these are parents arriving late but some are instances of parents actually forgetting their children), a model based on no data, but that simply always predicted on-time arrival would be right 0.885 of the time. Evaluation using precision and recall would output high values, but would lack a way to distinguish how much of that number comes from the excellence of the model, and how much simply from the sheer number of negative examples.

As an alternative, we evaluate the model using a technique from signal processing (Roberts 1959 called the receiver operating characteristic (ROC), which is a more conservative measure of performance (Fogarty, Baker & Hudson 2005). Figure 5.7 shows two ROC plots. For each plot, the y-axis shows correct predictions, and the x-axis shows incorrect predictions. The points inside each square represent different ratios of correct predictions to incorrect predictions. Points along the diagonals mean the ratio is even, and the model is performing no better than a coin flip – for every one correct prediction, there is one incorrect prediction. The upper left corner is perfection, with all correct predictions and no mistakes.

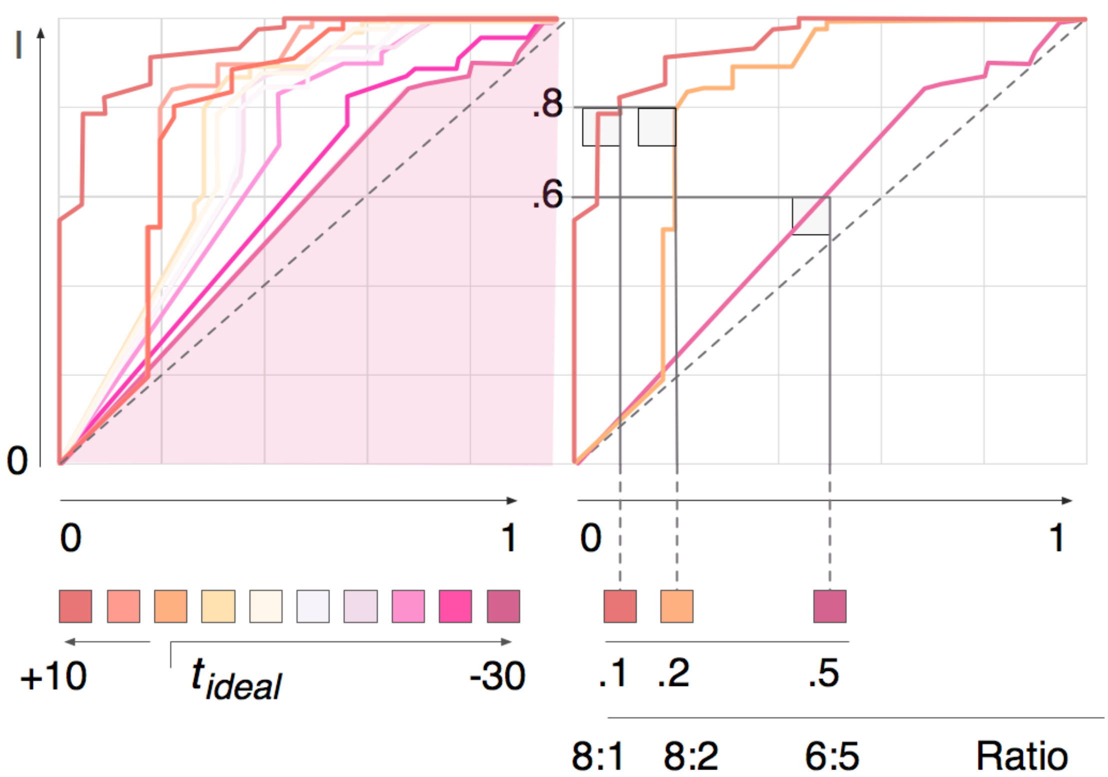


Figure 5.7. Forgotten child model performance. At left, ROC curves show performance improving from 0.640 at tideal-30 to 0.826 at tideal+10. At right, the values demonstrate the relationship between right and wrong guesses.

We can use this property of ROC curves to visualize how a notification system would balance the desire of the parent to never miss a pick-up, against the cost of sending wrong information (e.g., an unnecessary reminder). For any given number of correct predictions, an ROC curve indicates how many incorrect predictions the model will also produce. At tideal-30 (Figure 5.7, right, dark pink line), for every 6 correct predictions the model makes 5 incorrect predictions. When viewed as percentages, every rate of accurate predictions between 0 and 1 has a corresponding rate of inaccurate predictions between 0 and 1, producing a smooth curve. If we continue to follow this curve up and to the right, we can see that the ratio improves little. At tideal (light orange line), for every 8 correct predictions the model makes 2 incorrect predictions. At tideal+10 (dark orange line) for every 8 correct predictions the model makes only 1 incorrect prediction.

We can also measure the area beneath an ROC curve to describe a model's cumulative performance across all confidence values. At thirty minutes before tideal, the area under the ROC curve is 0.649 (Figure 5.7, pink area). The performance gradually rises as the pick-up time approaches, and is highest tideal+10, at 0.826.

5.5 Discussion

This paper describes a successful initial demonstration of the feasibility of our approach to the sensing and modeling of pick-ups and drop-offs, and hopes to spur investigation of routine as a versatile and enabling abstraction. In this section, we discuss possible directions, and identify ways to continue towards optimal performance.

5.5.1 Explanation of Results

As a broad reaching proof-of-concept, this work required many simplifications. In this section we discuss their impact, and extensions to the work as a whole.

Building on the ride model

Our ride detection model provides ample evidence that the large scale detection of rides is within reach. Still, across all families, the model overlooks about ten percent of rides (false negatives), and makes incorrect detections (false positives) around ten percent of the time. Because our hierarchical approach to modeling means that errors in ride detection propagate to downstream models, causing further errors, improvements in ride detection will pay threefold, helping to improve driver and forgotten child prediction as well.

A variety of ways exist to improve upon our ride detection. Because we sample GPS only once per minute, pick-ups, or examples of co-location that happen on a faster time scale are simply missed. In our fieldwork, we observed busy families carrying out pick-ups and drop-offs below this detection threshold. An intelligent approach to sampling would increase rates during times when data collection would be more valuable (i.e., when a person is moving), and lower the sampling rate during periods of stasis, avoiding battery depletion. This approach would require the integration of other low-level sensors into the model (e.g., accelerometer, noise or light). The addition of Bluetooth could also improve co-location and co-travel accuracy by providing additional proximity cues to the model.

Missed rides are also caused by the model's simple ride representation. We defined travel in terms of one parent, one child and one car. The model has no representation of other modes of transport, causing it to miss common activities like walking, riding bicycles, and taking the bus. For simplicity we limited our observations to the nuclear family, but in reality families plan and coordinate with their extended families, friends and carpoolers, all whom were outside the scope of this investigation. The model also requires that activities occur while people are at a location. Activities like paper routes, however, occur over a wide area that contains home, neighbors, and schools, making it appear to the model as an unusual occurrence of travel.

Building on the driver prediction model

The driver prediction model learns parental responsibilities at more than 70% accuracy with only one week of training data, and about 85% accuracy with four weeks of training data. These are satisfactory numbers when seen as a technical problem. A deployed system, however, will face unknown scrutiny from coordinating parents during stressful times. Even small errors may deter adoption, encouraging examination of ways to achieve better results with less training.

While we explored a general-purpose algorithm for use across all families, we know that there is great variation in the ways families plan, coordinate and improvise. Even within families, as children grow, parents age, interests, even entire geographies, evolve. Exploration remains to find algorithms both for family style, and for attending to and integrating to the inevitable changes.

The driver prediction model also showed a remarkable potential for detecting large-scale transitions in routine. Because families experience the most stress during times of large-scale routine change, an algorithm tuned to this class of events could effectively function as a seasonal boundary detector, offering an index of routineness to other models providing services to families, helping the driver prediction model identify seasonal boundaries in training data and achieve better learning faster.

Building on the forgotten child model

As the forgotten child model is venturing into new territory, precise assessment of its performance would be premature. ROC analysis showed that the model has about sixty percent accuracy at thirty minutes before a parent forgets a child. With about twenty actual incidents of forgetting children per family, this would equate to forty alerts over six months, or about 1.5 per week. Given the stress caused by forgetting a child, would this number of alerts constitute an annoyance, or prompt a parent to take a moment and double-check their plan and their assumptions?

This question is further complicated by the question of information delivery. It is unknown how early a forgotten pick-up needs to be detected in order to be of use. A message that comes too late to enable a parent to arrive on time might be marginally helpful, but the real goal is to make this detection early enough to ensure prevention of the event.

Improved models will also need to address the temporal complexity of coordinating parents. In some families, ten minutes late might be considered on time. In others, it might constitute abandonment. A range might more faithfully represent an ideal time than any particular minute. Also, if a parent plans to be late, then their late arrival time is their ideal time, and not the one the model assumes.

5.5.2 Applications of models of routine

The haphazard introduction of learning systems into the home has been a subject of concern to researchers, to whom learning represents a possible mechanism for taking control away from families. Ultimately, we distinguish a belief that aspects of family life can be modeled from the belief that family life should be automated. We advocate a measured approach where intelligence is applied in such a way that it does not take on the role of parent and does not conflict with the social structure within the family. Our work does not focus on optimizing the work of families in order to allow an ever-increasing number of activities to be performed. Instead, our intention is to help family members more elegantly and effortlessly perform their role within the family by providing the resources they need to better understand what they do and what they plan to do.

The models that are the focus of this paper have direct application across all aspects of family logistics. Models of routine can directly support family planning. If the calendar is largely devoid of routine information, and that absence leads directly to errors in making plans, then this paper shows how machines can learn some of that missing information. Models of routine can directly support family coordination. Ambient display systems – even location systems – could display sensed pick-ups and drop-offs, helping parents stay informed about unfolding plans, and more aware of plans that could need adjustment. Finally, models of routine can directly support family improvisation. When parents make the rare but critical errors that lead to forgotten children, the ability to respond earlier – or even to avoid the situation together – creates a new kind of protection.

5.6 Summary

In this chapter, we demonstrated that dual-income family transportation routines can be sensed and modeled without any supervision using the GPS available on commodity mobile phones. Towards that end, we gathered a large data set of family location, and of pick-ups and drop-offs. Using simple heuristics and statistical models, we demonstrated that pick-ups and drop-offs can be sensed, and their drivers predicted. We also demonstrated a model that can predict when parents are going to forget to pick-up their children at activities before these damaging events happen.

We provided examples of how learned models of family routines can function as an enabling technology. We described how they could be added to digital calendars to help families make better plans, to reminder systems and to location systems to help families coordinate on routine days, and to function as a safety net, helping observe and prevent incidents where children are forgotten at their activities.

We intend this work to stimulate discussion around the broad applicability of routine as an enabling abstraction. Considering our choice of exploration over optimization, a significant amount of the modeling space remains open to investigation. Additionally, our introduction of a new kind of probabilistic information to the calendar opens a significant space to explore how we can visualize and interact with this kind of data.

Chapter 6. Validation

6.1 Introduction

Early chapters in this document argued that the purposeful, targeted documentation of transportation routines would support families when they experience coordination problems. The previous chapter demonstrated that documentation of routines could be generated without (human) supervision, using only the GPS available in commercial mobile phones. This chapter closes the hypothetical loop and proves that families find the documentation of routines to be desirable, and valuable, and that it helps them feel more in control of their lives.

We describe two laboratory studies that present families with documentation of their routines during simulated routine tasks. First, we simulate familiar coordination settings across a group of families – like to make an orthodontist appointment, or to change which parent will make a pick-up – and provide them with an application that visualizes their documented routines. Second, we simulate familiar coordination settings using the family's own data. The first study shows that families can interpret, and desire the capabilities of a routine documentation system. The second study shows that families find the same information useful when it contains the real complexity of the family's own life needs.

We deliver the new documented routines in using a compact new visual form that we call the Family Time-Flow (FTF). The FTF combines where parents and children are, and what responsibilities each parent will complete. It creates a shared visual representation of the current and future states of family logistics.

The studies do not require that the information about routines be sensed or learned. In fact, it may be that this information is not documented merely because there is no lightweight, portable way to document them currently. Regardless if the information is learned or input by hand, bth studies provide compelling narrative and questionnaire-basd evidence that support the main thesis of this document: **routines do prove a powerful resource for coordination. Documentation of routines help families feel in control of their lives.**

Parents report that the new visualization is intelligible. They also describe that the new calendaring system allows them to have a more complete view of their entire plan than they currently have. This wider perspective, they continue, helps them visualize a variety of alternative solutions to planning problems, and see potential problems in plans at their point of creation. This change in perspective allows family members to gain an accurate overall description of the plan. Family members report they can make better decisions when adding events, when changing plans; this also creates a way to foreground potential conflicts, and, ensures communication and confirmation of situated decision-making during improvisation.

6.2 Design of the Family Time-Flow

Previous chapters identify the content that the FTF needs to provide. That information includes coverage of the entire family – their whereabouts, availability, the equipment they have, and what responsibilities they intend to complete. This view will need to encode the geospatial, and temporal movement of various individuals. It will also need to visually distinguish events like pick-ups, drop-offs, and claimed and unclaimed responsibilities.

6.2.1 Design exploration

Visual design began with an exploration of 61 comparable representations of temporal and spatial data across industries from aircraft maintenance to film production logs, helping to identify common practices and tradeoffs (see Appendix A for the study report). This exploration also included individual and shared organizing systems, both digital and on paper. Faced with the need to trace the paths of multiple individuals on a small screen, early explorations encode time along the vertical axis, and explore a focus plus context approach towards exploring the visualization.

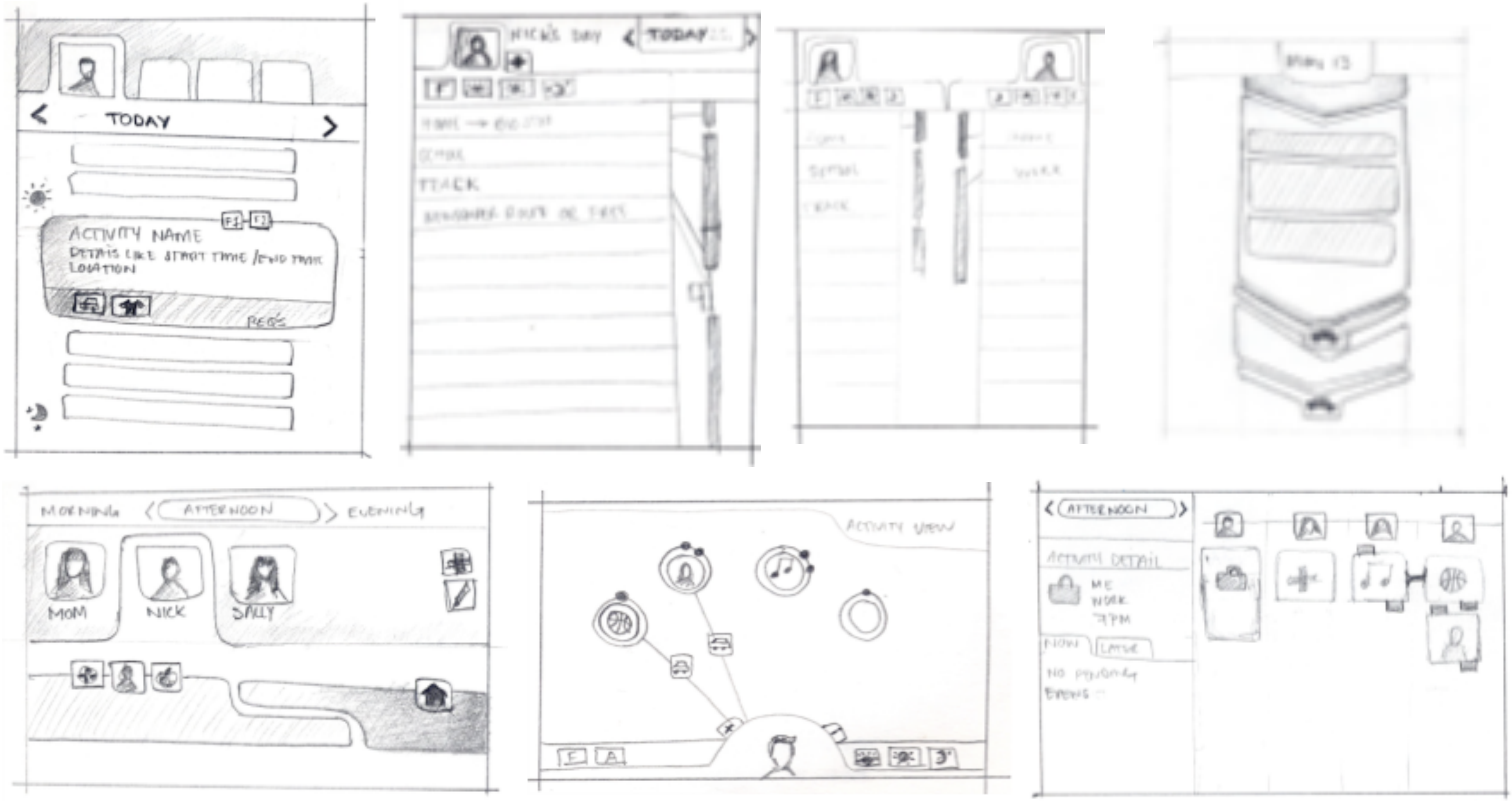


Figure 6.1. Early paper-based sketches of the FTF, which encode time along the vertical axis, and explore a fish-eye lens approach towards encoding the information for a small screen size.

Electing to encode place and time as the top-level primitives, and individuals as color traces, a design emerged with the flexibility to represent the movement of multiple individuals (see Figure 6.2). The most critical advance came through decoupling the physical location with the name of the place for each row. In other words, once the ordering of the place rows did not need to correspond to physical geography, the representations were able to maintain a compactness that was unavailable previously.

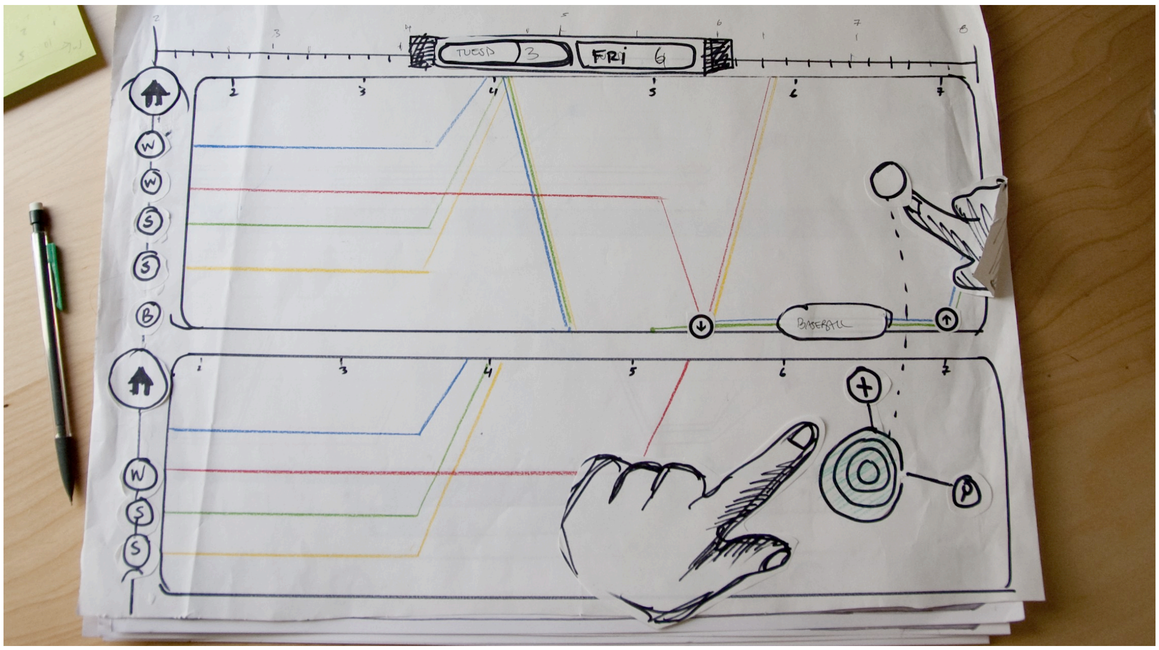


Figure 6.2. The first breakthrough in FTF prototyping came in breaking the mapping between the geo-spatial relationship of places and their location on the y-axis. This allowed for a compact representation.

6.2.2 FTF visual vocabulary

Because of the amount of information encoded in the FTF, its purpose is best explained through example. In the following section, we describe how the visualization transforms learned models into a legible diagram in three steps.

First, in the FTF, each row represents a different place the family goes (see Figure 6.3, left). Colors represent the location of individual family members. In the example, Dad is green, and D7 is pink. Time is on the horizontal axis. When a colored line is horizontal, a person is at a particular place. In the example, Dad, is home from 2:30pm to 5pm. Thicker horizontal bands represent specific scheduled events. In the example, we can see that the D7 is at school from 2:30pm to 4pm. She has Band practice from 3pm to 4pm. Diagonal lines indicate travel between places. The slope of the line indicates the speed of the journey. In the example, D7 takes the bus home from school at 4pm, and arrives home at 4:30pm. She is then home from 4:30pm until 5pm. To, follow an individual through their day, just trace the line of that color across the diagram from left to right.

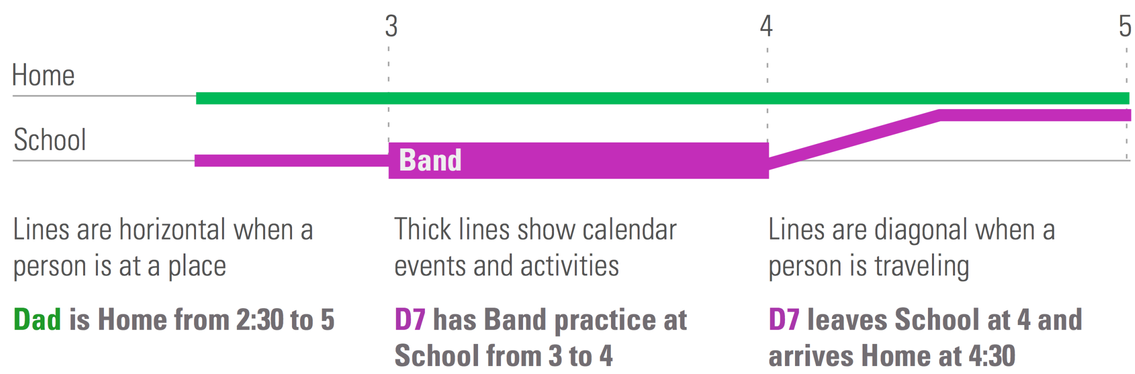


Figure 6.3. In the basic symbology of the FTF, colors are people and the x-axis is time. A colored horizontal line means a person is at a place. A diagonal line means they are traveling between places. A thick horizontal line means a schedule event is happening at a particular place

Second, one of the main tasks of the FTF is to draw attention to the transportation of children, we use dedicated symbols indicate situations when parents drive children between places. An upwards-pointing arrow shows that a child has been picked up, the downward-pointing arrow shows that a child has been dropped off (see Figure 6.4, middle). The location of the arrow (as a row) indicates where the child was picked up or dropped off. Co-travel, when parents drive children from one place to another, is inter-connecting dots along a diagonal. Color also indicates the participants in pick-ups, drop-offs, and co-travel. The outside color of a circle indicates which parent is driving. The inside color indicates which child(ren) are passengers. In our example (see Figure 6.4, middle), at 3pm, Dad picks up D7 at home and drops her off at school at 4pm.

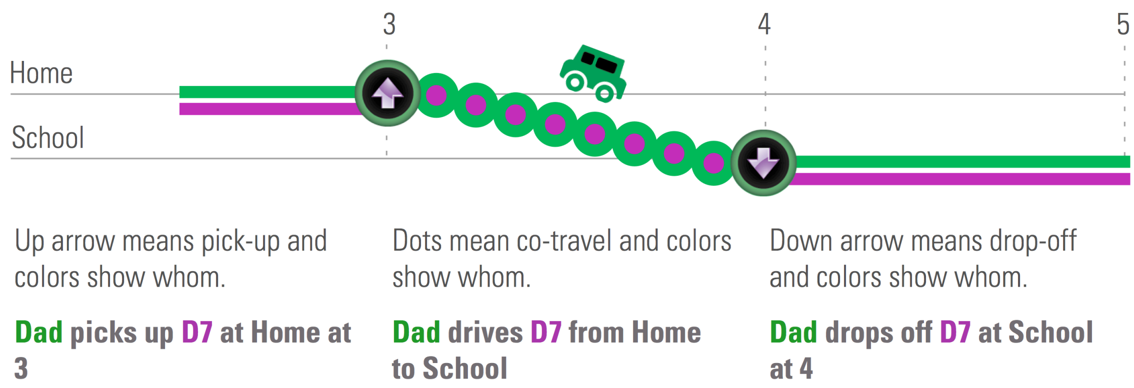


Figure 6.4. Special symbols indicate when parents give children rides. The up and down arrows indicate the location of pick-ups and drop-offs, and the diagonal dots indicate co-travel, or travel with parents and children together.

Third, the FTF can express the uncertainty and flexibility families use to express their real-world plans and routines (Frissen 2000) (Colbert 2002) (Ito & Okabe 2005) (Ling & Campbell 2009). While opaque colored lines indicate that a person is or will be at a location, transparent colored lines mean a person might be at a place. In the example (see Figure 6.5), D7 officially has Band practice from 3pm to 4pm, but D7 sometimes arrives as early as 2:45pm, and sometimes stays as late as 4:15pm. The FTF encodes this flexibility by extending the thick colored line that represents Band practice between using a transparent box, bounded with dotted lines.

The FTF can also encode the uncertainty in a plan. In the example (see Figure 6.5, right), because Dad knows that D7 sometimes stays after Band practice, he does not usually leave at a fixed time. Instead, Dad can leave any time from 3:45 to 4:15pm. Instead of a single line to indicate travel, a transparent box is used instead, representing the range of times over which travel could occur. If Dad leaves at 3:45 he will probably arrive at 4pm. If Dad leaves at 4pm, he probably will arrive at 4:15pm. He also could leave and arrive at any time in that given range. Dad does not always leave before 4pm. If Dad leaves home after 4pm, he will probably arrive after 4:15pm, and D7 will probably have to wait for him. The red circle indicates the latest Dad can depart without D7 having to wait. We can see that Dad sometimes does leave between 4 and 4:15pm, arriving between 4:15 and 4:30pm. These journeys are also shown with transparency, but the color is changed from Dad's green to the orange of warning. Orange is used to indicate plans that could happen but that probably will result in lateness.

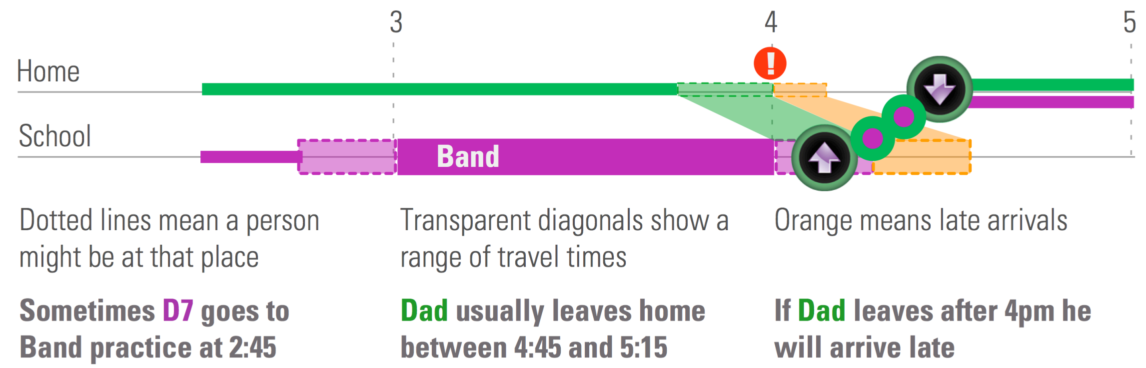


Figure 6.5. The FTF encodes ambiguity as transparency. Band practice sometimes starts early and ends late. Dad leaves to pick up D7 any time from 3:45pm to 4:15pm, leaving a transparent polygon between Home and School. Orange indicates a time range that will lead to late outcomes.

6.2.3 How the FTF expresses real-world complexity

With this basic visual vocabulary, we can now describe how the FTF can encode the plan for an entire family for over an entire day. We first describe a deterministic example, and then one that includes more real-life uncertainty.

The first example, Figure 6.6, shows representative scenario that we drew from fieldwork. It does not show the situation of any particular family, but rather information that you would find across many families. The family includes two children D7 (pink) and S11 (blue), and two parents, Mom (yellow) and Dad (green). On this day, each child participate in one activity, and the two parents sharing driving responsibilities.

The FTF illustrates the family's plan between 3pm and 8pm. To follow Mom's day, we trace her path from left to right across the diagram. Mom plans to leave work at 3:45pm, arriving home at 4pm. At 4:30pm, Mom drives D7 to swimming, drops her off, and then returns home. Later that evening, at 6pm, Mom leaves home to pick up her son from Rock Band practice at school. The two of them drive home together. Dad stays at work until about 4:15, and plans to arrive home at 5pm. At 5:30, Dad drives to swimming, and picks up D7 at 6pm. The two of them drive home after swim practice.

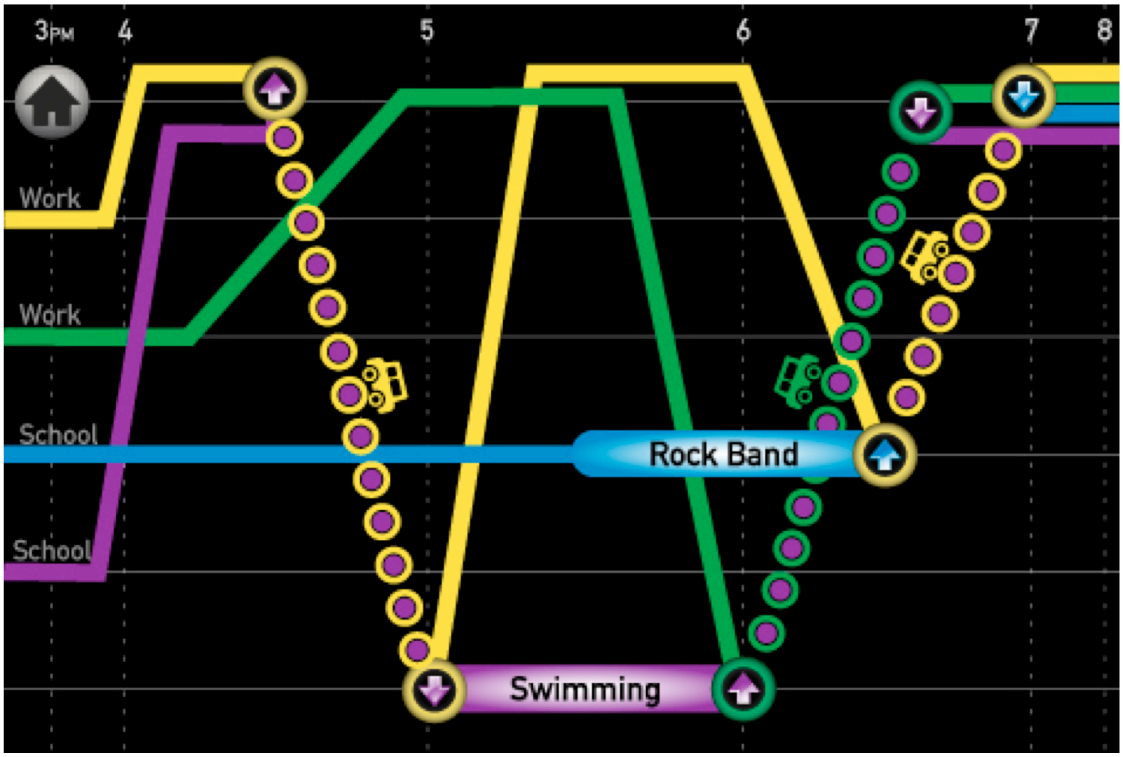


Figure 6.6. The thick horizontal bands make it easy to glance at the FTF and see which children need to be picked up, and where they are, and which parent has the responsibility for each pick-up.

A more complex example, that displays the actual plan from one study family, displays the ambiguity that real plans contain (Fiese et al. 2002) (Davidoff et al. 2006), and allows parallels parents' real-world practice of clarifying plans when necessary but not sooner.

This plan is made more complex by Mom's off-site visit at work, which is listed on her calendar as 'Group Outing.' The outing is scheduled to end at 5pm, but in the past they have lasted until as late as 5:30pm. S11 has a basketball game at 5:50pm. The FTF makes clear that if Mom leaves any later than 5pm, S11 will be late for his basketball game. Mom sometimes leaves basketball games because she doesn't have any other time to take care other chores. She plans to pick S11 up at 7pm, but because where she will be coming from is unknown. The FTF encodes this ambiguity with a line that fades in from nowhere and arrives at basketball at 7pm. Similarly Dad plans to drop D7 off at Karate at 5pm, and then go shopping. All that can be specified is that Dad plans to pick up D7 from Karate at 6pm. Again, his line is drawn as though appearing from nowhere in particular, but arriving at Karate at 6pm.

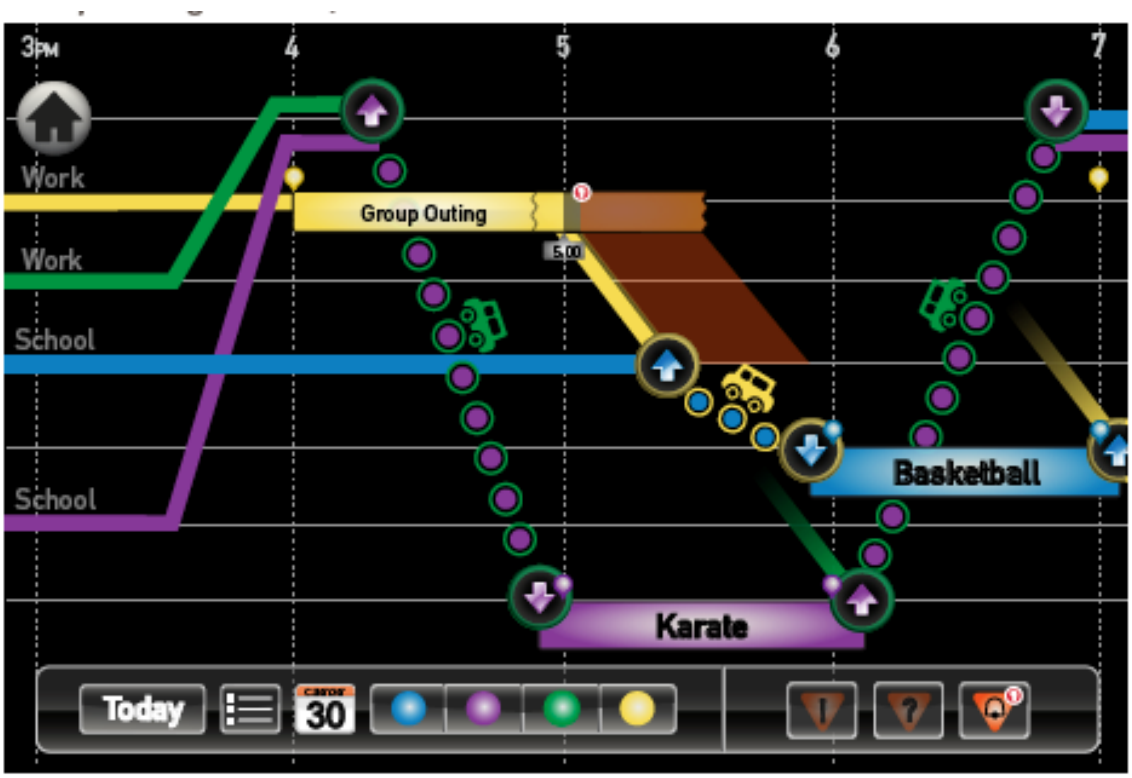


Figure 6.7. The thick horizontal bands make it easy to glance at the FTF and see which children need to be picked up, and where they are, and which parent has the responsibility for each pick-up.

6.3 Approach

With a visualization established that could encode the requisite sophistication and ambiguity, we designed two laboratory studies to demonstrate the efficacy of providing routine information. The studies looked to prove the following hypotheses:

1. Parents can understand the visual representation of their own routines
2. The routine visualization addresses problems that families really experience
3. The routine visualization helps parents solve problems they want solved

We used two steps to make a thorough evaluation of these claims. Each stage relied upon experience prototyping (Burns et al. 1994) (Buchenau & Suri 2000) with dual-income parents to answer these questions.

First, we asked parents to play their own role in a fictitious family, and simulated familiar situations where they would have to plan or coordinate. This first study principally looked to make sure that family members could understand the visual representation. Second, we used the FTF to document real family routines, and asked parent to troubleshoot real events that happened to them.

6.3.1 Study 1 Protocol

While presenting parents with stories, places and activities from their own lives would elicit a more realistic response to the tool and situation, our first goal was to evaluate if parents can make sense of a potentially radical visual departure from their current calendaring tools. We created a persona family, with two children involved in a variety of activities, and asked the parents to play the role of parent to the persona family. We carefully articulated a normal week for the family down to the minute, and expressed the events to the family through the FTF. We then asked parents to particulate in four role-playing scenarios. In each scenario, we asked parents to respond to changes in their intended plans using the tool.

We asked parents to think aloud while they used the tool, and engaged them in semi-structured interviews after each scenario. After the study, we asked parents to complete the TAM-3 survey, the most modern version of the Technology Acceptance Model (Davis 1989).

		Mobile	Large Display
	Setting	Office	Kitchen
1	Stimulus	Late meeting	Child is sick
	Task	Rearrange carpool	Rearrange entire day
	Setting	Orthodontist's office	Kitchen
2	Stimulus	Prompt from nurse	Call from orthodontist
	Task	Make appointment	Reschedule appointment

Table 6.1. Participants completed four tasks. In the mobile scenario, participants used an i-Phone to access the mobile application. The two large display tasks had the participant interact with a large display in their kitchen, mounted on a simulated refrigerator.

Across ninety minutes, we placed parents in four representative situations, drawn from our family field research, that allowed us to view how parents access different resources and social situations, and tasks which, would place different information needs and access to individuals (see Table 6.1). Two scenarios occurred in a mobile context, and parents were provided with an i-Phone version of the application. Two scenarios occurred at home in the kitchen, and parents were provided with a large screen refrigerator display.

To quickly create the necessary variety of settings, we developed a technique we call picture worlds. Picture worlds are life-sized poster are clipped onto large sheets of foam board, arranged along 3 walls, and used much like a theater's flat sets to create a shallow illusion of 3-D space. A few tangible props complete the illusion. A table on wheels is a dinner table when shown against a kitchen background. When boards are reversed to create a medical waiting room, the table is wheeled into place and used as a desk.

Figure 6.8 outlines participants' basic experience. In Figure 6.8 Scene 1 The participant is presented with the basic facts about their persona family, and then walked through a sample day using the i-Phone applications. Each scenario starts by asking the participant to perform a distraction task to help them assume their role. In Figure 6.8 Scene 2 we see a participant pretending to write a check for a dentist appointment. The confederate just outside the frame to the left is playing the role of the medical secretary. The confederate triggers the stimulus, and asks the participant to respond to the situation. In Figure 2 Scene 3 the confederate uses the mobile FTF application to decide when to schedule a follow-up dentist appointment. In Figure 6.8 Scene 4 we see the participant performing the distraction task in the office, unpacking a box. After receiving a text message, Figure 6.8 Scene 5 shows the participant using the mobile application to reschedule a pick-up. Figure 6.8 Scene 6 shows a participant using the large display application to update the dentist's appointment.

The next paragraphs describe the scenarios and screens presented to parents. We describe the backstory, stimulus and task. For each task, we also present the screens that parents were shows. The participating parent is always shown in yellow. Their spouse is green. The son is blue, and the daughter is magenta.

Task: Mobile 1

It is the job of the participating parent to take their daughter to swimming. The daughter goes home after school, so the parent's job is to go home, pick her up, and then drop her off at swimming (see Figure 6.9). The participating parent moving about their workplace, a factory floor, and receives a call from their spouse. The parent can go over the plan with their spouse using the i-phone application. The spouse has to stay at work late for a meeting. The parent has to adjust their schedules so that the children can still attend their events.

Task: Mobile 2

In task 2, the parents is placed in the office of a busy dentist. They are asked to schedule the next appointment for their son, and are given three choices. Each choice will require the parent reschedule their day. The parent uses the i-phone application to look at their routine schedules for the day in question, and selects the day where they believe the least rescheduling would be required.

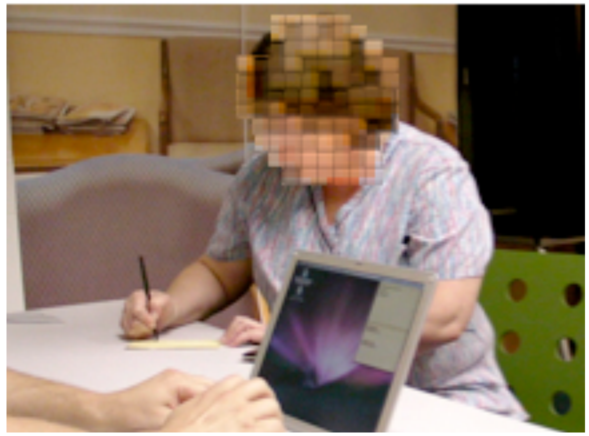
Task: Large Display 1

In task large display 1, the parent is at home cleaning their kitchen. They receive a call from the dentist, asking to reschedule the appointment they just made. The parent has the FTF visible on a large display built into their refrigerator (see Figure 6.11). The large screen shows all three days on the same large screen. The parent is again asked to select a time that they can drive their child to the dentist. Each of the choices the dentist provides conflicts with an event. The parent uses the FTF to think out which day would cause the least trouble making changes.

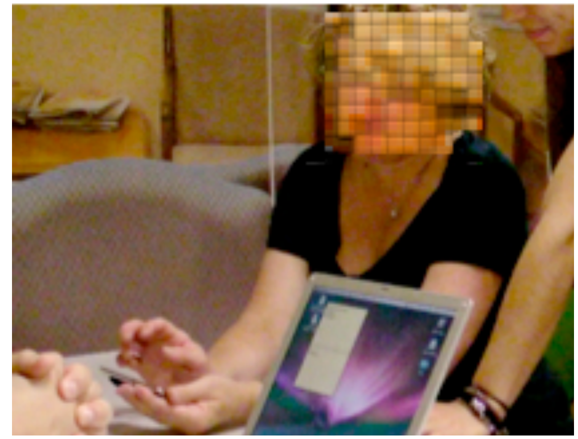
Task: Large Display 2

The parent is told that they have just woken up to find their child sick. Their spouse has an important meeting at work, so it becomes the participants' job to bring the sick child to the doctor, and to rearrange the driving with their spouse so that the other child can attend as many of their normal activities as they can. The parent uses the FTF on the large display in the kitchen (Figure 6.12) to solve the problem situation.

1. Participants are walked through a warm-up task



2. At the orthodontist, parents are asked to complete a payment



3. And use the mobile tool to make an appointment.

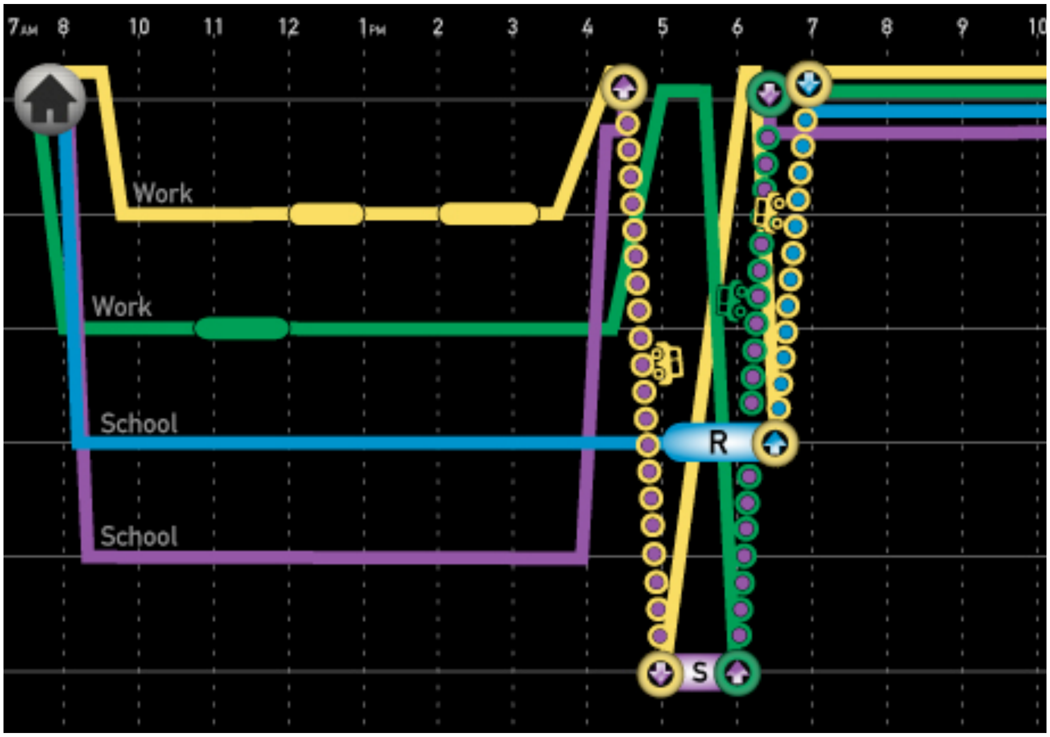
4. In the kitchen, parents are asked to put away dishes…

5. An email arrives asking they reschedule their appointment

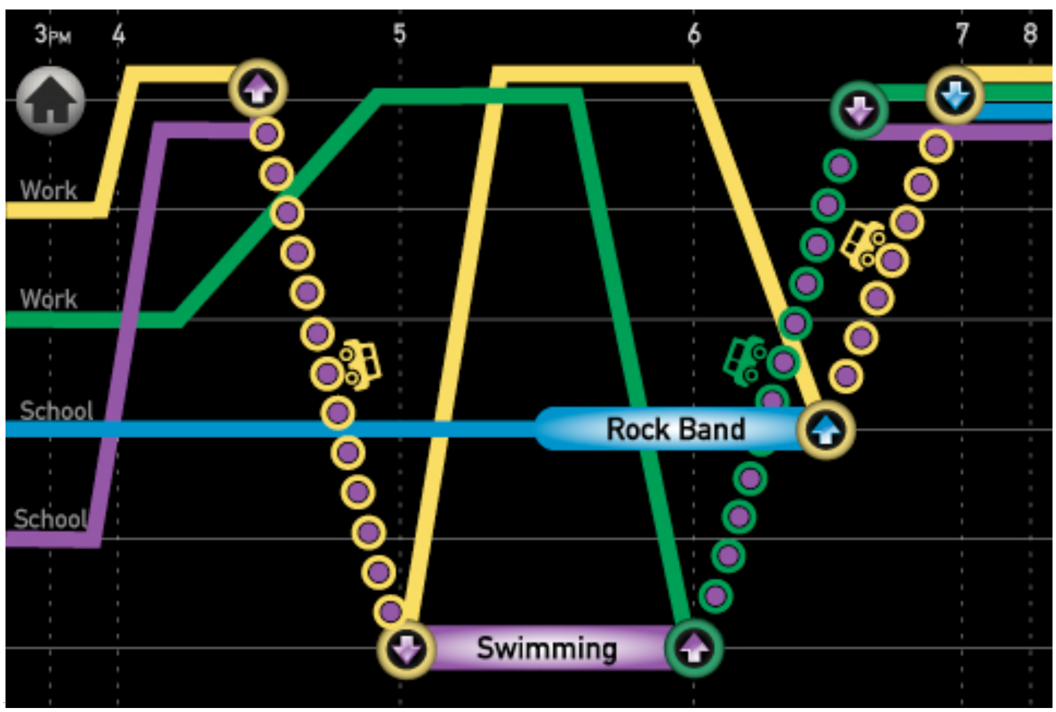
6. Using the large display to inform their decision.

Figure 6.8. Two scenarios showing how parents use the FTF to adapt to their situations. The top row shows a mobile scenario, where the participant is at the doctor's office, using an i-Phone app. The bottom row shows the FTF on a large screen in a simulated kitchen.

Step
1


7AM 8 10 11 12 1PM 2 3 4 5 6 7 8 9 10
Work
Work
School
School
R
S

Step
2


3PM 4 5 6 7 8
Work
Work
School
School
Rock Band
Swimming

Step
3

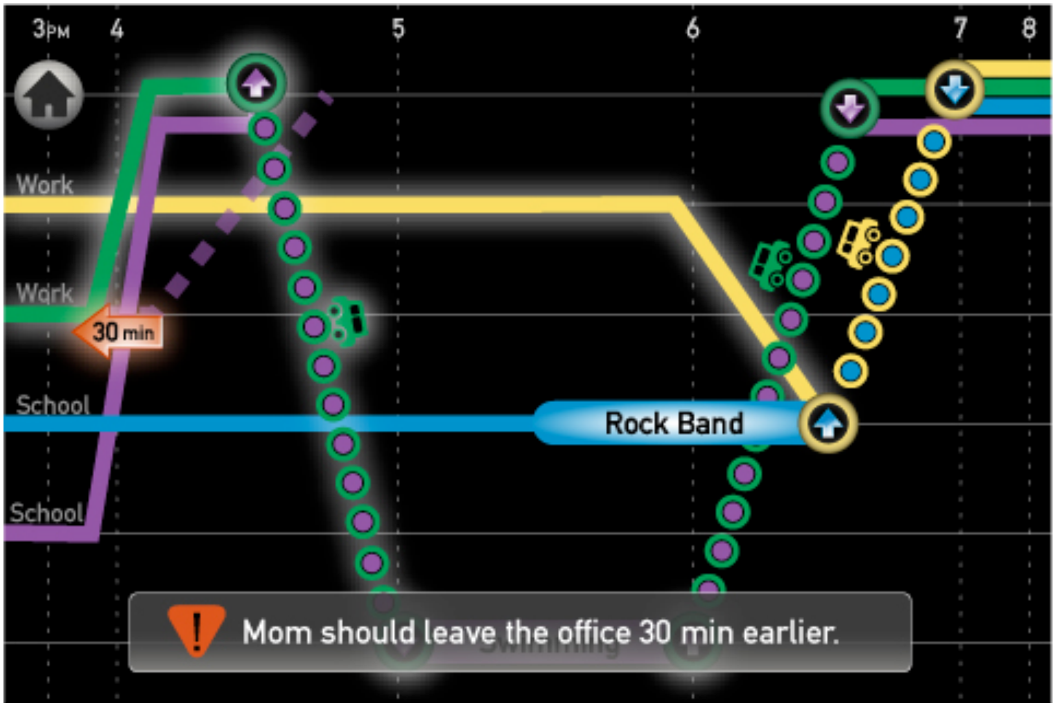
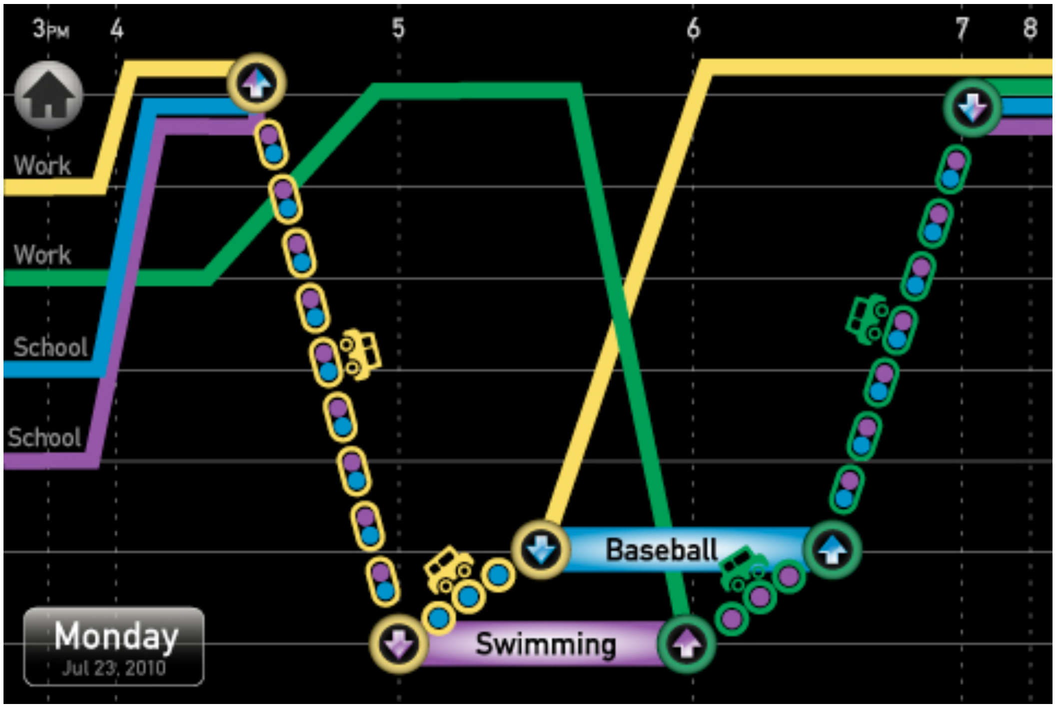
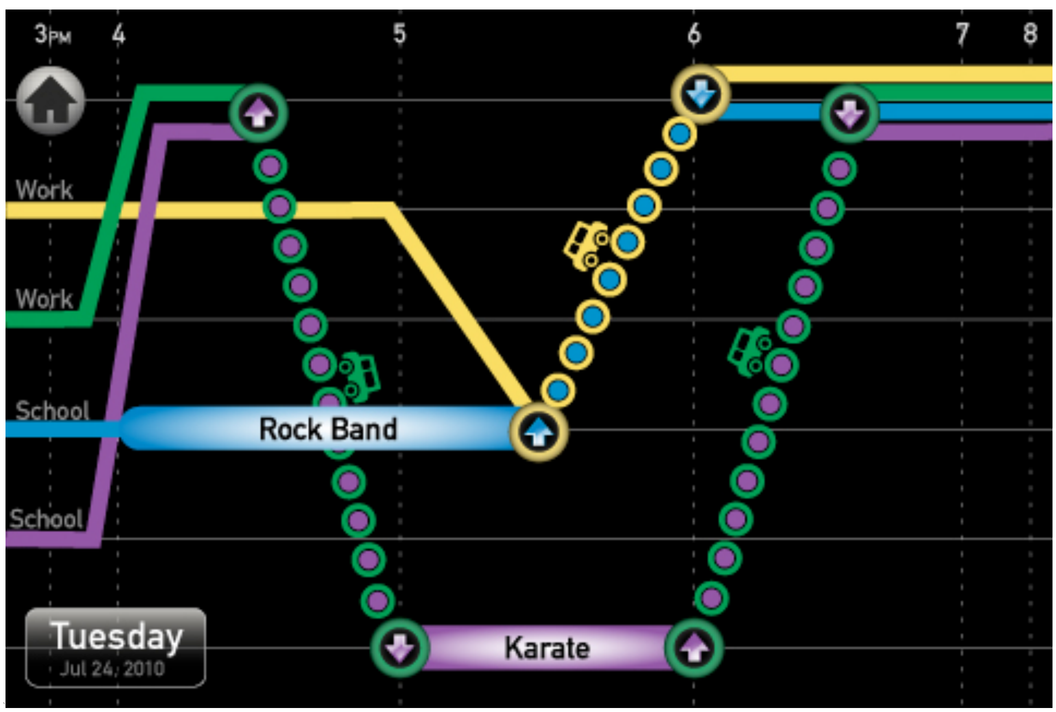


Figure 6.9. Scenario Mobile 1 begins with the parent at their office. After receiving a call from their spouse, the parent uses an i-phone to troubleshoot their plans with their spouse. The application opens to a view across the entire day (Step 1). Zooming in, the participating parent must drive their daughter to swimming (Step 2). Their spouse's late meeting requires they renegotiate the plan. The resolution is shown in Step 3.

Step
1


3PM
4
5
6
7
8
Work
Work
School
School
Baseball
Swimming
Monday
Jul 23, 2010

Step
2


3PM
4
5
6
7
8
Work
Work
School
School
Rock Band
Karate
Tuesday
Jul 24, 2010

Step 3

Step 4

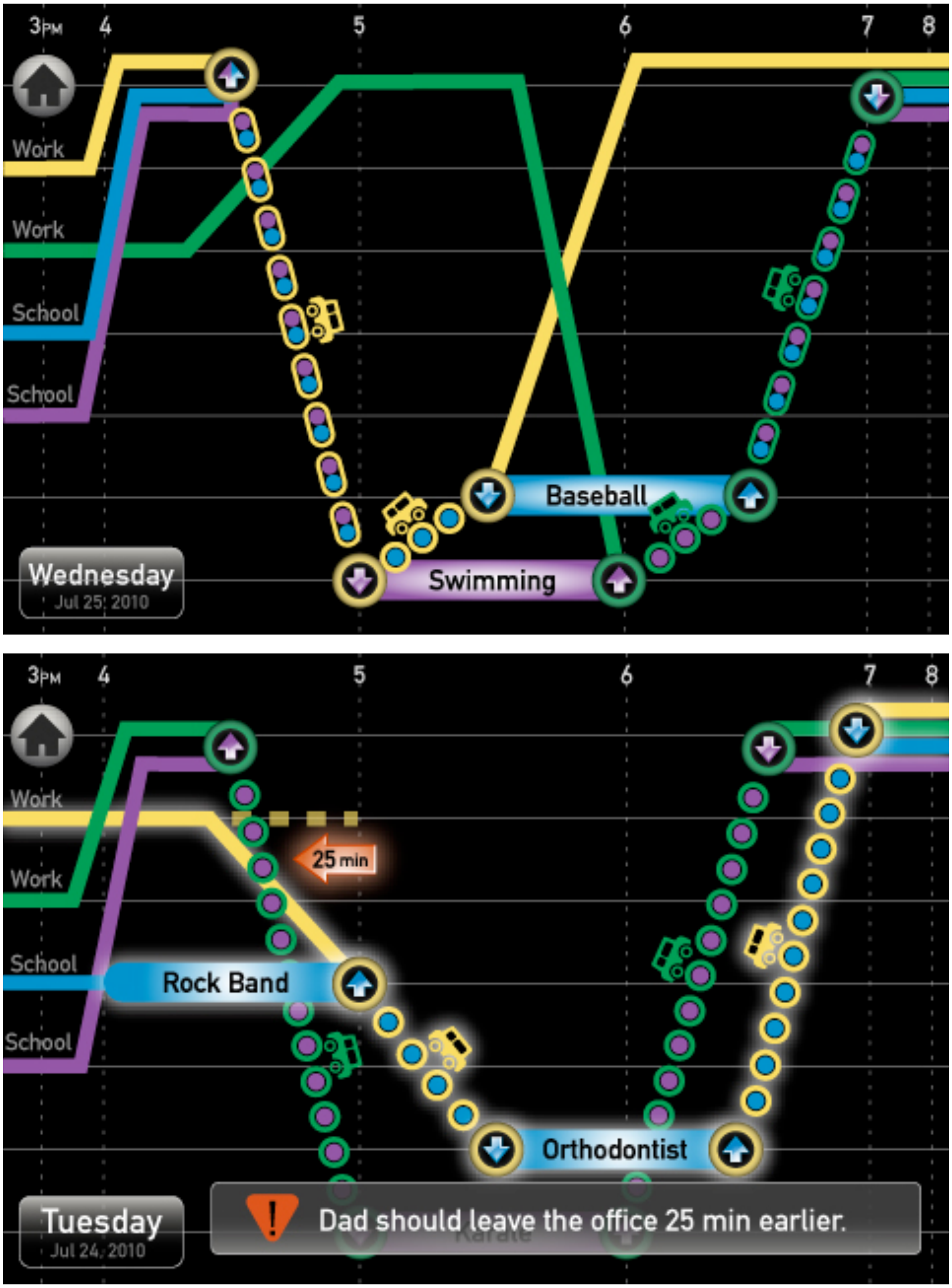
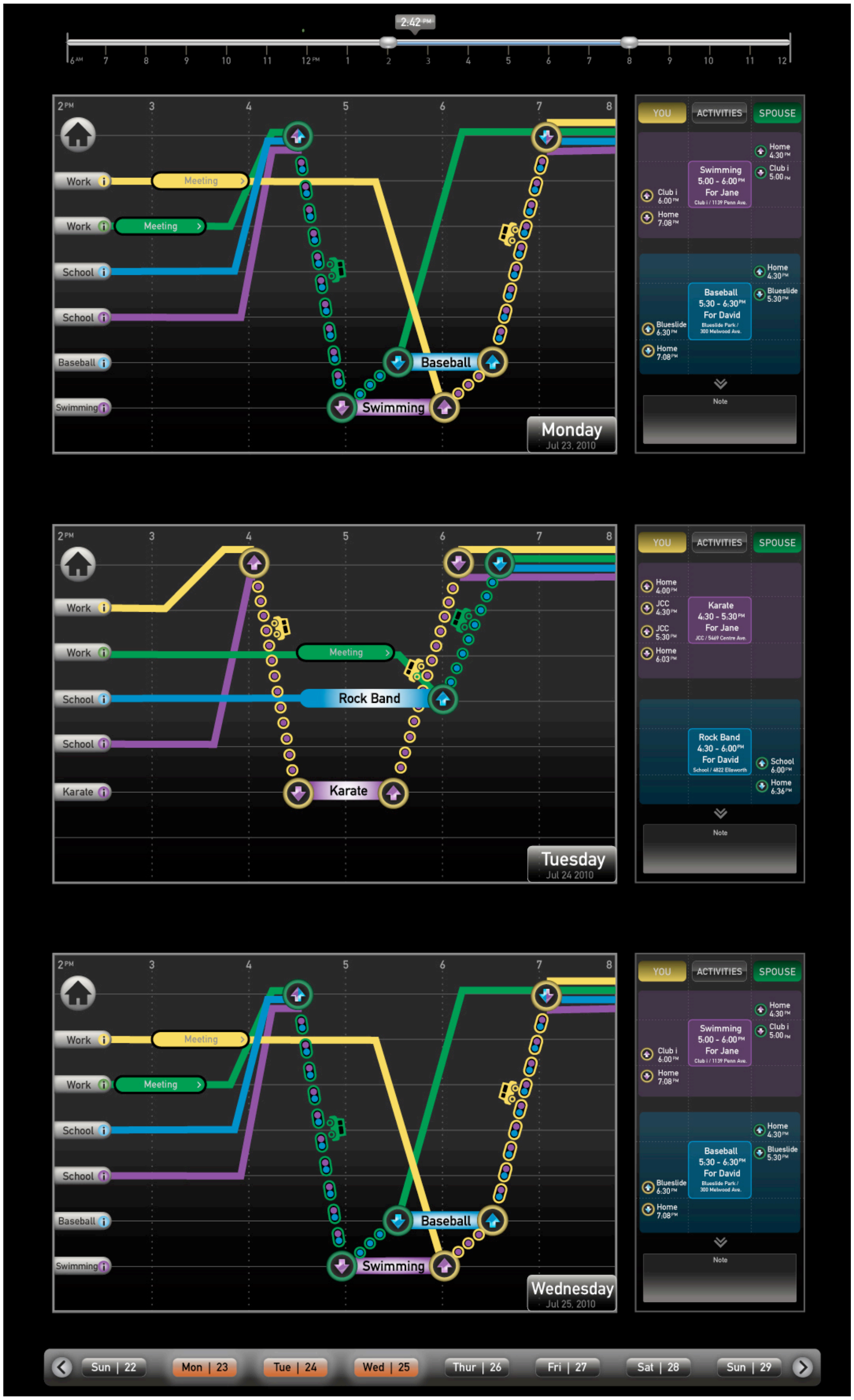


Figure 6.10. Scenario mobile 2 places the parent in an orthodontists' office. They are asked to schedule the next appointment for their son. Each of the options provided by the dentist conflicts with existing plans. The parent uses the FTF to determine which day will require the least radical changes to their overall plan

Step

1



Work
Meeting
Work
Meeting
School
School
Baseball
Swimming
Baseball
Swimming
Monday
Jul 23, 2010
YOU
ACTIVITIES
SPOUSE
Swimming
5:00 - 6:00 PM
For Jane
Baseball
5:30 - 6:30 PM
For David
Note
Work
Work
Meeting
School
Rock Band
School
Karate
Karate
Tuesday
Jul 24 2010
Karate
4:30 - 5:30 PM
For Jane
Rock Band
4:30 - 6:00 PM
For David
Note
Wednesday
Jul 25, 2010
Sun | 22
Mon | 23
Tue | 24
Wed | 25
Thur | 26
Fri | 27
Sat | 28
Sun | 29

Step

2

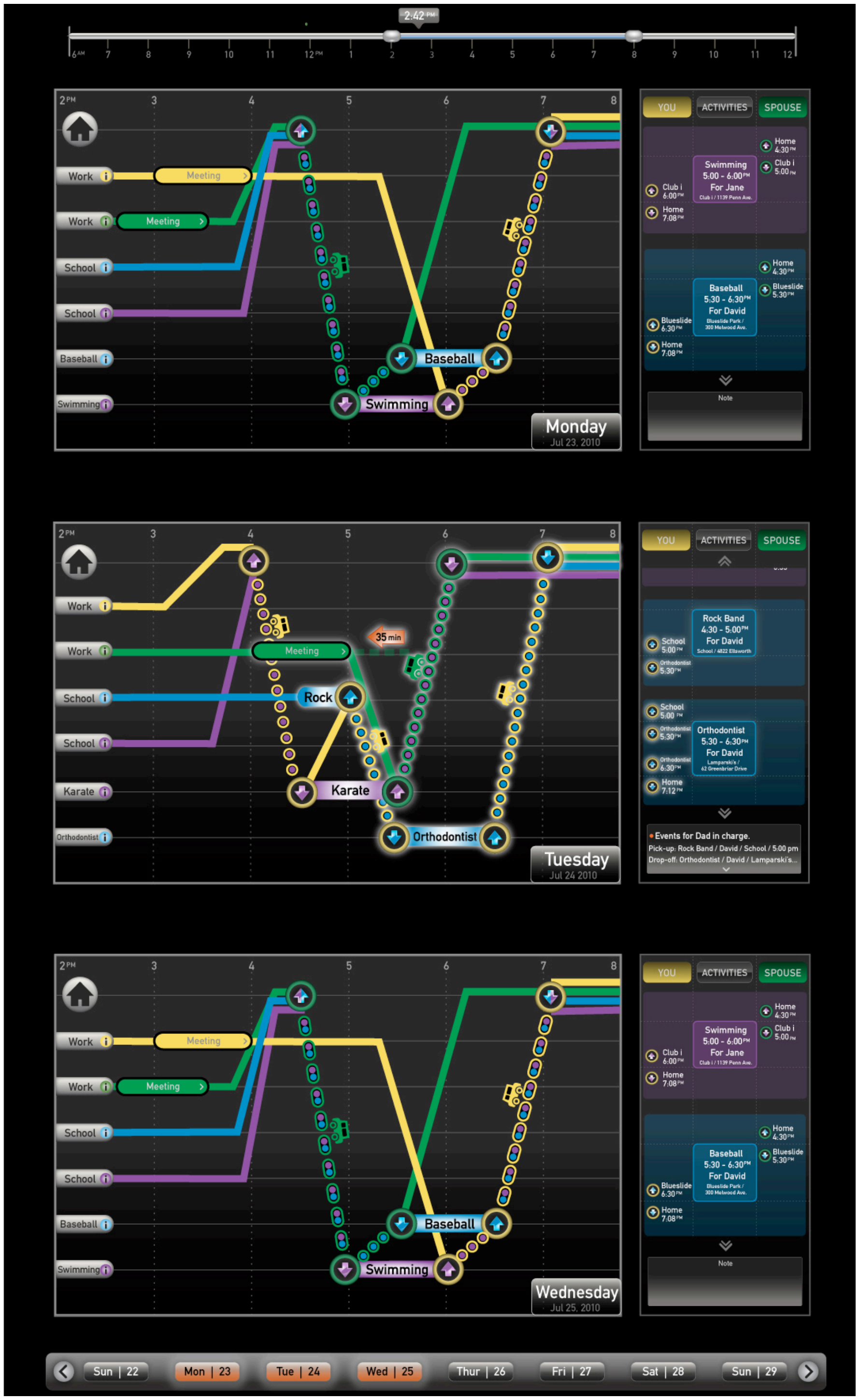
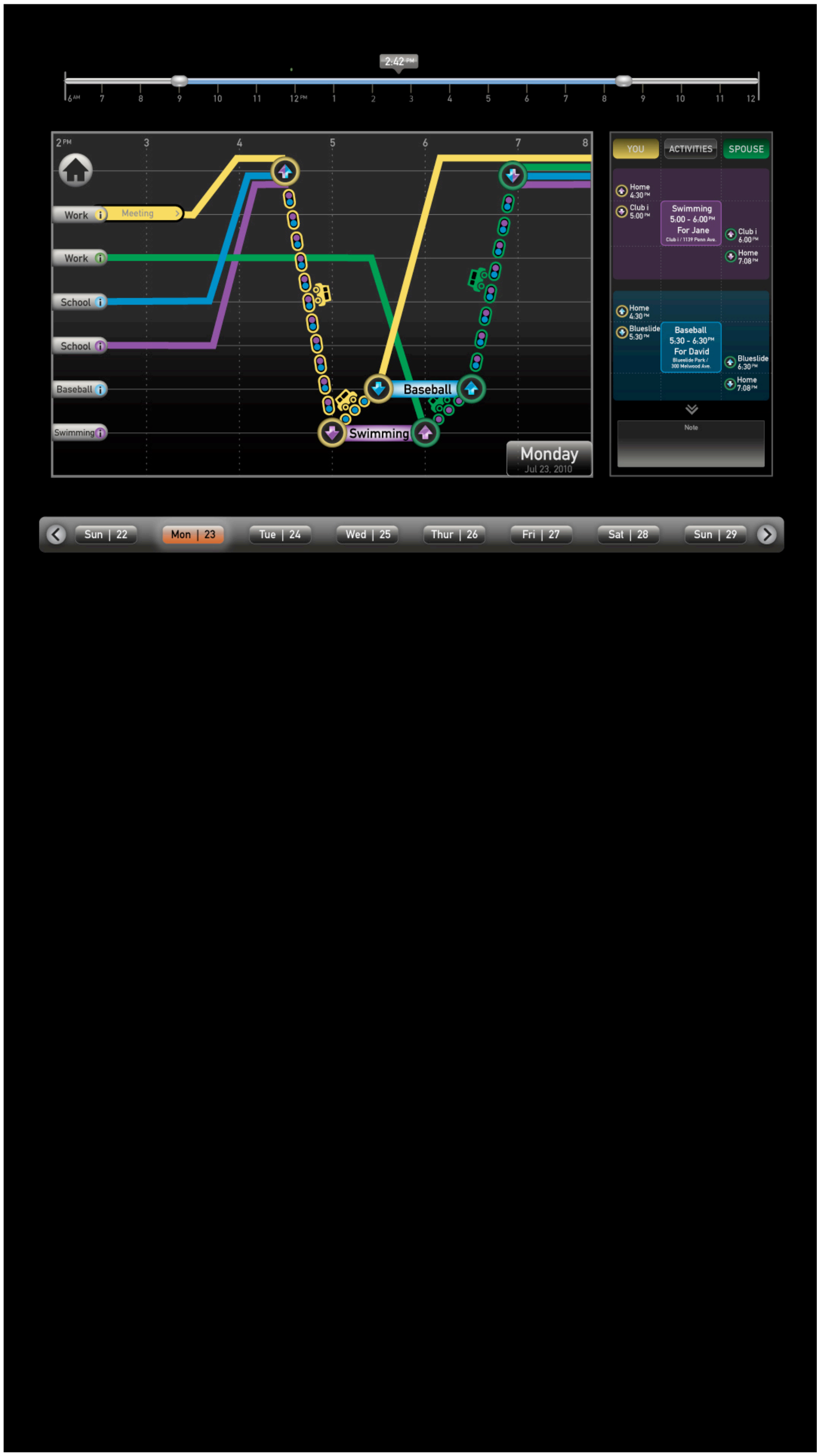


Figure 6.11. In Large display scene 1, the parent is called back by the dentist and asked to reschedule their appointment. They use the FTF on the large display in the kitchen to problem solve the day with the least impact.

Step

1



2:42
Work
Meeting
Work
School
School
Baseball
Swimming
Baseball
Swimming
Monday
Jul 23, 2010
YOU
ACTIVITIES
SPOUSE
Swimming
5:00 - 6:00
For Jane
Baseball
5:30 - 6:30
For David
Home
Club i
Blueslide
Note
Sun | 22
Mon | 23
Tue | 24
Wed | 25
Thur | 26
Fri | 27
Sat | 28
Sun | 29

Step
2

Figure 6.12. In Large display 2, the parent is told to pretend they wake up to find that one child is sick. Because their spouse has an important meeting at work, the parent has to arrange to get the child to the doctor, and to never leave the sick child unattended.

6.3.2 Study 2 Protocol

Study 2 repeated the same protocol as study 1, replacing the data from the persona family with actual data from the participating family. A preliminary phone interview allowed for the capture of the basic information the display would include – family members, activities and their places and times. The interview then solicited the family's logistical plan from the previous days, which were entered into a web-based application to visualize the plans using the visual vocabulary of the FTF.

The same protocol was followed as Study 1, where participants were asked to role-play the same four scenarios, Complexities like the conflicting times for the orthodontist appointment, or a meeting that would interrupt current plans, were constructed using each family's data individually. So in Study 2, while each family experienced scenarios that created the same kinds of planning problems, the actual details of both plans and eventual solutions were unique to each family. As in Study 1, interviews were conducted after each scenario and upon conclusion of all four scenarios.

6.3.3 Measures

Between scenes, semi-structured interviews focused on two main subjects. First, to assess the validity of the problems and the value of the information delivered, participants were asked to discuss the situations we asked them to participate in. Interviewers asked if they were familiar situations and if participants conceive of the problem in the same way -- as a problem with the information available to them.

Next, questions focused on four aspects of the visualization. First, we asked, if the overall representation is meaningful. We asked participants to describe where everybody was, and who was responsible for what task during the day, and asked them if their interpretation required effort.

Second, we asked participants if they could easily see the consequences of their decisions. This included the ability to add an item, and come away with an understanding of the changes that this new event introduces, or the ability to look across a variety of days and make a choice about the consequences of picking one day over another (orthodontist appointment scenario).

Third, we asked if the parent was able to address any unresolved details for the plan. For example, this included situations when there was no parent responsible for transportation (late meeting scenario), or who takes over for a job when we remove a parent from the day (sick child scenario). Lastly, we asked parents to extrapolate the situation they just experienced to their own family.

After all four scenarios, participants completed a subset of the Technology Adoption Model 3 (TAM-3) survey (see Table 6.2) an instrument from organizational behavior research that has been shown as a reliable predictor of technology adoption (Davis 1989) (Venkatesh & Davis 2000) (Venkatesh et al. 2003).

TAM Dimension	*Definition*
Perceived usefulness	The degree to which an individual believes that using the system will help him or her to attain gains in job performance.
Result demonstrability	Tangibility of the results of using the innovation.
Behavioral intention	The degree to which a person has formulated conscious plans to perform or not perform some specified future behavior.
Computer playfulness	The degree of cognitive spontaneity in microcomputer interactions.
Computer anxiety	The degree of an individual's apprehension, or even fear, when she/he is faced with the possibility of using computers.
Perceived enjoyment	The extent to which the activity of using a specific system is perceived to be enjoyable in it's own right, aside from any performance consequences resulting from system use.
Computer self-efficacy	The degree to which an individual beliefs that he or she has the ability to perform specific task/job using computer.
Output quality	The degree to which an individual believes that the system performs his or her job tasks well.
Perception of external control	The degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system.

Table 6.2. TAM-3 dimensions which were included in the study. These dimensions describe aspects of system use that are relevant to the domestic context.

We excluded TAM scales that encapsulate concepts relevant to the workplace but no the home. We also adapted the language of the TAM-3 to reflect the domain of family logistics. We also administered a brief, self-authored questionnaire on logistics dimensions, probing parents on the FTF's ability to augment awareness and planning.

6.4 Findings

For Study 1 we recruited 12 parents from the local area. For Study 2 we recruited 7 parents from the local area. Since results were nearly identical across both studies, we report them together, and describe differences where appropriate. We again looked to draw families from a wide variety of social and economic backgrounds (see Appendix A for more complete demographic information).

Both qualitative interviews, and the TAM-3 results clearly support the main hypothesis of this dissertation. Parents found that the documentation supported their planning and coordination efforts, and decidedly embraced the capabilities the FTF made possible.

To summarize, both studies confirm that routine information helped parents because:

1. Visual overview make it easier to see the big picture
2. Easier to see consequences of your choices
3. Can plans instead of guesses at the point of opportunity
4. Reduce time-lapsed errors
5. Between 6 and 7 on every TAM dimension

6.4.1 Visual overview make it easier to see the big picture

By displaying everything everybody intends to do, the FTF helps give an overview of what everybody in the family plans to do that day. P3 describes the overview as 'a schematic picture, you know, where the plan needs to be changed.' One advantage of this overview is that responsibility is more clearly defined. 'That way it clearly delineates the rules -- you know where you have to be and where I have to be -- and the change that's coming. And it would eliminate a lot of stress,', says P1. P4 just says 'it's nice to have a map.' P3 elaborates, 'The color-coding gives me an idea mentally of who needs to be where, when, and gives me a 'quick shot' that I can put together, as opposed to trying to write everything down on a piece of paper.

6.4.2 Easier to see the consequences of your choices

Parents reported that the ability to see the entire plan made it easier for them to see how decisions to change one part of the plan would affect the overall plan. Parents observed, for example, that when they relied on the other parent to drive, as in the doctor's appointment scenario, they often 'needed to get clearance to set up a schedule [for that parent] because they [other parent have to] leave early, and so then come in early,' describes P6. The comment refers to the fact that the overall plan view reminded the participant that scheduling a task for their partner meant they would also have to reschedule that entire day. It was more obvious that the decision did not exist in isolation, but would impact other members of the family in ways that they simply not have in their mind (even if they might know them)

6.4.3 Can plan instead of guess at the point of opportunity

Parents experience anxiety when they must guess. This design helps resolve the issue. Parents often expressed that their plans at the orthodontist were more like guesses. They found it very hard to know who would be doing what at a point in the future. Because they schedule a time that turns out to not be possible, parents then express that they have to reschedule the appointment. Instead, they found that the FTF could help them see more reliably what other people are doing, allowing them to take advantage of making plans at the doctor's office. 'Instead of having to call the doctor later and miss the appointment or it could fill up...It's extremely useful because you have opportunities that you might not have later and you might have to cancel or reschedule.', says P2. 'Appointments might fill up if you say something like 'I'll go home and look at my calendar and get back to you' You would know about your own plan, but this would give you the information about everyone else's plan as well'

6.4.4 Reduce time-lapse errors

Our study of the FTF uncovered a situation that often leads to coordination problems that we call the time-lapse error. In this situation, a family member asks another to perform some task for or with them, and the person intends to create a reminder for themselves (like, for example, putting it in their calendar) but some interruption changes the person's focus, and they forget to create the reminder. P4 describes this situation. 'I would ask him to put…[the pick-up]…in his phone but there's no way to know [if he did].' The FTF allows family members to create events and add other family members to those events. This means that a family member can see if the other actually created the event, and act on their behalf.

6.4.5 TAM results

The TAM-3 is administered using a 7-point Likert scale (from strongly disagree to strongly agree). Parents scored the FTF between 6 and 7 on every dimension (see Table 6.3).

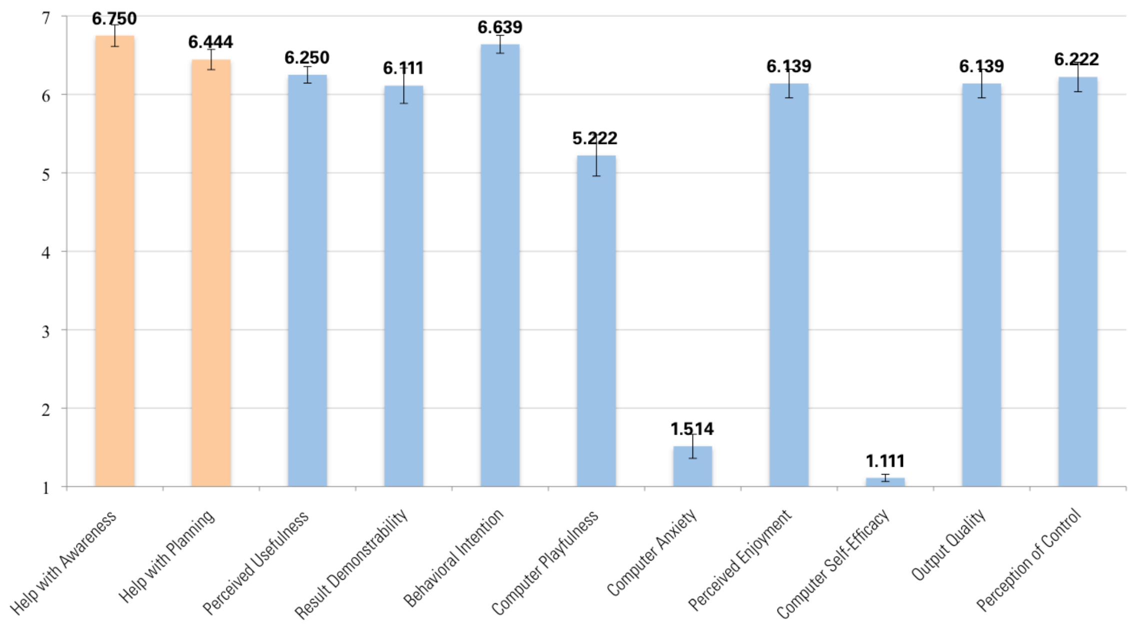


Table 6.3. Mean TAM-3 values for parents' evaluation of the FTF (n = 17). Error bars also indicate the standard deviation.

6.5 Discussion

Using the Family Time-Flow, families can more explicitly identify unclaimed or ambiguous responsibilities, monitor the completion of plans, and identify possible scheduling conflicts. By adding an FTF to a calendar application as an additional view, the calendar can become a more complete, flexible and able tool for family coordination. On one compact screen, the Family Time-Flow combines where parents and children are, and what responsibilities each parent will complete. It creates a shared visual representation of the current and future states of family logistics. The overall effect is to create several benefits for families.

The FTF's ability to provide a high-level summary becomes clear when we visually compare the FTF with a paper or even digital calendar. P11's personal calendar, for example, shows her individual organizational structure, and the schema she developed. Her children participate in basketball and what she calls 'intramurals,' a general sports activity for younger children. Days with basketball games are circled. The circle reminds mom to find out the time of the game on or near game day, but the information needs to be stored in her head. CCD, and piano are more regular, and do not appear on the calendar at all. Mom has to keep all of this information in her head, and when making changes, she also has to keep in her head all the cascade of changes that a change might cause.

The FTF's ability to make the consequences more visible relies on the same simple idea. Parents generally have a system that requires them to remember all the details of any given plan. When they make a plan change, the FTF shows them how their decision affects not just their own day but the entire plan, and every other member of the famiy.

Current coordination resources do not provide this information. Calendars, for example, largely contain non-routine information (Neustaedter 2007) (Davidoff, Dey & Zimmerman 2010). But often a variety of routine information is required when making plans, and improvising changes to plans. Without a resource to provide that information, people have to **recall** the plans and routines of other family members (Beech et al. 2004). Their tacit knowledge of one another's routines can be inaccurate, incomplete, and inconsistent (Baecker 2002) (Davidoff, Dey & Zimmerman 2010). With access to a resource that can provide information on the plans and routines of other family members, people can then **recognize** the plans and routines of other family members.

The TAM-3 also supports one of the main agendas of this line of research. While parents believe that the FTF can reduce problems with planning, and increase their awareness of other family members, they also feel that the FTF increases their experience of control. The perceived usefulness scale is worded such that the questions say "…helps me in my role as a parent." In other words, the FTF helps parents feel that they are doing a better job as parents.This is highly-suggestive that parents express a strong preference for the capabilities that the FTF can bring to their lives. These high scores around adoption also strongly support observations from fieldwork with parents that logistics is a troubling part of their lives, and that they desire to have it supported in some way.

As a technology, the FTF is agnostic to the means through which information is entered. In other words, parents can enter all the information manually, or it could all be learned through sensing and machine learning. The FTF displays whatever information the underlying models contain. So while only a field study could give a more ecologically valid answer about whether parents would enter planning information manually, the FTF does not require any particular form of input.

Chapter 7. Discussion and Conclusion

This work uncovers that families need but do not have access to routine information. It then develops a way to capture and represent that information, and proves that its presentation to families is valuable both functionally and socially. Parents claim that with the technology they can coordinate better, and that by reducing the background of anxiety, make them feel as though they can engage their children during their activities, effectively feeling like better parents.

From the perspective of HCI, this work relies on the methods of a variety of disciplines, along the way making contributions to each. This work explored how the concept of the routine can be analyzed by anthropology, and learned specific functional and social issues in family life. This work used interaction and experience design to focus and apply ways to intervene in family life in ways that are socially appropriate and desirable. And lastly, this work used the techniques of computer science to demonstrate that commodity hardware can automatically document the information that was earlier identified as valuable but missing.

This work then uses a novel visualization to close the loop, and prove that parents want the information that was earlier identified, and that when provided, it both serves their functional need to coordinate more effectively, and their social desire to feel like better, and more engaged parents.

7.1 Support for the Thesis

This thesis was demonstrated in three principal ways. First, to demonstrate how routines can inspire the design of new kinds of interactive systems, a series of field studies were undertaken. First, an observational study was conducted with 24 dual-income families. Over the course of a year, participating families shared their coordination experiences in the context of their homes. Extensive analysis of calendaring and other tools was conducted. With this work pointing towards the routines of children's activities, we conducted a needs validation demonstrating 20 storyboards to 18 additional dual-income families. With this work helping to re-frame our understanding of the problem, we conducted a series of user enactments with 12 additional families. Over the course of three years, a deep understanding of how routines participate in family coordination emerged, as well as a design philosophy for how computational support could help families.

The fieldwork served to drive a clear set of ways that a system that could document routines would be able to help dual-income families coordinate. Since families need but do not have access to information about the plans and routines of other family members, we can support coordination by providing that missing information to them. This effectively creates a new kind of coordination resource.

Second, because routines are developed from the repeated performance of certain actions, they lend themselves to sensing and machine learning. In other words, since families currently do not document their routines, one way to generate that documentation is to have computational systems learn them. Machine learning of family routines creates a new kind of coordination resource.

This is demonstrated through the collection of a massive dataset of family coordination. Using mobile phones as a sensing platform, we demonstrate that the GPS available on commodity hardware can sense with parents pick up and drop off their children at their activities. We demonstrate that we can use machine learning to model which parent will make the next pick-up for an activity. And we demonstrate that we can detect if a parent will actually remember to conduct a pick-up.

Third, models of routine can enable new kinds of coordination systems. To demonstrate this we create a new kind of way to visualize the family routine, and use experience prototyping with 19 parents and two studies to demonstrate that the ability to see this routine data is both intelligible and desirable. This study demonstrates the value of having information about routines, and therefore validates the work to learn routines (or manually collect them).

The study also validates that the ability to access routine information can help reduce the background of anxiety that parents experience during coordination. The added capabilities can free some of the attentional resources required to manage everyday tasks, helping family members be more present to engage with one another as they perform their everyday tasks, instead of being distracted by the struggle to maintain control.

7.2 Larger Impact

7.2.1 Expanding routines to other domains

This work lays the foundation for a new kind of technology to support family coordination. But the ultimate outcome of the work is a validation that the study, modeling and exploitation of routines can lead to the creation of new capabilities. When extended across a variety of domains, the routine can prove to be a capable abstraction. By understanding the routines of the workplace, organizations might come to understand trends in employee behavior, observe patterns of routine communication and identify runaway projects, or understand the types of training that lead to the most productive work outcomes. Any process that can be modeled as a routine can both be understood in terms of its constituent parts, as well as when the process unfolds in a non-routine way. Understanding the amount of 'routineness' of certain events can help with personalization of technologies, affecting costs and benefits in value tables.

7.2.2 A new frame to examine support applications

The study uncovered an important perspective that offered a critical lens into the creation of technologies for families, but extends to any group that depends on support applications. A variety of technologies can be considered problem-solving, and will contribute value to their users through the performance of this service. Because of the nature of family coordination, we uncovered an opportunity not only to fix problems, but to help people become better at their jobs. This different framing of the problem offers a new perspective on how support technologies can be designed. Similar to Zimmerman (Zimmerman 2009), by considering an application a tool to fix a problem, designers will create a technological crutch. But considering an application a way to help individuals become more competent at what they do, the technology fulfills a fundamentally different role in the lives of its users. It becomes a teaching tool, and one that helps them grow in their social and individual identify.

7.2.3 Mobile telephone supporting meso-scopic social science

Scientists in a variety of disciplines are using the sensors on commodity mobile phones to generate a new body of unsupervised knowledge. At the macroscopic level, mobile phone GPS has been used to examine movement patterns, demonstrating, for example, that people tend to stay within 30 miles of home (González, Hidalgo & Barabási 2008), or to model the formation of social networks (Eagle & Pentland 2006), or the propagation of disease (Madan et al. 2010). GPS has also been used to model the routines of single individuals, including destinations (Marmasse & Schmandt 2000) (Brumitt et al. 2000) (Ziebart et al. 2008) and route choices (Liao et al. 2007).

A space remains, however, for the exploitation of mobile phone as sensor at the small group level. While in this study we have chosen families, other groups that might be explored include small groups collaborating remotely, or a crew of construction workers at a site. The small group presents more computational complexity than problems of individual routines, and when no ground truth need be captured for large-scale social studies, the large-scale study appears as a tempting area to explain. But the study of the small group affects many different aspects of life.

7.3 Additional Research Opportunities

To enable the models and applications developed in this paper to move from laboratory to the real world, simplifications will need to be removed, each introducing added complexity

7.3.1 Multiple families

While many of the families that participated in our studies managed a great deal of their pick-ups and drop-offs largely within the nuclear family, a variety of other situations exist that will undoubtedly add complexity to the problem. First, various families relied on their local extended family to support their tasks. Whether in the form of child care (making sure little ones are not alone) or by supervising and implementing rides, extended family were not given sensors in the data collection or modeling phases of the study. Additionally, families that have more resources might rely on permanent, semi-permanent, or stopgap services from a nanny or babysitter. Lastly, parents often rely on other parents to support their transportation. Parents can include a trusted group of regular go-to parents, or be more opportunistically chosen from parents whose children participate in whatever activity the child is participating in.

For all of these groups, we have no sense of how often they are employed, either on an across or within family model. Additionally, we have no models of the transportation preferences of this group. By participating in coordination, they also would naturally be represented in the FTF. The inclusions of other parties complicates the view.

7.3.2 Equipment for activities

Another opportunity exists to include the routines of the equipment related to activities to family support applications. For a single activity like soccer, equipment could include, for example, cleats, socks, shorts, jersey and a water bottle. Equipment has the same kind of constraints as events. There are partial orders in which equipment need to be prepared. Clothes need to be washed before they can be put in the activity bag. The activity bag needs to be placed by the door on the day of the event. A series of constraints also guide the preparation of equipment. Soccer jersey needs to be washed the night before a game, probably in the evening, so that it has time to dry. A child has to bring the equipment with them in the morning before they leave home. Each action has a complex set of conditions that, should any fail can lead to the forgetting of certain pieces of equipment.

Our field studies showed us that both parents and children forget equipment more often than there are casualties of transportation. We elected to focus on transportation because while less frequent, the events tend to be much more severe when they do occur.

Chapter 8. References

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Chapter 9. Appendices

Appendix A Participant Demographics

Field Study Participant Demographics

Family	*Mother*	*Father*	*Children*
A	NP, Administrative assistant	NP, Carpenter	S15, S18
B	47, Department manager	48, Art gallery director	D9, D15
C	41, Professor	39, Teacher	S1, D5
D	38, Business manager	41, Marketing manager	S5, D8, S10
E	NP, Professor	NP, Carpenter	S15
F	45, Secretary	46, Truck driver	D15
G	32, Surgeon	31, Graduate student	S5
H	36, Project manager	34, Graduate student	D1, D5
I	52, Nurse	53, Steam fitter	S15, D19
J	49, Administrative assistant	50, Manager	D15, S20
K	54, Events coordinator	55, Salesman	S21
L	43, Legal secretary	46, Landscaper	S11, D15, D17, D19
M	N/P, Administrative Assistant	NP, Salesman	9, 15
N	40, Writer	40, Software engineer	9
O	N/P, Physician	NP, Project Manager	7, 13
P	50, Executive assistant	50, Manager of development	16, 21
Q	39, Professor	31, NP	4, 6
R	45, Café manager	51, Architect	9, 15
S	39, Graduate student	39, Researcher	12
T	38, Biotech manager	32 Accountant	4
U	48, Court investigator	50, Sherriff	13, 17, 21
V	45, Architect	57, Designer	6, 7
W	NP, NP	NP, NP	3, 6, 7
X	49, Teacher	52, Attorney	9, 11, 14, 20, 22

Data Collection Study Participant Demographics

Data collection occurred across six months. Resource constraints forced the dropping of families C and D after three months. Grey bars indicate weeks with total rides above the mean (18), and orange indicates below. Comparable statistics were not collected during the study pilot.

Family	*Parents*	*Income*	*Kids*	*Activities*	*Rides per Week*
Code	*Mom then Dad*	*in $1,000's*	*Son/Daughter Age*	*Top 5 by rides given during study*	*From Nightly Interviews*
A	37, Data Manager 35, Healthcare Manager	100+	S9, D7, D4	Swimming, soccer, hockey, drama, religious class	
B	55, Medical Secretary 52, Factory Manager	60-80	S17, S9, S7	Baseball, basketball, football, altar service, boxing	
C	43, Museum Director 35, Elementary Teacher	40-60	S14, S6	Robotics club, baseball	
D	40, Administrator 40, Purchasing Manager	100+	S13, S9	Baseball, karate, football	
E	50, Nurse 51, Medical Technician	60-80	S15, D10	Color guard, band, track, trumpet, piano, scouts	
F	49, Surgeon 50, Programmer	100+	S16, D10	Track, ultimate frisbee, French, violin, swimming	

Validation Participant Demographics

ID	Mom Age	Profession	Dad Age	Profession	Income Range $1,000	Number of Children age 6-15
Study 1						
1	44	Marketing manager	44	Construction	80-100	3
2	46	Medical coder	46	Design engineer	60-80	2
3	51	Market research	56	Creative director	over 100	1
4	25	Accountant	26	Software engineer	80-100	3
5	46	Senior care worker	49	Programmer	over 100	1
6	41	Nurse practitioner	50	Benefits specialist	60-80	3
7	40	Mortgage servicer	51	Service manager	60-80	4
8	51	Doctor/scientist	52	Programmer	over 100	1
9	46	Geriatric caretaker	49	Physicist	over 100	1
10	31	Nurse	50	Banker	N.R.	3
11	37	Medical secretary	47	Factory manager	60-80	4
12	46	Marketer	38	N.R.	80-100	3

Appendix B Field Study Protocol and Cultural Probe Package

Field Study Protocol

Activity	Shadowing
Stimulus	Can you start by walking us through yesterday morning?

1. What time was that?
2. Describe your relationship with the snooze button?
3. Other morning facts to get:
    a. Shower
    b. Clothing
    c. Who prepared breakfast? What was it?
    d. News
    e. Weather
    f. Traffic
4. Do you help kids preparing to go to school?
    a. How many times did you check on them?
    b. Do they get ready on their own?
    c. How do you know the kids are getting ready?
    d. What do you check for them before they go to school?
    e. Do the kids usually get to school on time?

Activity	Shadowing
Stimulus	Can you walk us through a morning when the kids weren't getting ready on time?

5. Do you help kids preparing to go to school?

Activity	Shadowing
Stimulus	Can you walk us through the last really bad day because of the morning?

6. Are there any things that you often forget to do, or just don't do, that cause a bad day?

Activity Shadowing

Stimulus Where did the kids go yesterday after school?

7. How did you know that?
8. How did they get home?
9. Was that the plan in the morning? How did you know that?
10. Did the plan change during the day? How did you know?
11. Is there some place where the family shares their schedule?
12. How do you keep track of special events, field trips?

Activity Shadowing

Stimulus Can you walk us through what you do when you leave the house?

13. What do you check before you leave?
14. What are things you sometimes forget?

General Questions

15. What are some stressful parts of that morning?
16. What's are some delightful parts of the morning?
17. Is there anything you prepare for morning the night before?
18. What is mother's role / what is father's role ? any reason for that?

“What do you often forget ?”

1

Please take photos of three things you often forget.
(e.g. artifacts, dates, information, appointments etc.)

Please describe your experiences of forgetting these as a story.

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What is this? Why do you forget it ?

* Any related story?

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What is this? Why do you forget it ?

* Any related story?

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What is this? Why do you forget it ?

* Any related story?

“ What do you wish you never forgot? ”

2

Please take photos of three things you wish you never forgot. (e.g. artifacts, dates, information, appointments etc.)

Please explain why and if you have any related past experiences.

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What is this? Why do you wish you never forgot this?

* Have you ever forgotten this? How & why?

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What is this? Why do you wish you never forgot this?

* Have you ever forgotten this? How & why?

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What is this? Why do you wish you never forgot this?

* Have you ever forgotten this? How & why?

“ What did you create for your kids? ”

3

Please take photos of anything special you created for your kids.

Where do you keep these? Why did you create those?

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What is this? Where do you keep it?

* Why did you create this?

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What is this? Where do you keep it?

* Why did you create this?

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What is this? Where do you keep it?

* Why did you create this?

"What do you do as a family?"

4

Please take photos of activities you do as a family.
Please explain when and why you do these.

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What is this? When do you do this?

* Why do you do this? Is there any meaning?

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What is this? When do you do this?

* Why do you do this? Is there any meaning?

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What is this? When do you do this?

* Why do you do this? Is there any meaning?

“ What do you keep in plain sight to remind you of things?”

5

Please take photos of things you keep in plain sight to remind you of things in the following places: your room, the front door, the kitchen, your office desk, and your schedule.

Please explain why you keep these in plain sight and what they remind you.

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What do you keep in plain sight in your room?

* What does it remind you of?

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What do you keep in plain sight near the front door?

* What does it remind you?

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What do you keep in plain sight in your kitchen?

* What does it remind you?

Please leave this space blank
for the photo.

Please put the number of photo
you take below.

Num (   )

* What do you keep in plain sight on the office desk?

* What does it remind you of?

Please leave this space blank
for the photo.

Please put the number of photo
you take below.

Num (   )

* What do you keep in plain sight on your schedule?

* What does it remind you of?

“ What do you like about reminding you kids? ”

6

Please take photos of things you like reminding your kids to do. Please explain why you like this.

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What do you like reminding your kids?

* Why?

“What do you hate about reminding you kids?”

7

Please take photos of things you hate reminding your kids to do. Please explain why you like this.

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What do you hate reminding your kids?

* Why?

“ What do you like to be reminded? ”

8

Please take photos of things you like to be reminded.
Please explain why you like.

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What do you like to be reminded?

* Why do you like it?

" What do you hate to be reminded? "

9

Please take photos of things you hate to be reminded.
Please explain why you like.

Please leave this space blank for the photo.

Please put the number of photo you take below.

Num (   )

* What do you hate to be reminded?

* Why do you hate it?

Scenario Book

Family ___________

Carnegie Mellon

Human-Computer Interaction Institute HCII

Instructions: *Imagine there is a magic Genie who can go wherever you are. The Genie can remember everything it sees. It can remind you of important things whenever you want, and however you want.*

Please answer the following questions. Find a sticker that represents your answer and place it in the provided space. If there is no sticker that has your answer, just draw the answer.

1 What do you want to tell the Genie?

PLACE STICKER HERE or DRAW

What? ______________________

____

____

Why? ______________________

____

____

PLACE STICKER HERE or DRAW

What? ______________________

____

____

Why? ______________________

____

____

2 What do you **not** want the Genie to know?

PLACE STICKER HERE or DRAW

What? ______________________

____

____

Why? ______________________

____

____

PLACE STICKER HERE or DRAW

What? ______________________

____

____

Why? ______________________

____

____

3 What should the Genie **never** remind you to do?

PLACE STICKER HERE or DRAW

What? __________

Why? __________

PLACE STICKER HERE or DRAW

What? __________

Why? __________

4 When should the Genie never disturb you?

PLACE STICKER HERE or DRAW

When? __________

Why? __________

PLACE STICKER HERE or DRAW

When? __________

Why? __________

6 Create a "best case scenario"

PLACE STICKER HERE or DRAW	PLACE STICKER HERE or DRAW	PLACE STICKER HERE or DRAW	PLACE STICKER HERE or DRAW
The scene starts with...	The Genie appears by...	The Genie says...	You feel...
Where? ____________	What? ____________	" ____________	Why? ____________
Who's there? ____________			
When? ____________		____________ "	

Instructions: *Make a cartoon using the stickers that shows how you might use the Genie. Write a description below each panel. If you can't find a good sticker, then feel free to draw the contents of the panel.*

5 Create a "worst case scenario"

PLACE STICKER HERE or DRAW	PLACE STICKER HERE or DRAW	PLACE STICKER HERE or DRAW	PLACE STICKER HERE or DRAW
The scene starts with...	The Genie appears by...	The Genie says...	You feel...
Where? ______	What? ______	" ______	Why? ______
______	______	______	______
Who's there? ______	______	______	______
______	______	______	______
When? ______	______	______	______
______	______	______ "	______

Coordination Diary

Family___________

Carnegie Mellon

Human-Computer Interaction Institute

1 REMEMBER TO Go to the doctor

2 WHAT HAPPENED?

WHEN	WHO	WHAT DID YOU DO?	WHY	REMEMBER? EASY HARD
Mon 1pm	Mom	Wrote appointment on personal calendar	Just made the appointment	1 2 3 4 5
Mon 3pm	Mom	Wrote on wall calendar	Got home and saw the calendar	1 2 3 4 5
Fri 7am	Mom	Saw wall calendar	Was having breakfast and the calendar is easy to see	1 2 3 4 5
Mon 1pm	Mom	Remembered appointment	Glanced at clock and saw that it was almost time	1 2 3 4 5
				1 2 3 4 5
				1 2 3 4 5
				1 2 3 4 5
				1 2 3 4 5
				1 2 3 4 5

3 DID YOU REMEMBER?

- [x] YES
- [ ] NO

4 HOW DID YOU REMEMBER? OR WHY DID YOU FORGET?

Looked at clock and was reminded about the appointment

5 WOULD YOU WANT TO BE REMINDED?

WHEN? Yes, 2pm

HOW? Email and phone call

WHY? Its hard to get another appointment

1 REMEMBER TO Pick up son from baseball practice

2 WHAT HAPPENED?

WHEN	WHO	WHAT DID YOU DO?	WHY	REMEMBER? EASY HARD
in March	Son	My son asked me when I could pick him up from practice.	Season is starting. Son brought home his schedule	1 2 3 4 5
in March	Mom + Son	My son called his friends and picked a time. We discussed it	To arrange a carpool	1 2 3 4 5
in March	Mom + Son	My son told me Tuesday. We wrote it on the calendar for every week.	So we'd remember.	1 2 3 4 5
Sunday dinner	Son + Mom	Confirmed the week's carpool was on	We always do this on Sunday	1 2 3 4 5
Tuesday 4:30	Son	Called Mom to say practice is running late	So she doesn't have to wait	1 2 3 4 5
Tuesday 5:00	Mom	Called son to see if practice was over	To pick him up	1 2 3 4 5
				1 2 3 4 5
				1 2 3 4 5
				1 2 3 4 5

3 DID YOU REMEMBER?

- [x] YES
- [ ] NO

4 HOW DID YOU REMEMBER? OR WHY DID YOU FORGET?

Phone call from my son helped me remember

5 WOULD YOU WANT TO BE REMINDED?

WHEN? The day before

HOW? Make the calendar blink

WHY? I don't want my son to wait

1 REMEMBER TO ______________________________

2 WHAT HAPPENED?

WHEN	WHO	WHAT DID YOU DO?	WHY	REMEMBER? EASY HARD
				1 2 3 4 5
				1 2 3 4 5
				1 2 3 4 5
				1 2 3 4 5
				1 2 3 4 5
				1 2 3 4 5
				1 2 3 4 5
				1 2 3 4 5
				1 2 3 4 5

3 DID YOU REMEMBER?

- [ ] YES
- [ ] NO

4 HOW DID YOU REMEMBER? OR WHY DID YOU FORGET?

____

____

____

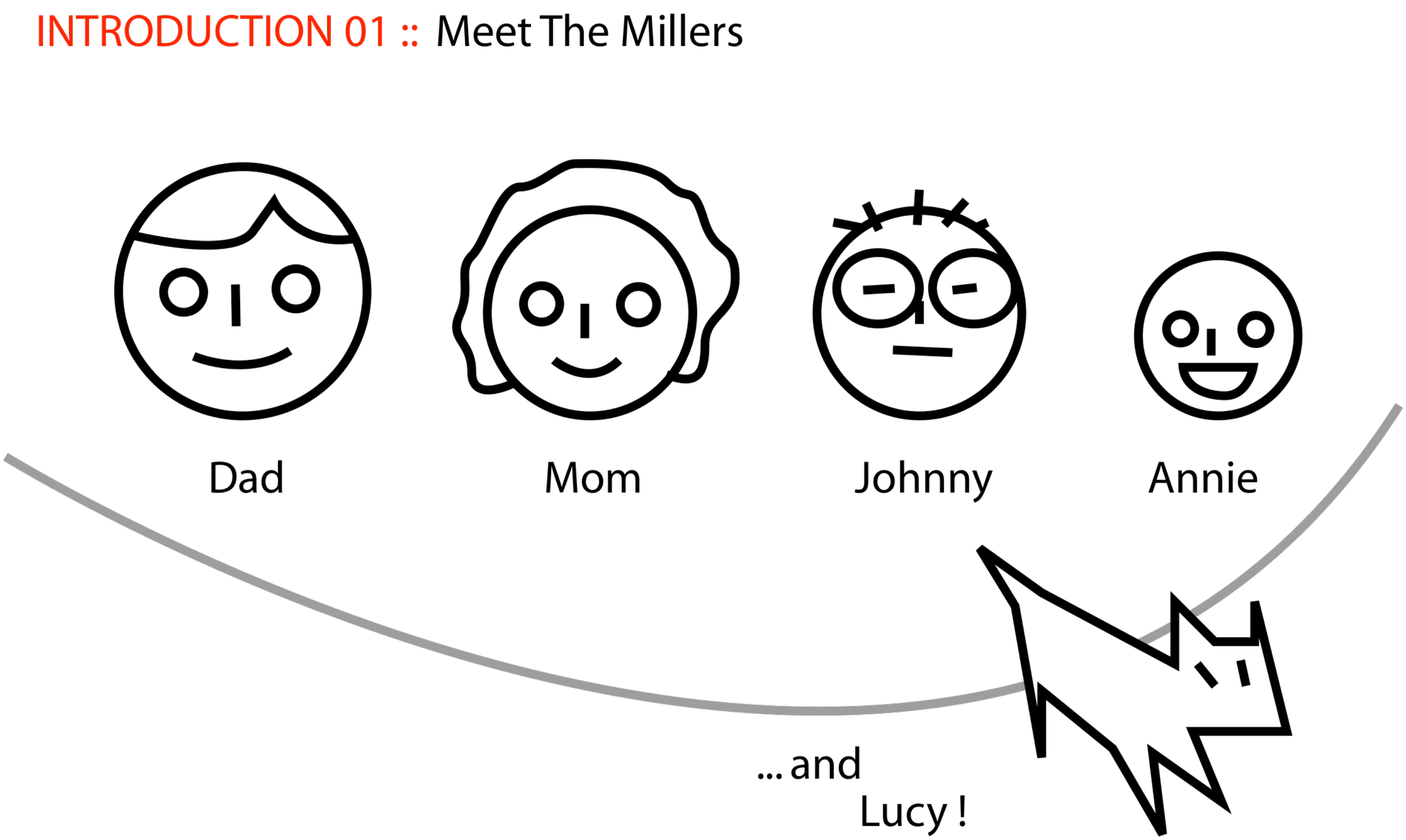
5 WOULD YOU WANT TO BE REMINDED?

WHEN? ______________________________

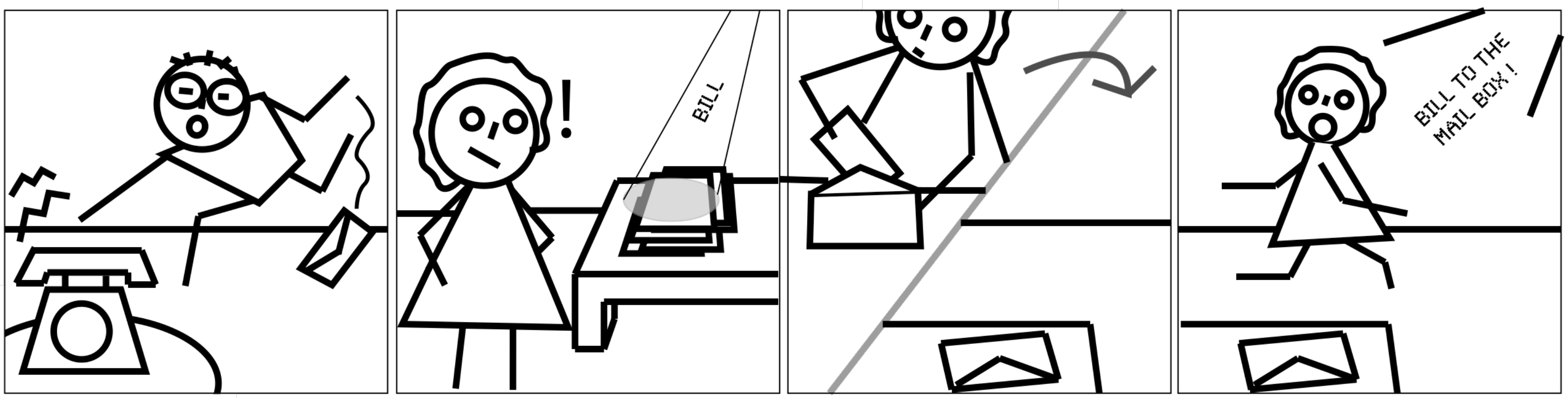
HOW? ______________________________

WHY? ______________________________

Appendix C Needs Validation Storyboards



SCENARIO 01 :: Missing A Bill Payment



1 The phone rings while Johnny's bringing the mail in. He drops the mail to answer the phone, and forgets about it. But there's a credit card bill in that pile!

2 5 days before the payment is due, the smart home alerts Mom that the bill is hiding in a pile.

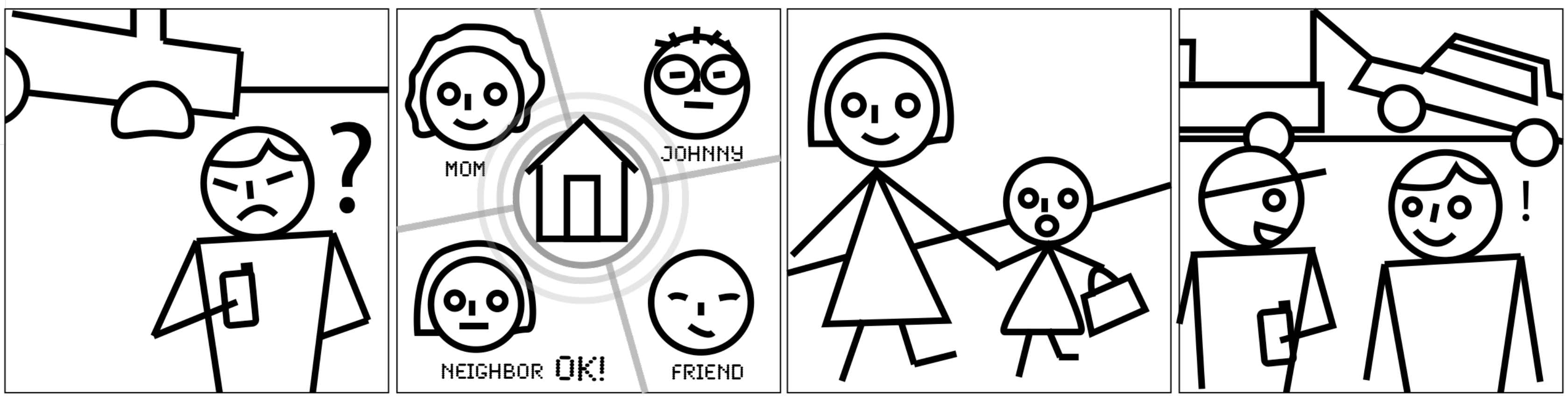
3 Mom puts the paid bill in an envelope, but forgets to put the envelope in the mailbox.

4 On her way out the door the next day, the smart home reminds Mom to put the bill in the mailbox.

SCENARIO 02 :: One of Those Days

Flat tire. Dead cell phone battery. Who's going to get Annie?

1 2 3 4



" I feel so helpless."

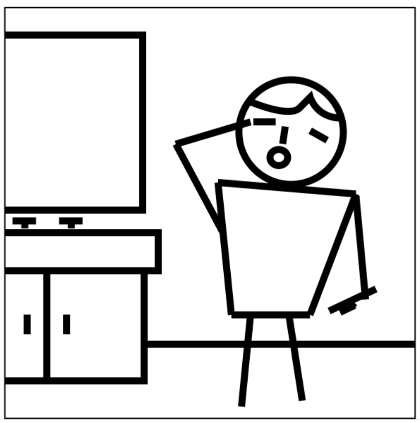
The smart home senses that Dad's going to miss Annie, and pings the people the Millers count on in a pinch.

The neighbor's not far from Annie. She agrees to get her.

The tow truck that comes for Dad tells him that Annie is safe and sound.

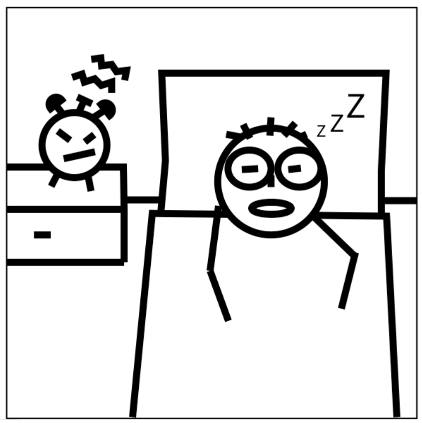
SCENARIO 03 :: 4-Snooze morning

1



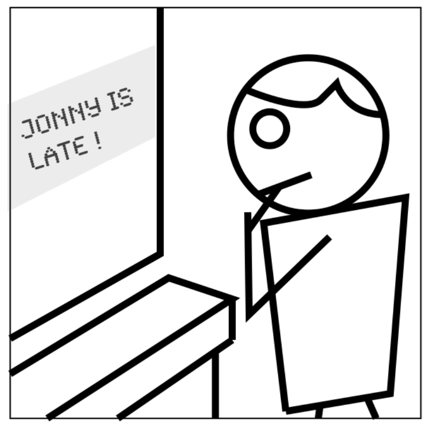
In the morning, Dad's busy getting ready for work...

2



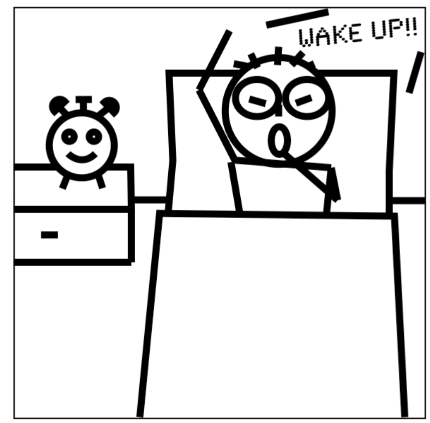
...Johnny's on his 4th snooze.
He's going to miss the bus.
Dad has an early meeting and can't drive him.

3



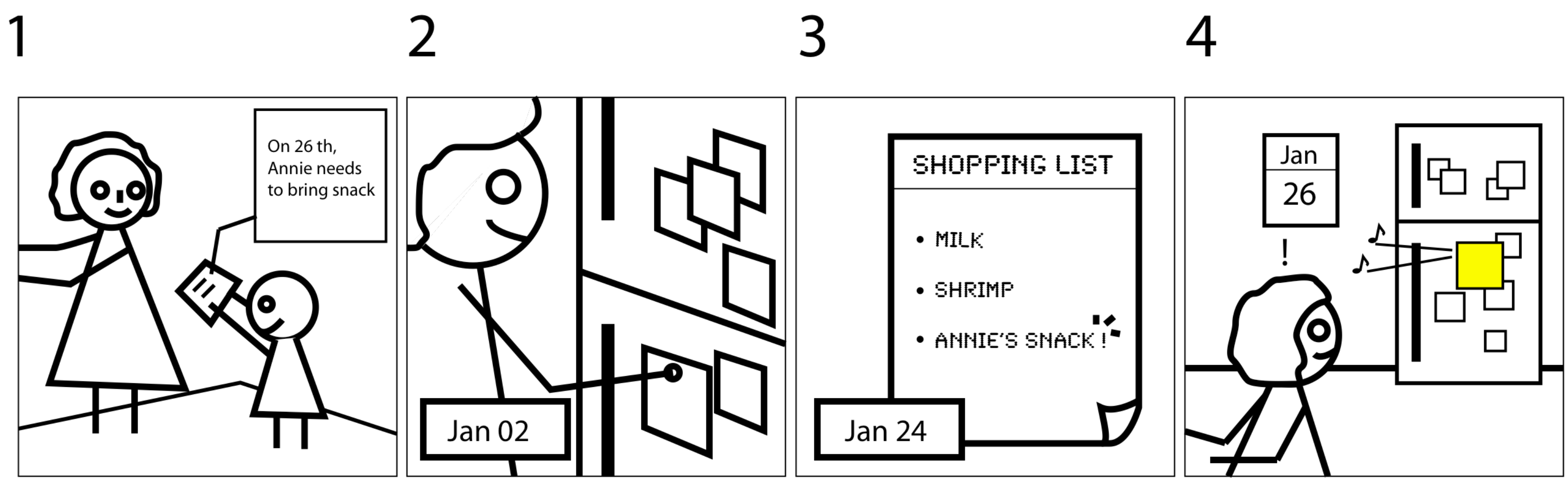
The smart home lets Dad know that Johnny's running behind.

4



Dad shouts to Johnny, telling him to get up. Johnny is cranky, but out of bed.

SCENARIO 04 :: Snack Day at School



Annie brings home a note from school. This month, it's her turn to bring in snack for everyone on the 26 th.

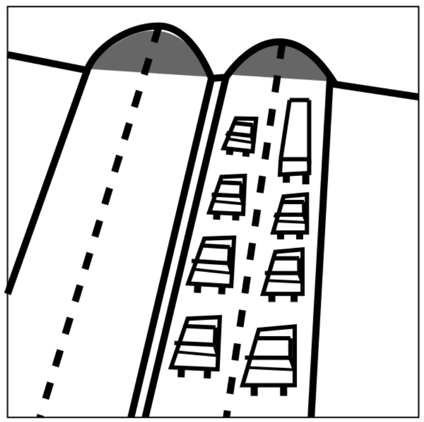
Today is the 2nd, and mom doesn't want to forget. She puts a note on the fridge. But the note is lost in a sea of notes.

On the 24th, the smart home adds Annie's snacks to Mom's shopping list.

The smart home rings a reminder sound as Mom walks past the fridge on the 26 th. She sees her note sparkling, and remembers to give Annie her cookies.

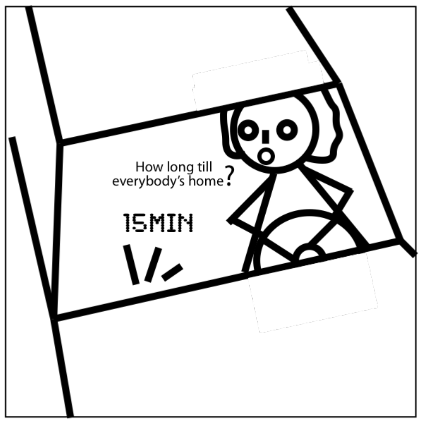
SCENARIO 05 :: Dinner Plans Change

1



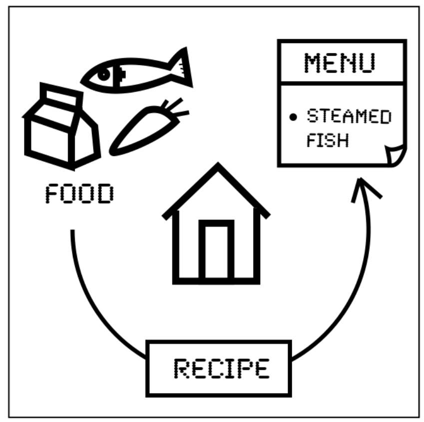
Mom's cooking tonight, but she's stuck in traffic, and running behind.

2



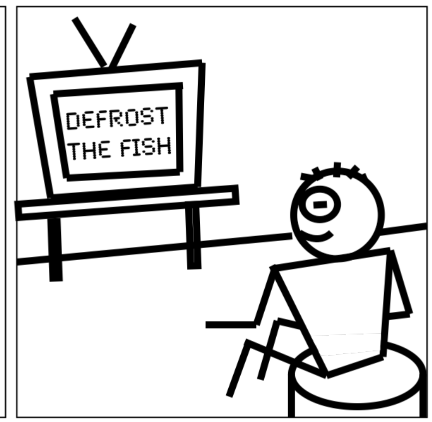
Johnny has a soccer game in 1 hour. Mom checks on everybody - 15 minutes until they get home.
She needs to get dinner started now.

3



The smart home checks what food's around, and gets a recipe mom can make in 15 minutes.

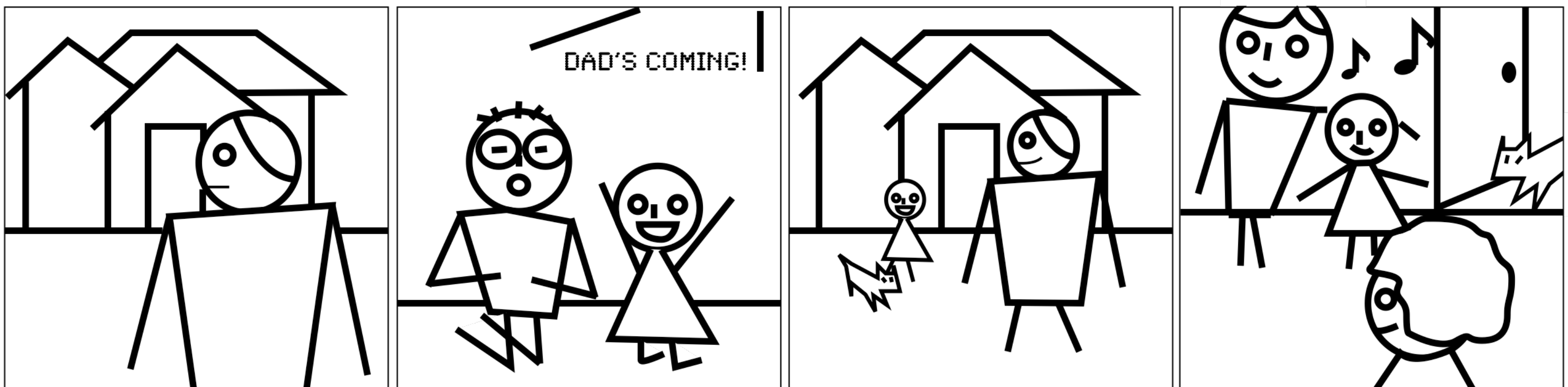
4



The smart home asks Johnny to get the fish out of the freezer.

SCENARIO 06 :: Welcome home Dad

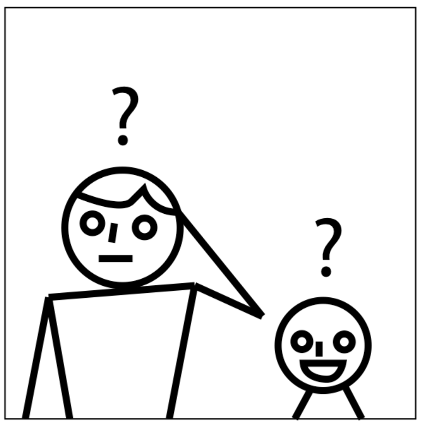
1 2 3 4



1. " It was a long day... Finally, I am home"
2. The smart home tells Annie and Johnny that Dad's almost home.
3. Annie and Lucy run outside to meet Dad.
4. Dad's "welcome home" theme song plays as he walks into the house. Mom hears the music, and comes to meet him.

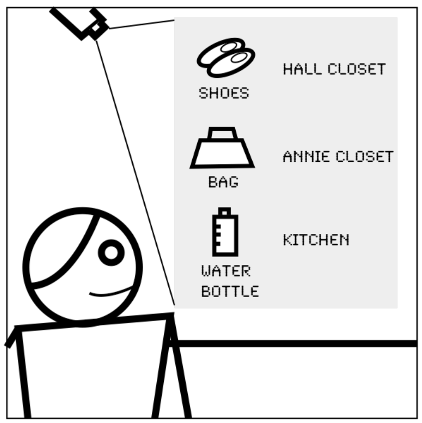
SCENARIO 07 :: Where Are The Ballet Shoes?

1



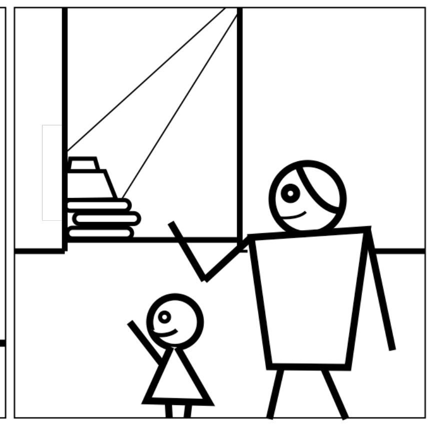
Mom's on a business trip. Dad has to take Annie to ballet. Mom always packs Annie's bag, so Dad has no idea what she needs or where to find it.

2



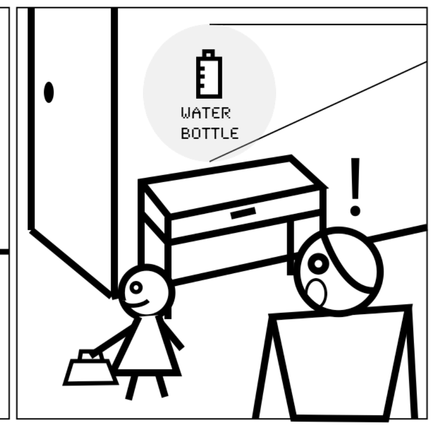
The smart home shows Dad what Annie needs, and where it's hiding.

3



The home spotlights the objects when Dad goes into each room.

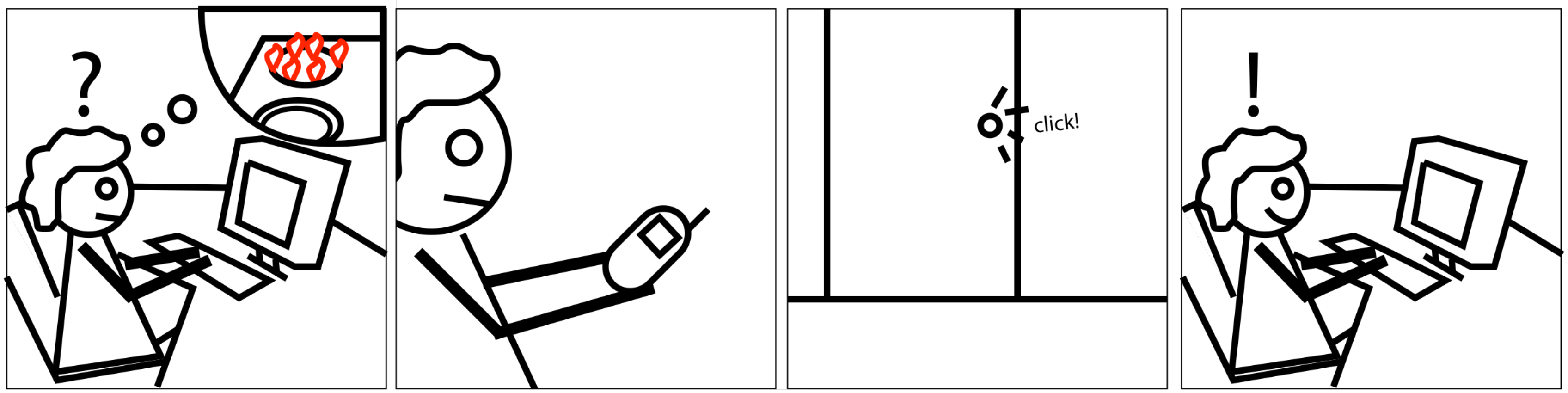
4



On the way out, the house reminds Dad he forgot Annie's water bottle. He grabs it from the kitchen and they head out the door.

SCENARIO 08 :: Worried about The Stove

1 2 2 3



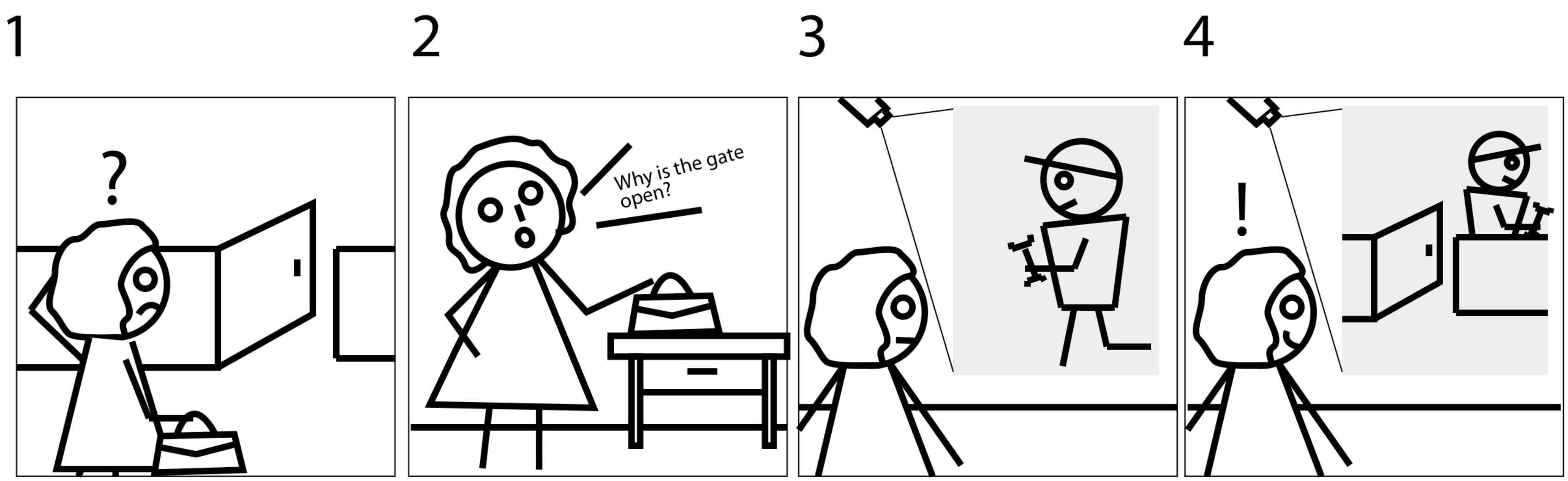
"Did I turn off the stove?? What if I left it on.."

" THE STOVE IS OFF. BUT THE FRONT DOOR IS UNLOCKED."

" Could you lock the door, pleas?"

" Ahhhhhhhhhhh. Now I can relax."

SCENARIO 09 :: What Happened?



1 Mom arrives home and sees that the back gate is open. She's worried.

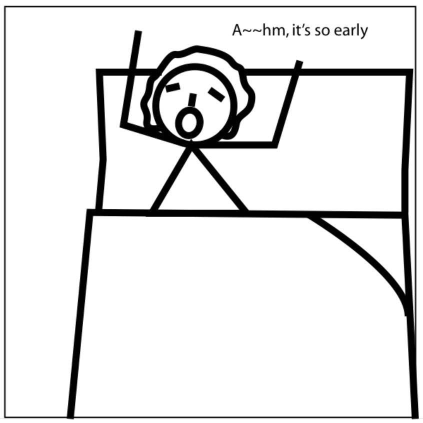
2 So Mom asks the smart home why the gate is open.

3 The smart home shows Mom a video.

4 ' Oh, it was only the cable guy.' Mom feels better knowing who's been in the yard.

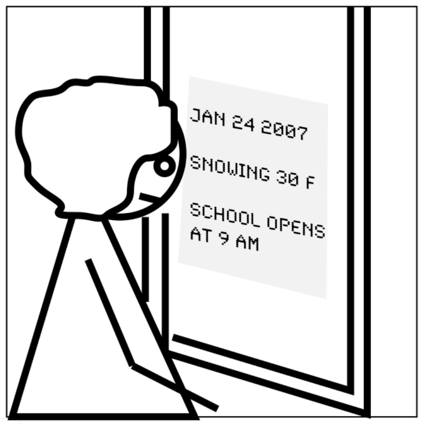
SCENARIO 10 :: Snowy Day School Delay

1



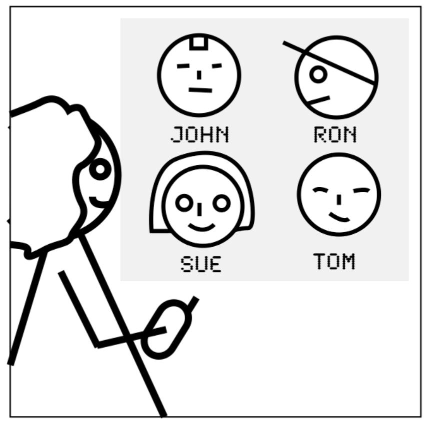
Mom still has to go to work. Somebody will have to watch Annie until school starts. The smart home wakes up Mom 15 minutes early.

2



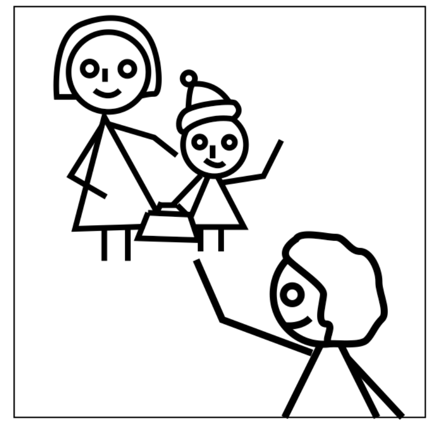
Mom looks at the window, and sees what's happening with school and the roads. She needs to go work by 8 am.

3



The smart home shows Mom who's available to help, and how often they've helped. Mom decides to call her neighbor, Sue.

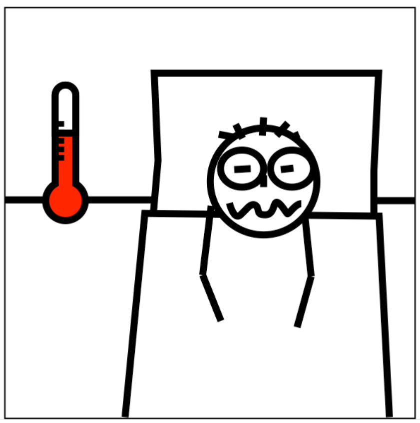
4



When she leaves for work, Mom takes Annie to Sue's house.

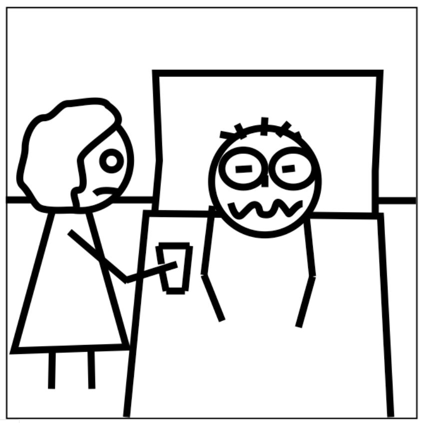
SCENARIO 11 :: Johnny's sick

1



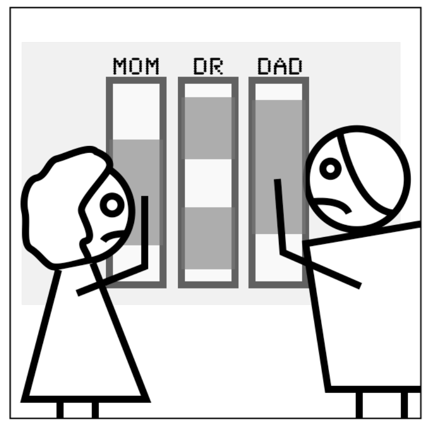
It's 4 am. Johnny's running a fever. Tomorrow morning could be crazy...

2



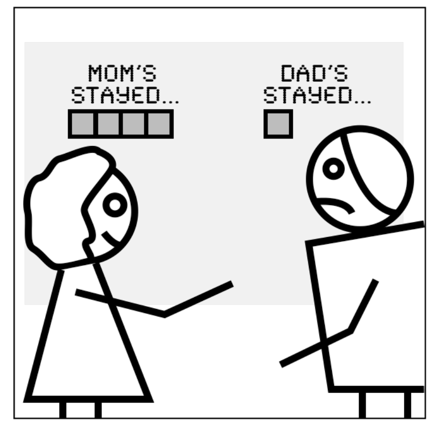
...But the smart home sees that Johnny's sick, and wakes up Mom and Dad. Mom and Dad give him some medicine to reduce the fever.

3



They check their calendars with the doctor's. The doctor can see Johnny at 3pm. But Mom and Dad are both busy all day long.

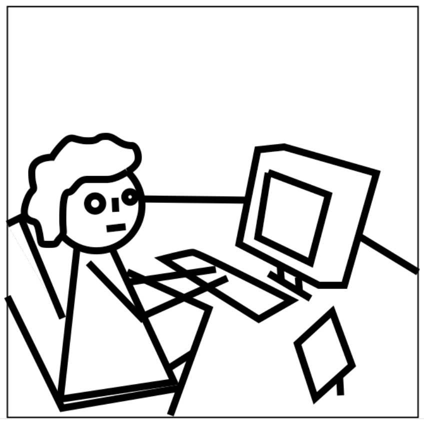
4



Mom and dad ask the smart home to show them who's stayed home more, and how many vacation days they have left. Dad agrees to stay home.

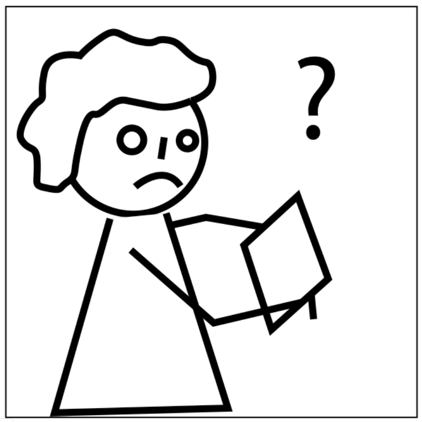
SCENARIO 12 :: Johnny Didn't Call

1



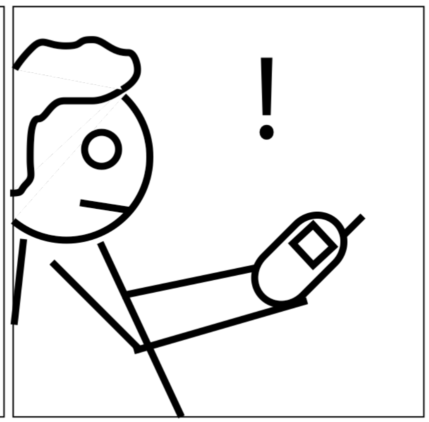
It's 3pm. Mom looks at her "family finder".

2



She notices that Johnny's not home yet. She gets worried.

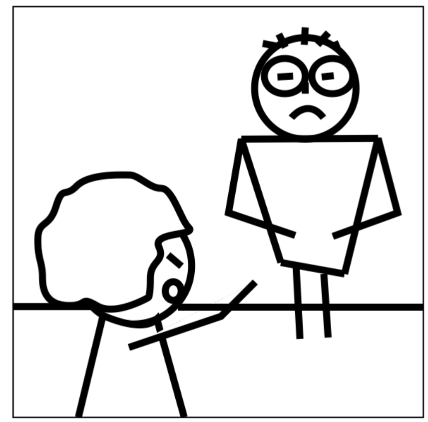
3



"Where's Johnny?"

"JOHNNY'S AT HIS FRIEND SIMON'S HOUSE.HIS PHONE IS OFF. SIMON'S PHONE IS 555-1212."

4



In the evening, Mom "reminds" Johnny that even high schoolers have to call home.

SCENARIO 13 :: Annie dresses herself

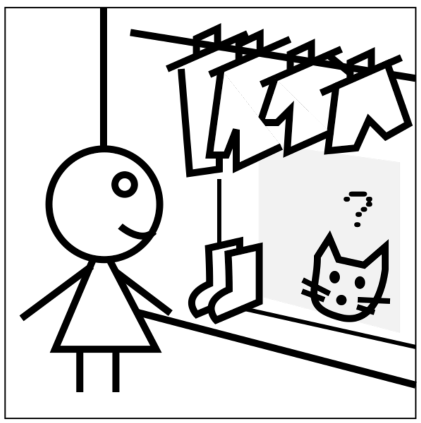
The smart home keeps Annie on track in the morning.

1

" MOM SAID 10 MINUTES MAX. "

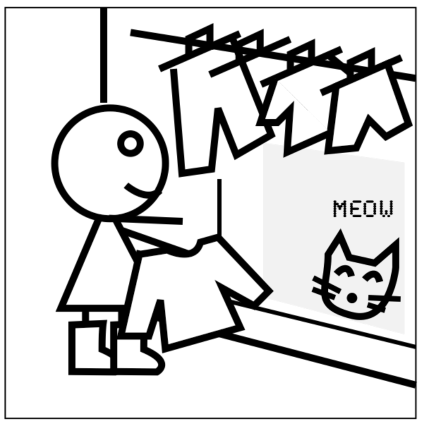
The smart home shuts off the TV.
Annie goes to get dressed.

2



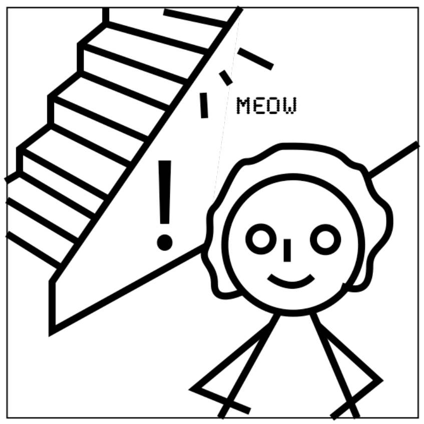
" IT'S SNOWING. WHAT SHOULD YOU WEAR?"

3



Annie picks a sweater and boots.
Her "cyber pet" meows with joy.

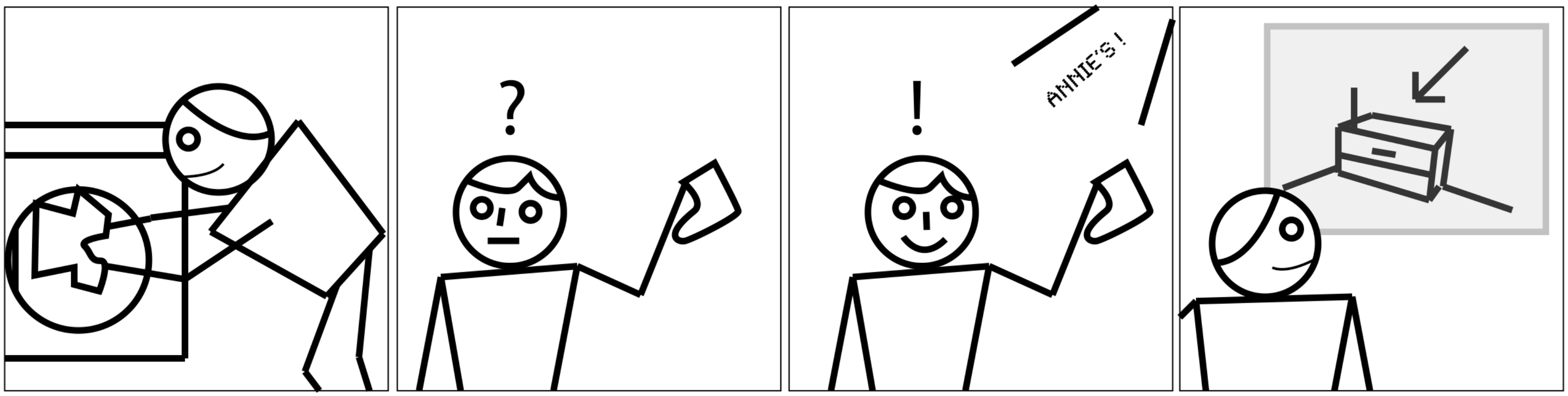
4



Mom's downstairs making breakfast.
She hears the cat's meow, and knows that Annie's dressed.

SCENARIO 14 :: Where does this go?

1 2 3 4



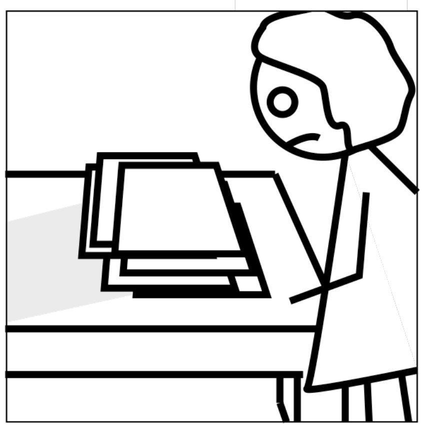
1. On his way past the washing machine, Dad picks up a pile of clean clothes.
2. “Whose socks are these?” And where do they go?”
3. The smart home tells Dad the socks are Annie’s...
4. ...and shows him where her sock drawer is.

SCENARIO 15 :: The Mystery Pile

1

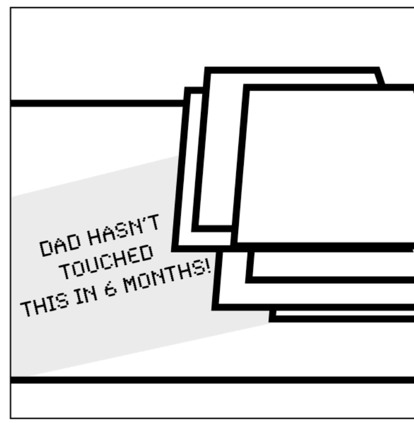
The whole family is coming over for the holidays. Mom decides to take on a "mystery pile" that's in the middle of the living room.

2



The smart home shows Mom who's stuff is in the pile, how long it's been there, and the last time they touched it.

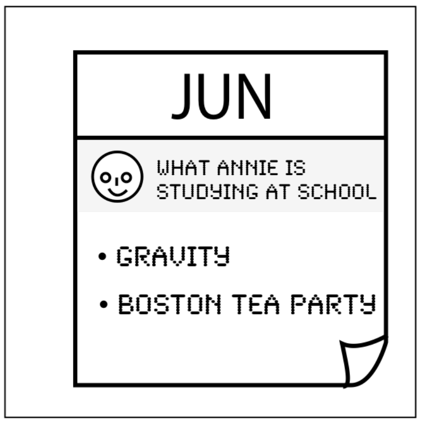
3



"Dad hasn't touched this in 6 months! It's outta here."

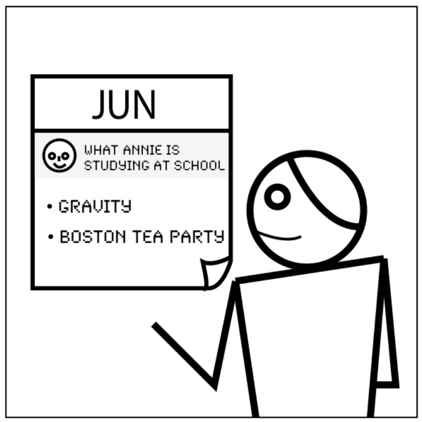
SCENARIO 16 :: Educational Opportunity

1



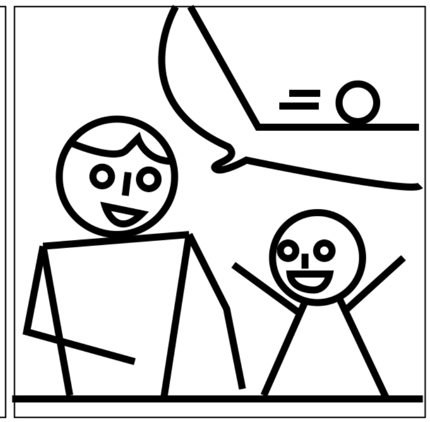
The smart home puts what Annie's studying in school on the family calendar.

2



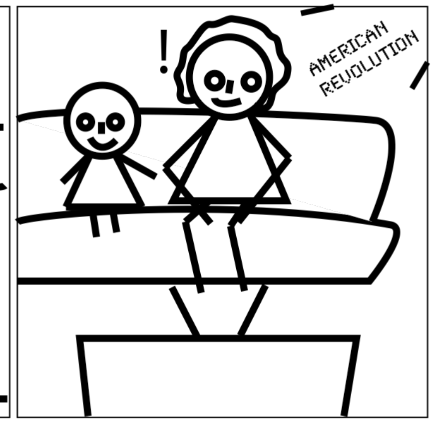
Dad takes a look at the calendar. He asks the smart home to help him make Physics more fun.

3



During dinner dad talks to Annie about an experiment they can do together. She's really excited about it.

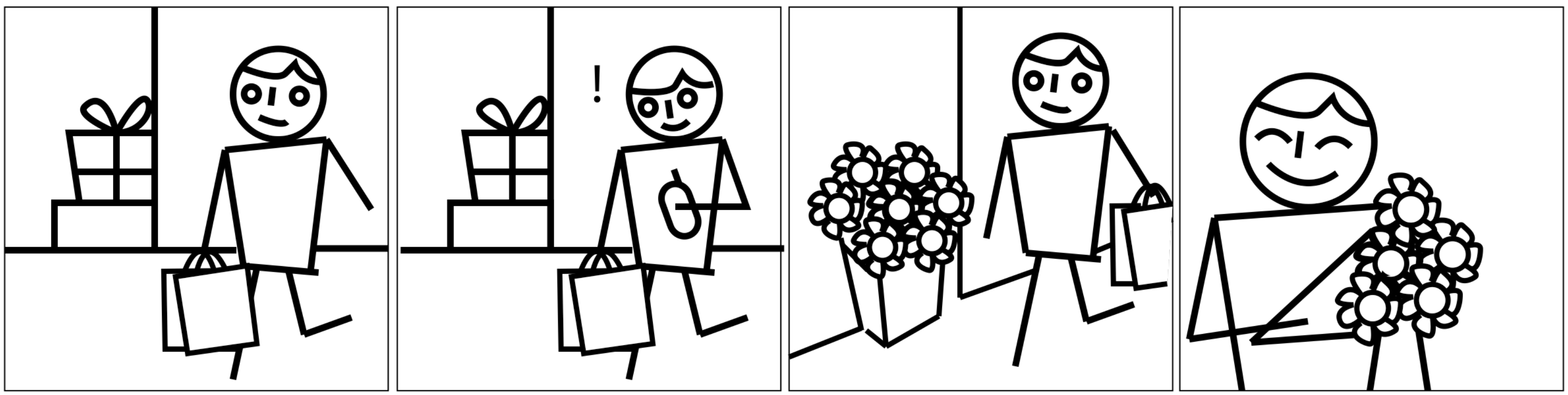
4



Later, the smart home tells Mom that there's a movie on cable about the American revolution. They decide to watch together.

SCENARIO 17 :: A Little Romance

1 2 3 4



1. Dad's at the mall. He doesn't know that he's right near Mom's favorite flower shop.

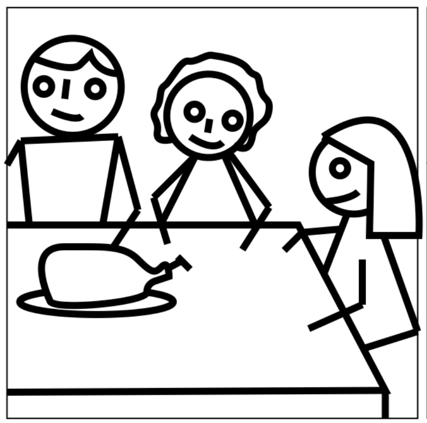
2. The smart home tells Dad the store's right around the corner.

3. Dad decides to get Mom a little surprise.

4. "That's so sweet of you."

SCENARIO 18 :: Thanksgiving Dinner

1

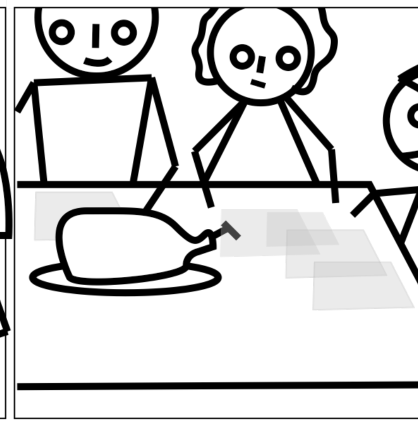


Everybody is at the table for Thanksgiving dinner.

2

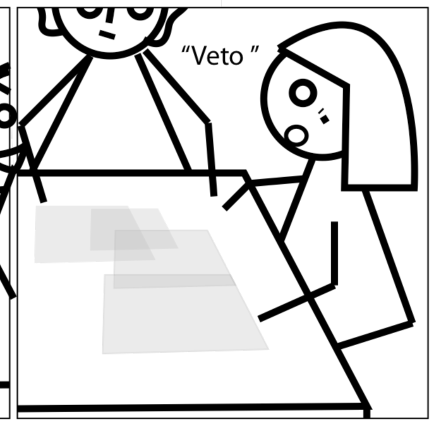
Somebody shouts "skeletons from our past"

3



The smart home selects random images from the house archive, and displays them on the table.

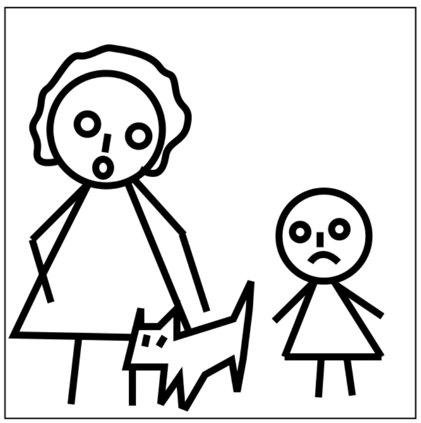
4



The cousin is embarrassed of a picture from her childhood. She shouts "veto, veto" and the house hides the picture and chooses another.

SCENARIO 19 :: "Do I Have To?"

1

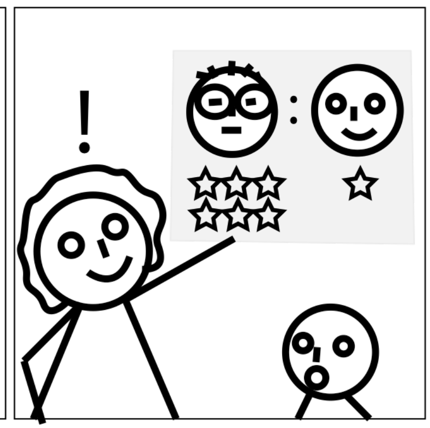


Mom asks Annie to walk the dog. Annie says "why do I always have to do it? What about Johnny?"

2

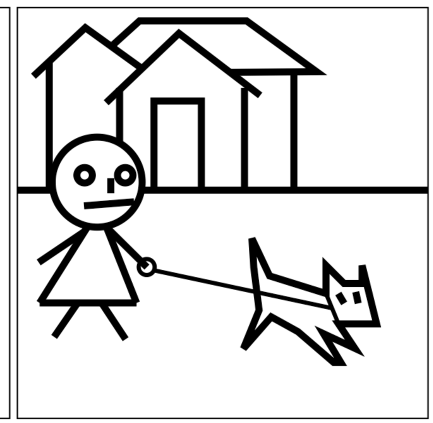
"Smart home, show me who walks the dog?"

3



The house produces a graphic that shows that Johnny walks the dog the most.

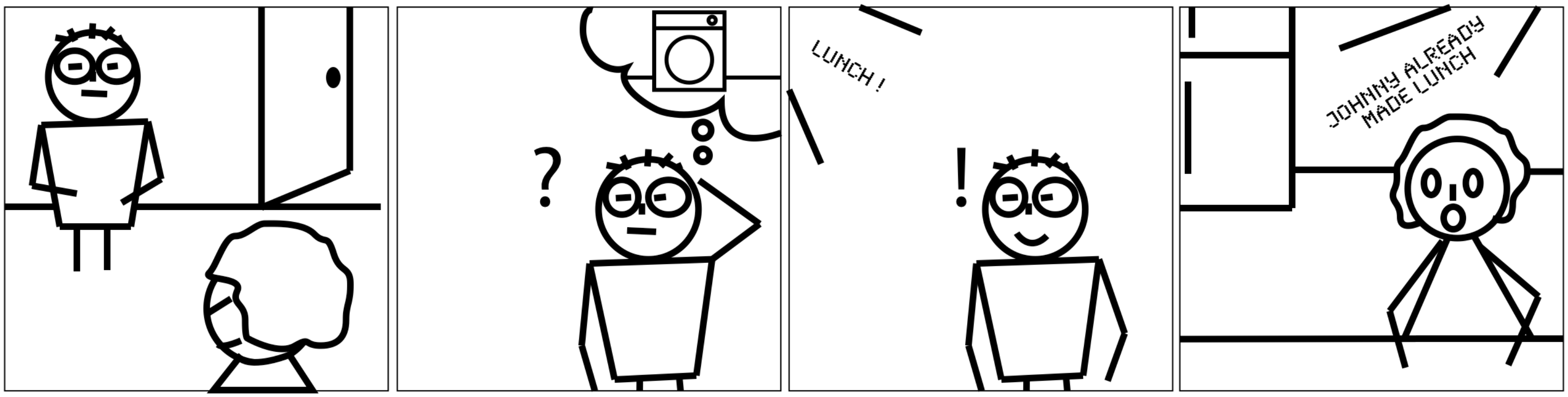
4



Annie takes the dog out.

SCENARIO 20 :: Good Karma

1 2 3 4



1. Johnny missed his curfew twice this weekend. Mom was worried sick about him.

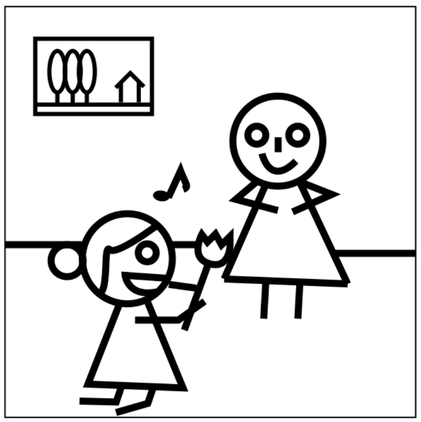
2. He wants to keep the peace at home. So he asks the smart home what chores Mom could use some help with.

3. Mom won't have time to make lunch for Annie. The house suggests that Johnny make her a PB+J sandwich.

4. The smart home tells mom that Johnny made lunch, and that she doesn't have to.

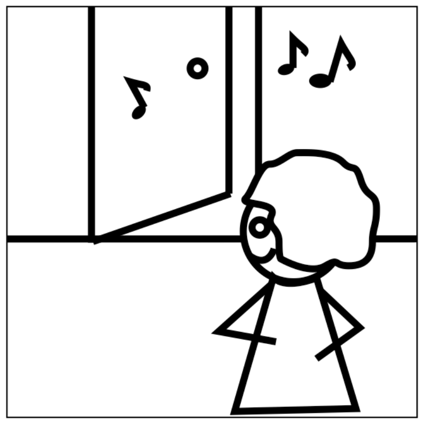
SCENARIO 21 :: Scrapbook

1



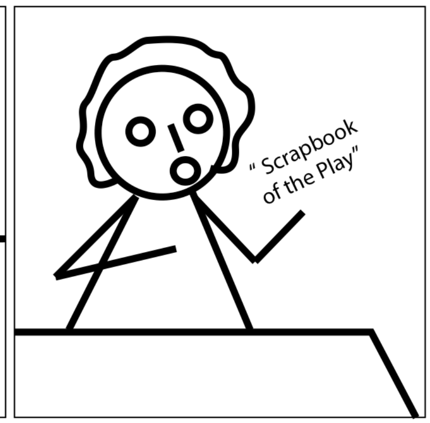
Annie and her friend are writing a musical play. They're practicing in her room.

2



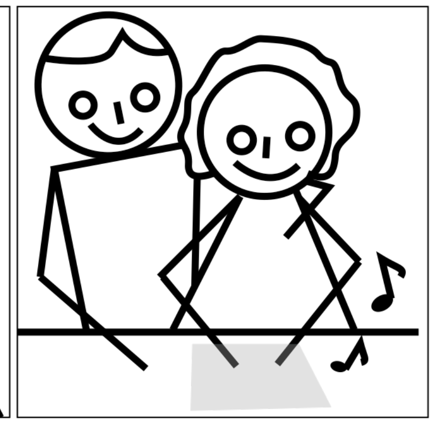
Mom hears the singing and giggling, and wants to watch, but doesn't want to disturb the scene with a grown up.

3



Later that night, Mom asks the smart home to make a scrapbook of the play.

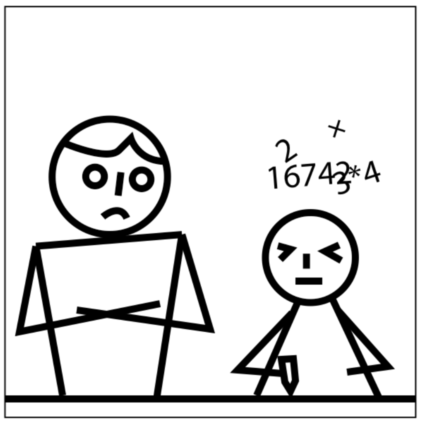
4



The smart home automatically puts together videos it recorded of the children playing, and adds a musical score.

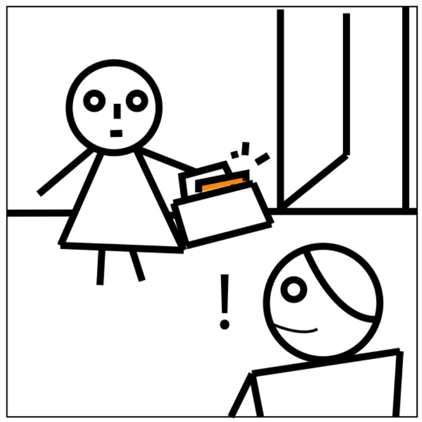
SCENARIO 22 :: Checking homework

1



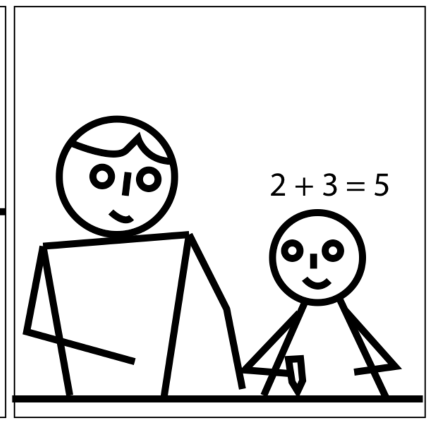
Annie's struggling with Math. Dad's worried. So he asks the smart house to keep an eye on her Math progress.

2



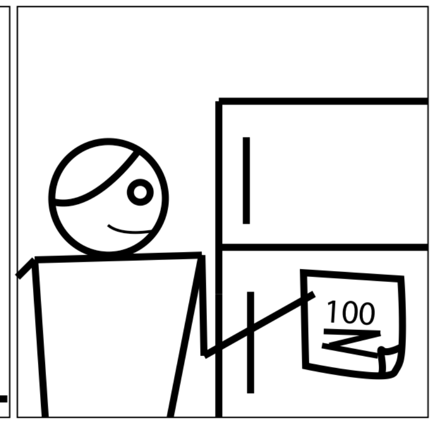
Annie's folder turns red whenever she has Math homework. Dad makes sure to check her work.

3



The smart home puts her test on the calendar, and Dad gives her extra help the night before.

4



Dad decides to put the test on the fridge.

Appendix D User Enactment Matrix and Scripts

Speed Dating Matrix

A compact representation of our Speed Dating Matrix for kids' activities. Concept dimensions form the row and column labels. Cells outline the content of user enactments, which juxtapose specified risk factors with social situations defined in the table structure. SH here refers to the "smart home." An extra row is added to explain deviation circumstances.

	Proactive	Soccer	Ballet	School
Begin	High	SH auto arranges carpool, interrupts to inform parent	SH auto adds lessons to calendar, interrupts to highlight conflict with doctor + reschedules	SH purchases supplies online, and prompts for optional items
	Medium	SH finds carpool availability, interrupts to inform parent	SH prompts to add to lessons to calendar, then highlights conflict and prompts to reschedule	SH auto adds supplies to shopping list and prompts to schedule shopping
	Low	SH informs parent when on phone with friend they could be driver	SH highlights schedule conflict when lessons are added manually	Constant ambient reminder via embedded picture frame
Routine	High	SH interrupts parent to inform that shin guards are not in bag	SH tells parent "you must" pick up your daughter from ballet	SH passes task from spouse to make lunch
	Medium	SH highlights bag as parent passes, indicating missing shin guards	SH tells parent "you should" pick up your daughter from ballet	SH adds lunch task to to-do list
	Low	Constant ambient reminder via embedded picture frame	SH asks parent to pick up daughter from ballet as favor to other parent	Constant ambient reminder via embedded picture frame
Deviate		What: Last-minute meeting and parent can't drive to soccer	What: Mom's away, and Dad needs a reminder of what to bring and when	What: Parents need to bring cookies for a school play in 2 weeks
	High	SH arranges new ride home for kid and informs parent	SH rearranges schedule and provides list of needed items	SH auto adds items to shopping list, auto schedules shopping
	Medium	SH asks friends for favor and relays their reply	SH suggests new schedule and suggests list of needed items	SH auto adds items to shopping list and prompts to schedule
	Low	SH asks friends for availability	Constant ambient reminder via embedded picture frame	SH prompts to add items to shopping list

Speed Dating Script

Introduction

Where	Office
When	N/A

Calendar:	Default
Photo frame:	Default
Laundry:	Default
Bags:	Default

Props:	Soccer picture

Experimenter: My name is Scott. I'll be helping you with the experiment today. I'll be reading from this script so that we can be sure that you have the same experience as other participants. If you have any questions at any time, feel free to interrupt me and ask.

The smart home of the future will, we believe, have much of the intelligence that people have. So the house will be able to recognize your family members when they come home. It will know where they are located, both within the house and outside the house. And the smart home will also have a basic understanding of what you and your family are doing. For example, if you're in the house doing the dishes, the smart home will be able to know that you're doing the dishes.

The home will also be connected to all sorts of information outside the house. This includes simple information like weather and traffic, as well as more complex information, like what's happening at school with your kids. The school will be able to send information directly to your smart house.

Lastly, the smart home will be able to talk to other smart homes. So your smart home might be able to contact the smart home of your friends and family, and exchange messages with them.

First, let's introduce you to your home...

Today, we don't yet have a functioning smart home. So we're going to use simple ways to pretend that room is a smart home. We're really just going to use people to play the role of the intelligence behind the house.

Let's show you what we mean.

In the kitchen, your calendar is a smart calendar. That means even though it's made of paper, we're going to pretend that its electronic, and connected to all the things that the house can do. You can write on it just like a normal calendar, and the smart home will be able to read and understand whatever you write.

The smart home might want to show you some things using the calendar. For example, if the smart home wants to remind you that you have a doctor's appointment today, the home might wait until you are in front of the calendar, and then it could make the appointment glow brighter.

Calendar: [highlight doctor's appointment]

Experimenter: We're going to use this yellow sticky note to represent when the calendar is "glowing." This is to grab your attention, and to suggest that you look at whatever is glowing yellow, like on a computer screen.

Your smart home will also have smart picture frames. The smart picture frames are also electronic, and the smart home can change their content. When the smart home changes the content of the smart picture frame, the smart home is trying to communicate with you. For example, normally, there will be a picture from a family vacation, like this one.

Picture Frame: [soccer picture]

Experimenter: But another time, when you look at the smart picture frame, you may see here a picture of children playing soccer. This picture could help remind your children to take their soccer equipment to school, and to remind you that they might need a ride home.

You'll find these picture frames in multiple locations throughout the home.

Sometimes the smart home will want to talk to you. Let me introduce [smart home]. S/he's going to play the role of the voice of the smart home. Your smart home has tiny speakers in every room, so it can communicate with you in every room of the house. When the smart home has something to tell you, you'll hear this tone [ding]. Your smart home also has microphones in every room of the house. So the smart home can hear you any time you want it to. If you want to hear what the smart home has to say, just say "yes" in a normal voice, and the smart home will tell you whatever it has to say. Let's give it a try.

Smart Home: [ding]

Participant: Yes?

Smart Home: Welcome to your smart home.

Experimenter: If you want to ignore the smart home, just don't say anything. If you want to hear the smart home's message later, just say "later."

The smart home is smarter than those phone systems you might have used with an airline or credit card company. You can feel free to speak to it in normal English.

Sometimes the smart home might want to help you find something you're looking for.

Flashlight: [something]

Experimenter: When the smart home shines a light on an object, it wants to help you notice that object. Here we're going to use a regular flashlight, shined by the smart home. You can imagine that every room will have some kind of projector on the ceiling, that can point to any object in the room.

You have a few possessions in our house. Here are your keys. And here is your cell phone. You should remember to take them with you when you go. And you'll want to put them somewhere when you head home.

Now, for this experiment, we're going to imagine you have two children. A boy named Johnny. He's 12. And a girl named Annie. She's 7. Johnny plays soccer, and Annie takes ballet lessons. They usually take money to school for lunch. But they're both finicky eaters. So on certain days, you make lunch for them.

As you move about the home and see things, it would be helpful to us if you would think out loud. That means that you should say the things you are doing, and the things that you see, and what you think they mean.

Lastly, today we're really interested in what you think. We didn't make this smart home. Our job is to help understand what you think and feel about it. So please feel comfortable telling us whatever you think. And we promise to break it to the design team gently. Your feedback can help us make the smart home better.

That's the introduction. Do you have any questions? Are you ready to begin? OK, then let's get started.

Soccer Beginning 1

Where:	Bedroom
When:	Morning

Calendar:	Default
Photo frame:	Default
Laundry:	Default
Bags:	Default

Props: Carpool schedule stickies

Experimenter: Johnny is starting the Fall Soccer season next week. You know you will need to set up a carpool some time soon, but you're a little busy right now.

This scene begins with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

Remember to think aloud as you move about.

Participant: [morning routine] [walks by calendar]

Smart home: [ding]

Participant: Yes?

Smart Home: Smart Home has arranged a carpool for Johnny's soccer season with his friends Tom and Daniel. I will update the calendar.

Calendar: [add carpool schedule to calendar]

Smart Home: Soccer practice is Monday, Wednesday and Friday. It ends at 6pm. You can pick the children up from school on Mondays. Tom's mom drives Wednesdays. Daniels's dad drives Fridays.

I have also added this to your personal schedule.

Soccer Beginning 2

Where:	Bedroom
When:	Morning

Calendar:	Default
Photo frame:	Default
Laundry:	Default
Bags:	Default

Props: Carpool schedule stickies

List of possible drivers and dates

Stickies with drivers name to put on calendar

Experimenter: Johnny is starting the Fall Soccer season next week. You know you will need to set up a carpool some time soon, but you're a little busy right now.

This scene begins with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

Remember to think aloud as you move about.

Participant: [morning routine] [walks by calendar]

Smart home: [ding]

Participant: Yes?

Smart Home: Would you like to quickly arrange a carpool for Johnny's soccer now?

Participant: Yes.

Calendar: [list of possible drivers and dates]

Smart Home: Soccer practice is Monday, Wednesday and Friday. It ends at 6pm. Tom, Daniel and Sally live close by.

Just tell me who you want to drive and when, and I will ask them.

Participant: ...

Calendar: [put carpooler names on calendar as participant says them]

Smart Home: Smart Home will inform you when ... and ... respond.

Soccer Beginning 3

Where:	Bedroom
When:	Morning

Calendar:	Default
Photo frame:	Default
Laundry:	Default
Bags:	Default

Props: None

Experimenter: Johnny is starting the Fall Soccer season next week. You know you will need to set up a carpool some time soon, but you're a little busy right now.

This scene begins with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

Remember to think aloud as you move about.

Participant: [morning routine] [walks by calendar]

Smart home: [ding]

Participant: Yes?

Smart Home: Would you like to quickly help arrange a carpool for Johnny's soccer now?

Participant: Yes.

Smart Home: Johnny's friends Tom, Daniel and Sally all live nearby and are playing soccer. Should I remind you about the carpool the next time you talk to each of them?

Participant: ...

Soccer Routine 1

Where: Living Room

When: Evening

Calendar: Default

Photo frame: Default

Laundry: Basket in living room, Uniform in front of dryer

Bags: Default

Props: Shin guards in garage

Image of shin guards for bag

Shopping bags

Experimenter: So in this scene, you'll be in your evening routine. You arrive home from shopping to an empty house. You put away your bag, you wallet and keys and then start dinner. You do a bit of laundry, set the table, eat dinner together, and then have a few minutes to read a magazine in the living room...

Participant: [carries shopping bags] [walks in door]

Smart home: [ding]

Participant: Yes?

Flashlight: [Shines on uniform]

Smart home: Tomorrow is Johnny's soccer day. His uniform is in the dryer. He probably won't forget it if you put it in his soccer bag, and move his soccer bag next to the door. The soccer bag is in his room.

Participant: [evening routine] [picks up bag]

Bag: [shows image of shin guards]

Smart Home: [ding]

Participant: Yes?

Smart Home: For soccer practice, Johnny will also need his shin guards. They are in the garage.

Participant: [evening routine] [goes to garage]

Flashlight: [shines on shin guards]

Participant: [evening routine] [reads magazine]

Smart Home: [ding]

Participant: Yes?

Smart Home: Annie's homework is complete. In Math, she made only 2 errors. Also, you missed your friend Sally's birthday. Smart home sent her flowers this afternoon.

Soccer Routine 2

Where:	Living Room
When:	Evening
Calendar:	Default
Photo frame:	Soccer
Laundry:	Default
Bags:	Soccer bag in living room
Props:	Shin guards in garage
	Image of shin guards for bag
	Shopping bags

Experimenter: So in this scene, you'll be in your evening routine. You arrive home from shopping to an empty house. You put away your bag, you wallet and keys, clean up a bit, and then start dinner. You do a bit of laundry, set the table, eat dinner together, and then have a few minutes to read a magazine in the living room...

Participant: [carries shopping bags] [walks in door]

Smart home: [ding]

Participant: Yes?

Flashlight: [Shines on bag]

Smart home: Tomorrow is Johnny's soccer day. He might forget his shin guards, as they are in the garage.

Participant: [evening routine] [goes to garage]

Flashlight: [shines on shin guards]

Participant: [evening routine] [reads magazine]

Smart Home: [ding]

Participant: Yes?

Smart Home: Annie's homework is complete. In Math, she made only 2 errors. Also, you missed your friend Sally's birthday. Smart home sent her flowers this afternoon.

Soccer Routine 3

Where:	Living Room
When:	Evening
Calendar:	Default
Photo frame:	Soccer
Door frame:	Soccer
Laundry:	Default
Bags:	Default
Props:	Shin guards in bag
	Glowing sticky for tomorrow soccer practice

Experimenter: So in this scene, you'll be in your evening routine. You arrive home from work to an empty house. You put away your bag, you wallet and keys, clean up a bit, and then start dinner. You do a bit of laundry, set the table, eat dinner together, and then have a few minutes to read a magazine in the living room...

Participant: [evening routine] [reads magazine]

Smart Home: [ding]

Participant: Yes?

Smart Home: Annie's homework is complete. In Math, she made only 2 errors. Also, you missed your friend Sally's birthday. Smart home sent her flowers this afternoon.

Soccer Deviation 1

Where:	Office
When:	Day

Calendar:	N/A
Photo frame:	N/A
Door frame:	N/A
Laundry:	N/A
Bags:	N/A

Props:	Email from boss
	Email from husband

Experimenter: Johnny informs you he has a soccer match on Wednesday evening at 4:45. This is the last soccer game of the season, and Johnny's playoff hopes are riding on this game. So you plan ahead.

You arrange it so you can leave work at 4:00. That should give you just enough time to pick Johnny up and make it to the game.

It's now 3:30 on Wednesday, and you're at work. You just received an urgent email from your boss.

Experimenter: [show email from boss]

Participant: [reads email]

Experimenter: Looks like you'll have to go to that meeting. As you are preparing for the meeting, you receive an email from your smart home.

Experimenter: [show email from smart home]

Participant: [reads email]

Soccer Deviation 2

Where:	Office
When:	Day

Calendar:	N/A
Photo frame:	N/A
Door frame:	N/A
Laundry:	N/A
Bags:	N/A

Props: Email from boss

Experimenter: Johnny informs you he has a soccer match on Wednesday evening at 4:45. This is the last soccer game of the season, and Johnny's playoff hopes are riding on this game. So you plan ahead.

You arrange it so you can leave work at 4:00. That should give you just enough time to pick Johnny up and make it to the game.

It's now 3:30 on Wednesday, and you're at work. You just received an urgent email from your boss.

Participant: [reads email]

Experimenter: Looks like you'll have to go to that meeting. As you are preparing for the meeting, your phone rings.

Smart home: [ring]

Participant: Hello.

Smart Home: Good afternoon! This is Smart Home. I have detected a conflict in your schedule. Soccer game is in conflict with board meeting. Would you like smart home to help you with this matter?

Participant: Yes.

Smart Home: Based on your family's schedule, your [husband/wife] may be able to help you. Should I ask him?

Participant: Yes.

Smart Home: One moment ... Your husband says he cannot. Among your friends, Mike, Sally and Gene look available. Should I ask one of them?

Participant: Call ...

Smart Home: Calling [friend] ... [Friend] agreed to pick up Johnny.

Soccer Deviation 3

Where: Office

When: Day

Calendar: N/A

Photo frame: N/A

Door frame: N/A

Laundry: N/A

Bags: N/A

Props: Email from boss

Email from husband

Experimenter: Your son, Johnny, informs you he has a soccer match on Wednesday evening at 4:45. This is the last soccer game of the season, and Johnny's playoff hopes are riding on this game. So you plan ahead.

You arrange it so you can leave work at 4:00. That should give you just enough time to pick Johnny up and make it to the game.

It's now 3:30 on Wednesday, and you're at work. You just received an urgent email from your boss.

Participant: [reads email]

Experimenter: Looks like you'll have to go to that meeting. As you are preparing for the meeting, your cell phone rings

Smart Home: Good afternoon! This is Smart Home. I would like to inform you of a conflict in your schedule. Soccer game is in conflict with board meeting. Would you like smart home to help you with this matter?

Participant: Yes.

Smart Home: Based on your family's schedule, your husband/wife may be able to help you. Would you like to call them?

Participant: Yes.

Smart Home: [dials spouse]

Spouse: Hi there. What's up?

Participant: ...?

Spouse: Sorry, I'm swamped as well. I wish I could help you out, but I can't at this moment.

Participant: ... [says goodbye]

Smart Home: This is Smart Home. Has your conflict been resolved?

Participant: No.

Smart Home: Among your friends, Mike, Sally and Gene look available. Would you like to call one of them?

Participant: Call ...

Smart Home: [ring ring]

Friend: Hello.

Participant: ...?

Friend: Sure. I'm heading that way anyway.

Participant: ...

Ballet Beginning 1

Where:	Living Room
When:	Evening

Calendar:	Default
Photo frame:	Default
Laundry:	In living room
Bags:	Default

Props:	Calendar, ballet lessons
	Calendar, conflict with orthodontist
	Ballet flyer

Experimenter: Your daughter Annie has really wanted to start ballet lessons. After a lot of discussion, you finally give in and tell her it's ok. You tell her to sign up at school. You'll figure out the details later.

So in this scene, you'll be in your evening routine. You arrive home from work to an empty house. You put away your bag, you wallet and keys and then start dinner. You do a bit of laundry, set the table, eat dinner together, and then have a few minutes to read a magazine in the living room...

Remember to think aloud as you move about.

Annie:	[enters] Mommy! Mommy! I signed up for ballet. Here. [hands flyer].
Smart home:	[ding]
Participant:	Yes?
Smart Home:	Annie's ballet lessons are now on the family calendar.
Calendar:	[Ballet lessons] [Sept. 14 conflict]
Flashlight:	[shine on conflict]
Smart Home:	Notice that Ballet on September 14 conflicts with orthodontist appointment. Would you like smart home to reschedule the appointment?
Participant:	...
Smart Home:	OK. I will inform you when the orthodontist confirms a new time.

or

Smart Home:	OK.

Participant: ... [evening routine] [walks by laundry room]

Smart Home: [ding]

Participant: Yes?

Smart Home: It would be helpful if you put away Johnny’s clothes.

Participant: [evening routine] [reads magazine]

Smart Home: [ding]

Participant: Yes?

Smart Home: You have so many things to do, and you always do them. You deserve a rest. Smart home has prepared a warm bath for you.

Ballet Beginning 2

Where:	Living Room
When:	Evening
Calendar:	Default
Photo frame:	Default
Laundry:	Living room
Bags:	Default
Props:	Calendar, ballet flyer
	Calendar, ballet lessons
	Calendar, conflict with orthodontist
	Ballet flyer

Experimenter: Your daughter Annie has really wanted to start ballet lessons. After a lot of discussion, you finally give in and tell her it's ok. You tell her to sign up at school. You'll figure out the details later.

So in this scene, you'll be in your evening routine. You arrive home from work to an empty house. You put away your bag, you wallet and keys and then start dinner. You do a bit of laundry, set the table, eat dinner together, and then have a few minutes to read a magazine in the living room...

Remember to think aloud as you move about.

Annie: [enters] Mommy! Mommy! I signed up for ballet. Here. [hands flyer].

Smart home: [ding]

Participant: Yes?

Smart Home: Annie's ballet lessons are shown next to the calendar. You can add them to the calendar now, or whenever you want to.

Calendar: [Ballet flyer on side]

[if adds to calendar]

Calendar: [Ballet lessons][Sept. 14 conflict]

Flashlight: [shine on conflict]

Smart Home: Notice that Ballet on September 14 conflicts with orthodontist appointment.

Participant:	... [evening routine] [walks by laundry room]
Smart Home:	[ding]
Participant:	Yes?
Smart Home:	It would be helpful if you put away Johnny's clothes.
Participant:	[evening routine] [reads magazine]
Smart Home:	[ding]
Participant:	Yes?
Smart Home:	You have so many things to do, and you always do them. You deserve a rest. Smart home has prepared a warm bath for you.

Ballet Beginning 3

Where:	Living Room
When:	Evening

Calendar:	Default
Photo frame:	Default
Laundry:	Living room
Bags:	Default

Props:	Calendar, ballet flyer
	Calendar, ballet lessons
	Calendar, conflict with orthodontist
	Ballet flyer

Experimenter: Your daughter Annie has really wanted to start ballet lessons. After a lot of discussion, you finally give in and tell her it's ok. You tell her to sign up at school. You'll figure out the details later.

So in this scene, you'll be in your evening routine. You arrive home from work to an empty house. You put away your bag, you wallet and keys and then start dinner. You do a bit of laundry, set the table, eat dinner together, and then have a few minutes to read a magazine in the living room...

Remember to think aloud as you move about.

Annie: [enters] Mommy! Mommy! I signed up for ballet. Here. [hands flyer].

Smart home: [ding]

Participant: Yes?

Smart Home: Annie's ballet lessons are shown next to the calendar. You can add them to the calendar now, or whenever you want to.

Calendar: [Ballet flyer on side]

[if adds to calendar]

Calendar: [Ballet lessons][Sept. 14 conflict]

Participant: ... [evening routine] [walks by laundry room]

Smart Home: [ding]

Participant: Yes?

Smart Home: It would be helpful if you put away Johnny's clothes.

Participant: [evening routine] [reads magazine]

Smart Home: [ding]

Participant: Yes?

Smart Home: You have so many things to do, and you always do them. You deserve a rest. Smart home has prepared a warm bath for you.

Ballet Routine 1

Where:	Bedroom
When:	Morning

Calendar:	Ballet lessons
Photo frame:	Default
Laundry:	Default
Bags:	Default

Props:	Husband's personal calendar
	Mom's personal calendar
	Ballet pick-up sticky

Experimenter: Now that Annie's started ballet, she needs a ride to and from ballet practice. You and your wife/husband usually decide who will drive sometime during the morning rush. But today your husband has an early day. He is already at work.

So this scene begins with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

Remember to think aloud as you move about.

Participant: [morning routine] [walks by calendar]

Smart home: [ding]

Participant: Yes?

Smart Home: Someone needs to pick up Annie from ballet this evening.

Calendar: [husband personal calendar] [wife personal calendar]

Your husband/wife has a very busy schedule. So you have been scheduled to pick up Annie from her lesson.

This has been added to your personal and the family calendar.

Calendar: [new pick-up]

Smart Home: Your husband/wife has also been notified.

Ballet Routine 2

Where: Bedroom

When: Morning

Calendar: Ballet lessons

Photo frame: Default

Laundry: Default

Bags: Default

Props: Husband's personal calendar

Mom's personal calendar

Ballet pick-up sticky

Experimenter: Now that Annie's started ballet, she needs a ride to and from ballet practice. You and your wife/husband usually decide who will drive sometime during the morning rush. But today your husband has an early day. He is already at work.

So this scene begins with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

	Remember to think aloud as you move about.
Participant:	[morning routine] [walks by calendar]
Smart home:	[ding]
Participant:	Yes?
Smart Home:	Someone needs to pick up Annie from ballet this evening.
Calendar:	[husband personal calendar] [wife personal calendar]
Smart Home:	Your husband/wife has a very busy schedule. Would you like to pick up Annie from her lesson?
Participant:	...
Smart Home:	OK. You have been scheduled to pick up Annie tonight at 6pm.
	or
Smart Home:	OK. Smart home will ask your husband/wife if they can pick up Annie from ballet
Calendar:	[new pick-up]

Ballet Routine 3

Where:	Bedroom
When:	Morning
Calendar:	Ballet lessons
Photo frame:	Default
Laundry:	Default
Bags:	Default
Props:	Husband's personal calendar
	Mom's personal calendar
	Ballet pick-up sticky

Experimenter: Now that Annie's started ballet, she needs a ride to and from ballet practice. You and your wife/husband usually decide who will drive sometime during the morning rush. But today your husband has an early day. He is already at work.

So this scene begins with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

Remember to think aloud as you move about.

Participant: [morning routine] [walks by calendar]

Smart home: [ding]

Participant: Yes?

Smart Home: Your husband/wife has left you a voice mail about Annie's ballet practice tonight. Should I play the message?

Participant: ...

Smart Home: Playing Message. "Honey, I'm sorry, but I'm swamped tonight. I can't pick up Annie. Could you do it today?" End of Message.

Smart home can send your husband/wife a voice mail in response. Would you like smart home to send them a message?

Participant: ...

Smart Home: Sending message. [optionally] Smart home will add this to your personal schedule and to the family calendar.

Calendar: [personal schedule ballet pick-up sticky]

Ballet Deviation 1

Where:	Bedroom
When:	Morning

Calendar:	Ballet lessons
Photo frame:	Default
Laundry:	Default
Bags:	Default

Props: Husband/wife’s personal calendar

Ballet pick-up sticky

List of what daughter needs for ballet

Ballet shoes in living room

Experimenter: Annie goes to ballet directly after school. So she has to remember to take all her ballet things to school on ballet days. Making sure Annie doesn’t forget anything becomes your husband/wife’s job.

Today, your husband/wife is away on a business trip. So in addition to your normal morning, you’ll have to make sure Annie gets out the door with her ballet stuff.

So this scene begins with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

Remember to think aloud as you move about.

Participant: [morning routine] [walks by calendar]

Smart home: [ding]

Participant: Yes?

Smart Home: Here's your schedule today.

Calendar: [Husband/wife personal schedule]

Smart Home: Because your husband/wife is away, Smart home has added ballet to your schedule. You need to leave work 30 minutes early.

Calendar: [Ballet pick-up sticky]

Smart Home: Annie must also take her ballet things to school. I have prepared a list of what Annie needs to bring to ballet.

Calendar: [List of what daughter needs for ballet]

Smart Home: I can help you find anything that's missing. Smart home will remind you at work and will provide directions for you.

Ballet Deviation 2

Where:	Bedroom
When:	Morning
Calendar:	Ballet lessons
Photo frame:	Default
Laundry:	Default
Bags:	Default
Props:	Husband/wife's personal calendar
	Ballet pick-up sticky
	List of what daughter needs for ballet
	Ballet shoes in living room

Experimenter: Annie goes to ballet directly after school. So she has to remember to take all her ballet things to school on ballet days. Making sure Annie doesn't forget anything becomes your husband/wife's job.

Today, your husband/wife is away on a business trip. So in addition to your normal morning, you'll have to make sure Annie gets out the door with her ballet stuff.

So this scene begins with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

Remember to think aloud as you move about.

Participant: [morning routine] [walks by calendar]

Smart home: [ding]

Participant: Yes?

Smart Home: Here's your schedule today.

Calendar: [Husband/wife personal schedule]

Smart Home: Because your husband/wife is away, you may want to add ballet to your schedule.

Calendar: [Ballet pick-up sticky]

Smart Home: Annie must also take her ballet things to school. If you want, I can prepare a list of what Annie needs to bring to ballet for you.

Participant: ...

Calendar: [List of what daughter needs for ballet]

Smart Home: I can help you find anything that's missing. I can also remind you at work that you have to leave early. Would you like smart home to remind you?

Participant: ...

Smart Home: Reminder is set.

or

Smart Home: OK.

Smart Home: I will provide directions for you at work.

Ballet Deviation 3

Where: Bedroom

When: Morning

Calendar: Ballet lessons

Photo frame: Ballet

Laundry: Default

Bags: Default

Props: Ballet image for photo frame

Countdown image for photo frame

What daughter needs image for photo frame

Ballet shoes in living room

Experimenter: Annie goes to ballet directly after school. So she has to remember to take all her ballet things to school on ballet days. Making sure Annie doesn't forget anything becomes your husband/wife's job.

Today, your husband/wife is away on a business trip. So in addition to your normal morning, you'll have to make sure Annie gets out the door with her ballet stuff.

So this scene begins with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

Remember to think aloud as you move about.

Photo frame: [ballet image] [event time] [list of items to bring]

School Beginning 1

Where:	Bedroom
When:	Morning
Calendar:	Default
Photo frame:	Default
Laundry:	Default
Bags:	Default
Props:	Email from school
	Shopping list
	Shopping list item stickies for fridge

Experimenter: So this scene begins with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

Johnny is starting 3rd grade in about a month. When you get up, you check your email, and notice that the school has sent you a list of supplies that he needs for the upcoming school year.

Remember to think aloud as you move about.

Email: [school supplies]

Smart home: [ding]

Participant: Yes?

Smart home: First day of school has been added to your calendar. Smart Home will purchase the required items for you online.

Participant: [morning routine] [looks at calendar]

Smart Home: [ding]

Participant: Yes?

Smart Home: The required school supplies have been purchased.

Shopping list: [check bought items]

Smart Home: Since Annie owns a backpack, it was unnecessary to buy one. Your required school shopping is complete. If you'd like, Smart home can buy the optional compass.

Participant: ...

Smart Home: OK. Smart home will purchase the optional items, and notify you when the purchase is complete

or

Smart Home: OK.

Participant: ... [morning routine]

Smart Home: at the wrong time [ding]

Participant: Yes?

Smart Home: Your cell phone is ...

School Beginning 2

Where:	Bedroom
When:	Morning

Calendar:	First day of school sticky
Photo frame:	Default
Laundry:	Default
Bags:	Default

Props:	Email from school
	Shopping list
	Shopping day sticky for calendar
	Shopping list item stickies for fridge
	Glowing shopping day sticky for calendar

Experimenter: So this scene begins with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

This scenario is going involve two smaller scenes that cover both today, and three weeks from today

Johnny is starting 3rd grade in about a month. When you get up, you check your email, and notice that the school has sent you a list of supplies that he needs for the upcoming school year.

Remember to think aloud as you move about.

Email:	[school supplies]
Smart home:	[ding]
Participant:	Yes?
Smart Home:	First day of school has been added to your calendar. The required school supplies have been added to your shopping list. Since Annie owns a backpack, I will not add one to the shopping list.
List:	[Required Item stickies]
Smart Home:	A shopping trip has been tentatively scheduled for two weeks from today.
Calendar:	[Shopping day sticky]

Participant: ... [morning routine]

Smart Home: at the wrong time [ding]

Participant: Yes?

Smart Home: Your cell phone is ...

School Beginning 3

Where:	Bedroom
When:	Morning
Calendar:	Default
Photo frame:	Green, school and school supply images
Laundry:	Default
Bags:	Default
Props:	Photo frame school image
	Photo frame school supply images
	Photo frame green border
Experimenter:	Johnny is starting 3rd grade in about a month. When you get up, you check your email, and notice that the school has sent you a list of supplies that he needs for the upcoming school year.
Email:	[school supplies]
Photo Frame:	[glowing school picture]

Participant: ... [morning routine]

Smart Home: at the wrong time [ding]

Participant: Yes?

Smart Home: Your cell phone is ...

School Routine 1

Where:	Bedroom
When:	Morning
Calendar:	Glowing lunch day sticky
Photo frame:	Lunch box
Door:	Lunch box
Laundry:	Default
Bags:	Default
Alarm clock:	Early start sticky
Props:	Lunch box image for photo frame
	Early start sticky for clock
	Lunch day sticky for calendar

Experimenter: It's 6 am. You are sleeping in your bed. The light turns on smoothly, and you wake up by the light. You check what time it is now.

So this scene begins with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

Remember to think aloud as you move about.

Participant: [morning routine] [walks into kitchen]

Smart Home: [ding]

Participant: Yes?

Smart Home: Smart home asked your husband to make lunch. He said you would do it. Here's the menu.

Fridge: [show menu]

Participant: [morning routine] ...

Experimenter: [cell phone rings] Your cell phone sounds like it's ringing.

Participant: [answers phone]

Smart Home2 This is your friend Sally's Smart Home. Can you pick up sally's daughter from school at 3pm and watch her for about an hour?

Participant: [morning routine] [finishes making lunch]

Smart Home: [ding]

Participant: Yes?

Smart Home: Annie won't forget her lunch box if you put it in her bag.

Participant: [Puts the lunchbox in her bag]

School Routine 2

Where: Bedroom

When: Morning

Calendar: Glowing lunch day sticky

Photo frame: Lunch box

Door: Lunch box

Laundry: Default

Bags: Default

Props: Lunch box image for photo frame

Lunch day sticky for calendar

Experimenter: So this scene begins with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

Remember to think aloud as you move about.

Participant: [morning routine] [walks into kitchen]

Smart Home: [ding]

Participant: Yes?

Smart Home: It's your turn to make lunch. Annie requests a bologna sandwich.

Participant: [morning routine] ...

Experimenter: [cell phone rings] Your cell phone sounds like it's ringing.

Participant: [answers phone]

Smart Home2 This is your friend Sally's Smart Home. Can you pick up sally's daughter from school at 3pm and watch her for about an hour?

Participant: [morning routine] [finishes making lunch]

Smart Home: [ding]

Participant: Yes?

Smart Home: Annie won't forget her lunch box if you put it in her bag.

Participant: [Puts the lunchbox in her bag]

School Routine 3

Where:	Bedroom
When:	Morning
Calendar:	Glowing lunch day sticky
Photo frame:	Default
Door:	Lunch box
Laundry:	Default
Bags:	Default
Props:	Lunch box image for door
	Lunch day sticky for calendar

Experimenter: So this scene begins with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

Remember to think aloud as you move about.

School Deviation 1

Where:	Bedroom
When:	Morning

Calendar:	Default
Photo frame:	Default
Door:	Default
Laundry:	Default
Bags:	Default

Props: Play flyer

Cookies and oranges stickies for shopping list

Play photo for photo frames

Cookies and oranges images for photo frames

Glowing shopping trip for calendar

Experimenter: This next part is going to occur in two time periods.

In the first part of this scene, you'll be in your evening routine. You arrive home from work to an empty house. You put away your bag, you wallet and

keys and then start dinner. You do a bit of laundry, set the table, eat dinner together, and then have a few minutes to read a magazine in the living room...

Remember to think aloud as you move about.

Participant: [evening routine] [sets the table]

Annie: [runs in] Mommy! Mommy! Look what they gave me at school [hands flyer]. I'm off to play [leaves]

Smart home: [ding]

Participant: Yes?

Smart Home: Automatically adding cookies and oranges to the shopping list. Shopping is tentatively scheduled for Thursday.

Participant ... [finishes evening routine]

Photo Frame: [Play photos with countdown and items to buy]

Experimenter: The second half of the scene begins with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

Remember to think aloud as you move about.

Participant: [morning routine] [glances at calendar]

Smart Home: [ding]

Participant: Yes?

Smart Home: You have shopping planned at 4pm today for Annie's snack for the play.

Calendar: [shopping trip glowing]

Smart Home: The needed items are on your shopping list.

School Deviation 2

Where:	Bedroom
When:	Morning
Calendar:	Default
Photo frame:	Default
Door:	Default
Laundry:	Default
Bags:	Default
Props:	Play flyer
	Cookies and oranges stickies for shopping list
	Play photo for photo frames
	Cookies and oranges images for photo frames
	Glowing shopping trip for calendar

Experimenter: This next part is going to occur in two time periods.

In the first part of this scene, you'll be in your evening routine. You arrive home from work to an empty house. You put away your bag, you wallet and

keys and then start dinner. You do a bit of laundry, set the table, eat dinner together, and then have a few minutes to read a magazine in the living room...

Remember to think aloud as you move about.

Participant: [evening routine] [sets the table]

Annie: [runs in] Mommy! Mommy! Look what they gave me at school [hands flyer]. I'm off to play [leaves]

Smart home: [ding]

Participant: Yes?

Smart Home: Automatically adding cookies and oranges to the shopping list. It seems like you have some free time on Thursday. Should we schedule shopping for Thursday?

Participant: ...

Smart Home: OK.

or

Smart Home: OK. I will put the date on the calendar. Do you want to be reminded?

Photo Frame: [Play photos]

Participant ... [finishes evening routine]

Calendar: [shopping trip glowing]

Photo Frame: [Play photos with countdown and items to buy]

Experimenter: The second half of the scene begins on Thursday, with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

Remember to think aloud as you move about.

Participant: [morning routine]

School Deviation 3

Where:	Bedroom
When:	Morning

Calendar:	Default
Photo frame:	Default
Door:	Default
Laundry:	Default
Bags:	Default

Props:	Play flyer
	Cookies and oranges stickies for shopping list
	Play photo for photo frames
	Cookies and oranges images for photo frames
	Glowing shopping trip for calendar

Experimenter: This next part is going to occur in two time periods.

In the first part of this scene, you'll be in your evening routine. You arrive home from work to an empty house. You put away your bag, you wallet and

keys and then start dinner. You do a bit of laundry, set the table, eat dinner together, and then have a few minutes to read a magazine in the living room...

Remember to think aloud as you move about.

Participant: [evening routine] [sets the table]

Annie: [runs in] Mommy! Mommy! Look what they gave me at school [hands flyer]. I'm off to play [leaves]

Smart home: [ding]

Participant: Yes?

Smart Home: Automatically adding cookies and oranges to the shopping list.

Photo Frame: [Play photos]

Participant ... [finishes evening routine]

Calendar: [shopping trip glowing]

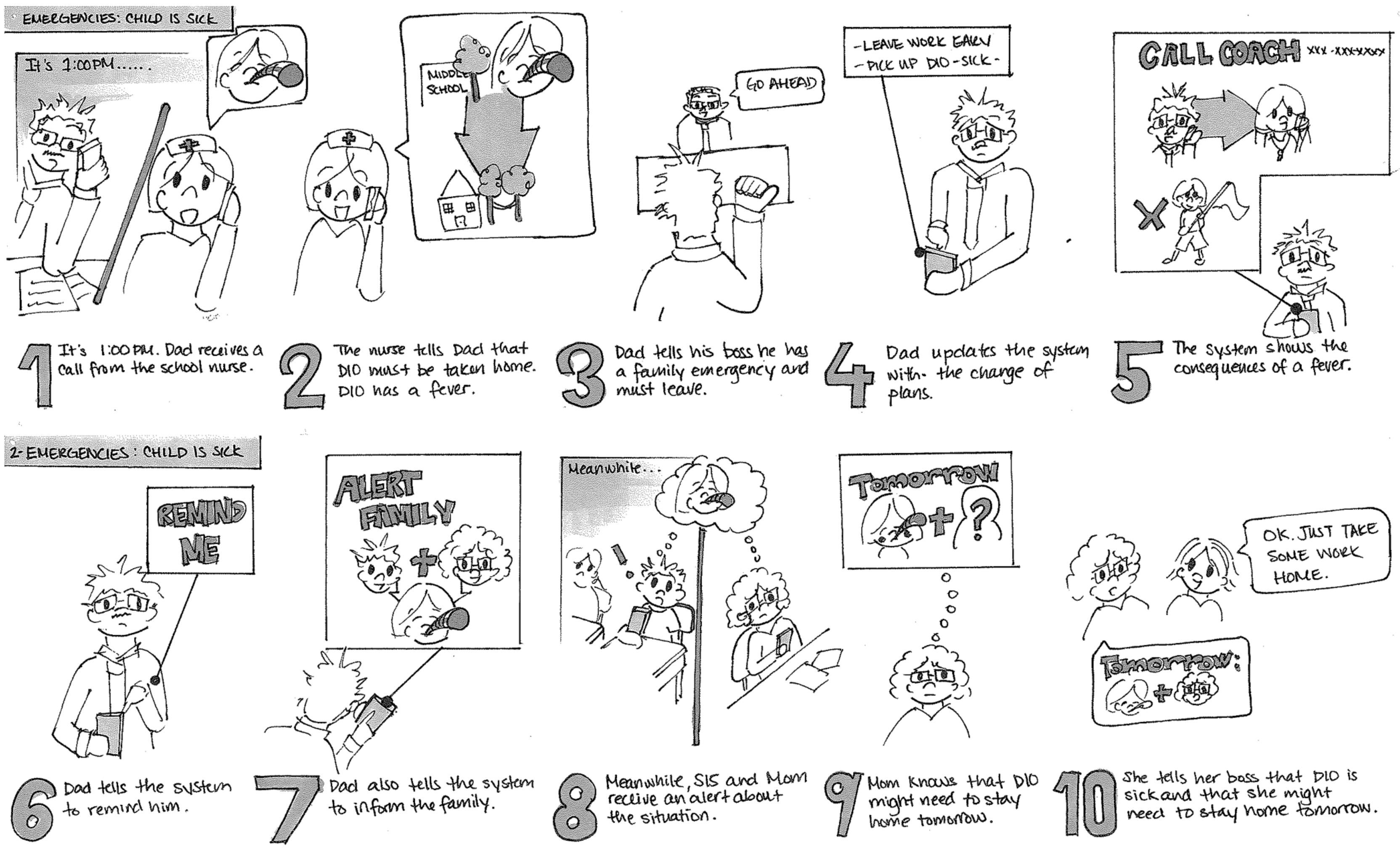
Photo Frame: [Play photos with countdown and items to buy]

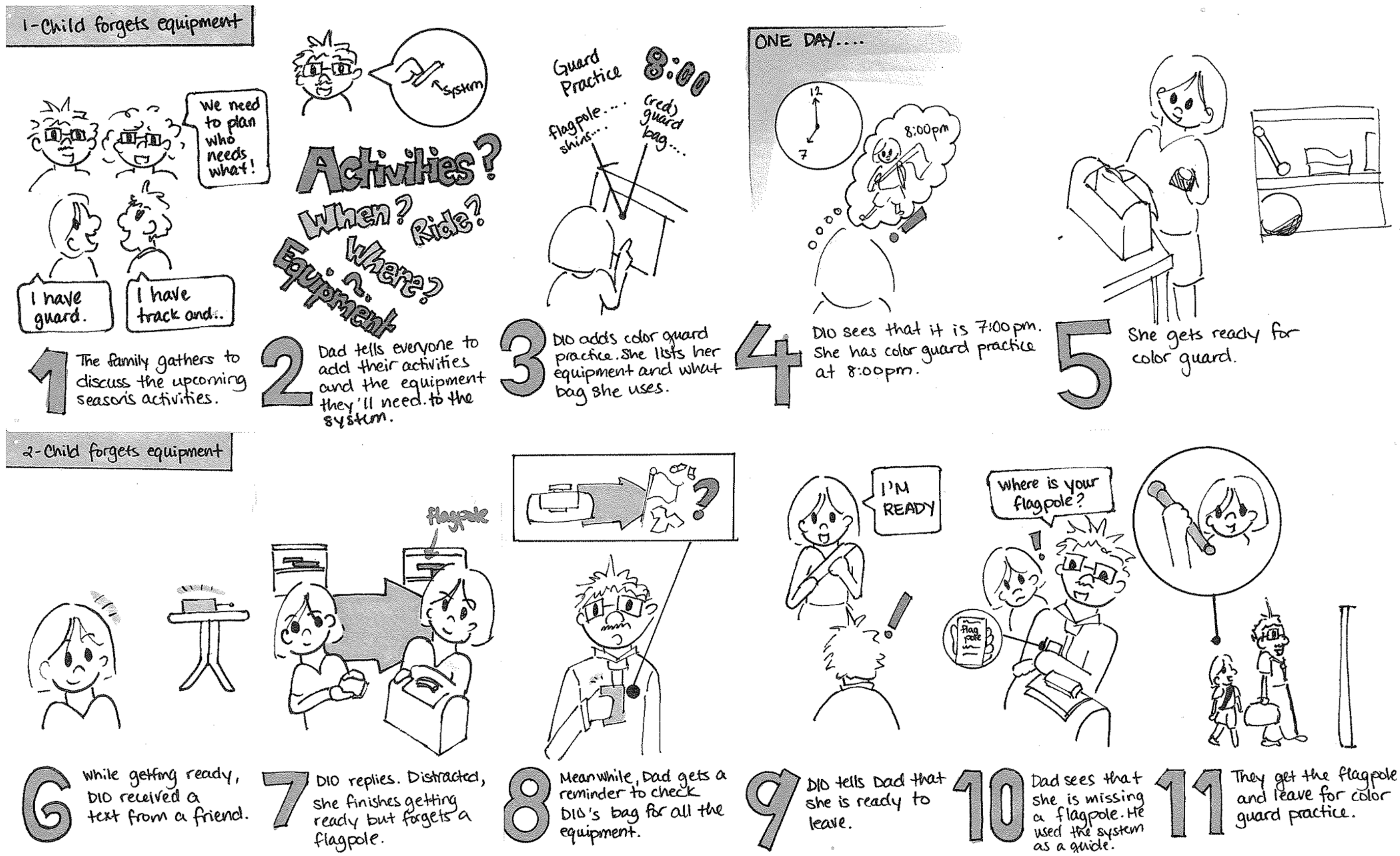
Experimenter: The second half of the scene begins on Thursday, with your morning routine. Your job is to get everybody out the door on time, with all their stuff. This means you and the kids will need to eat. Everybody has to remember to take their things with them when they go. For the kids, this means their homework. And for you, this means your keys and cell phone. You'll want to check the calendar and see what you have to do that day.

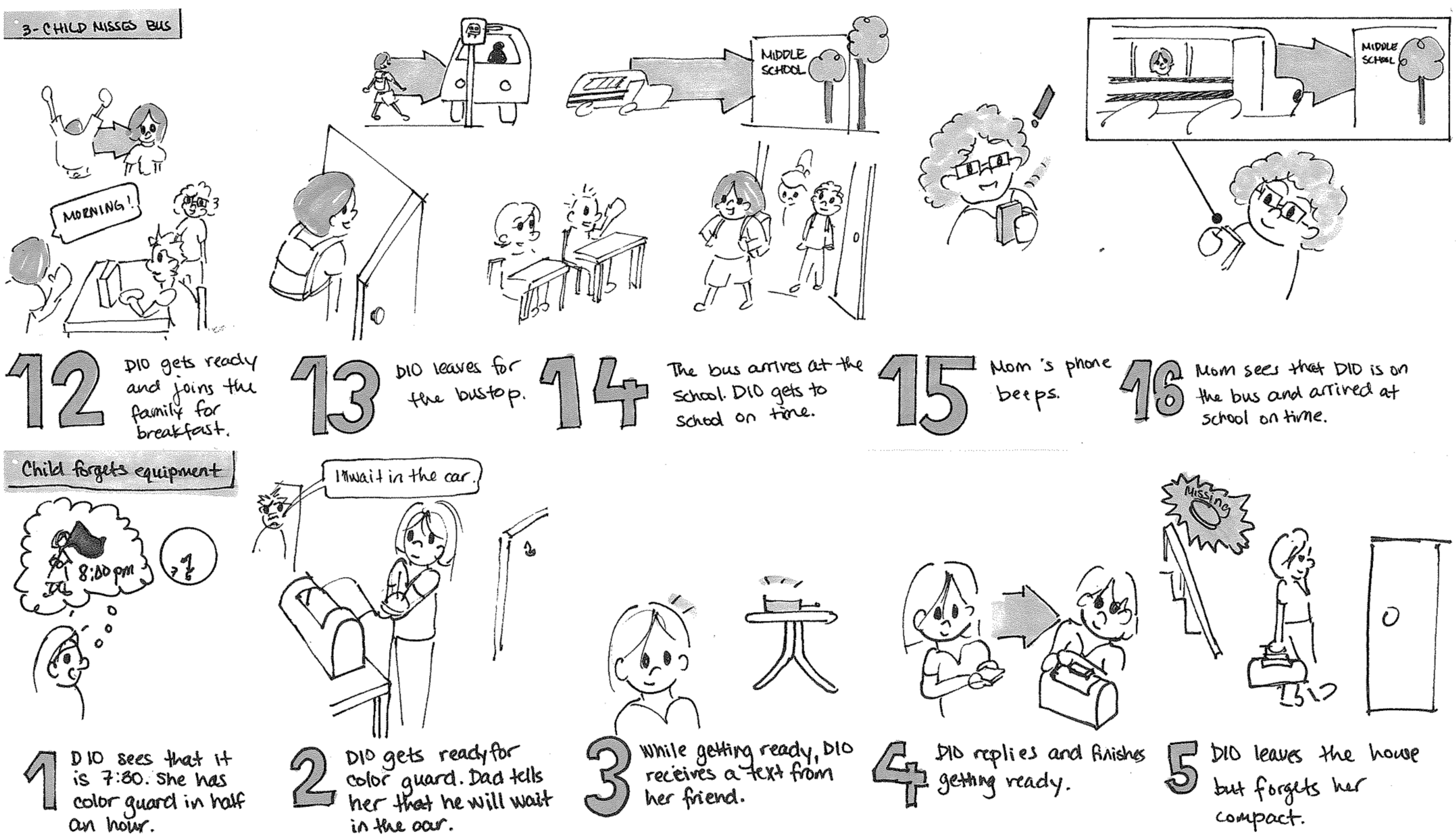
Remember to think aloud as you move about.

Participant: [morning routine]

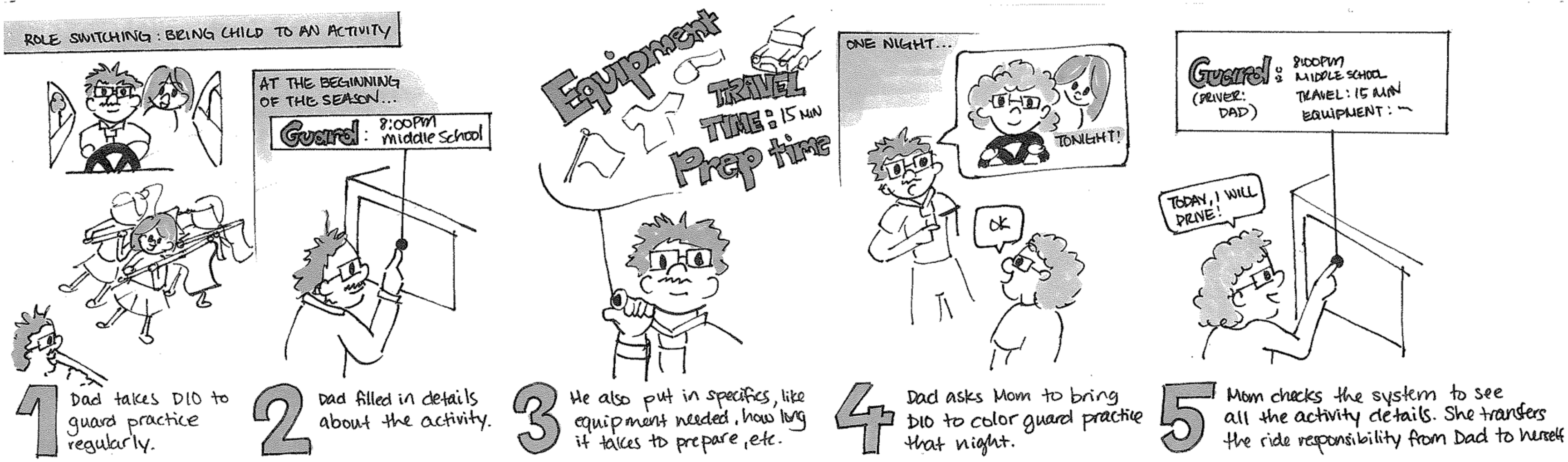
Appendix E Reminder System Storyboards

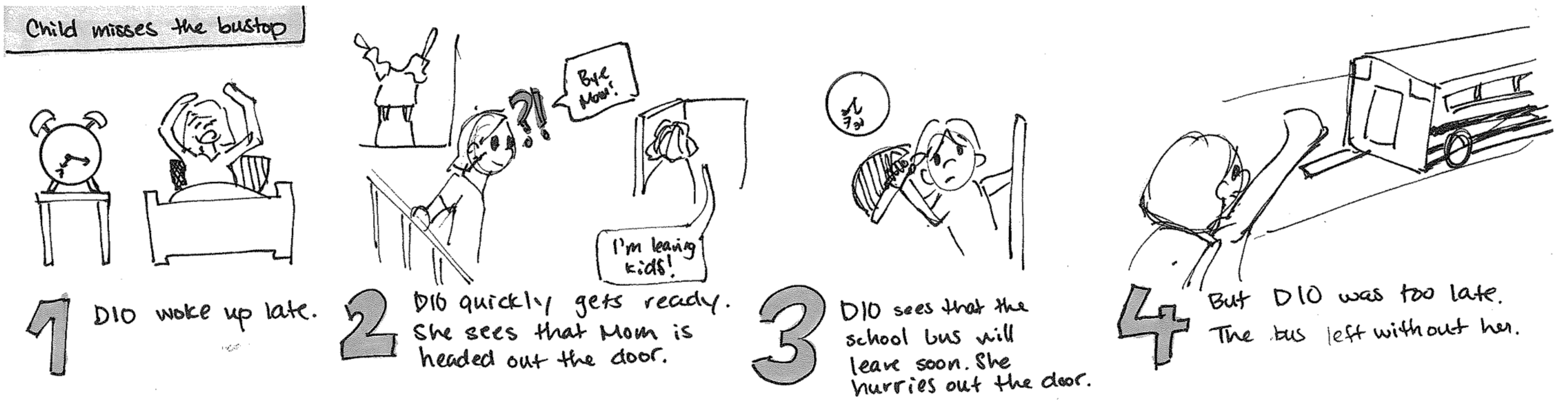


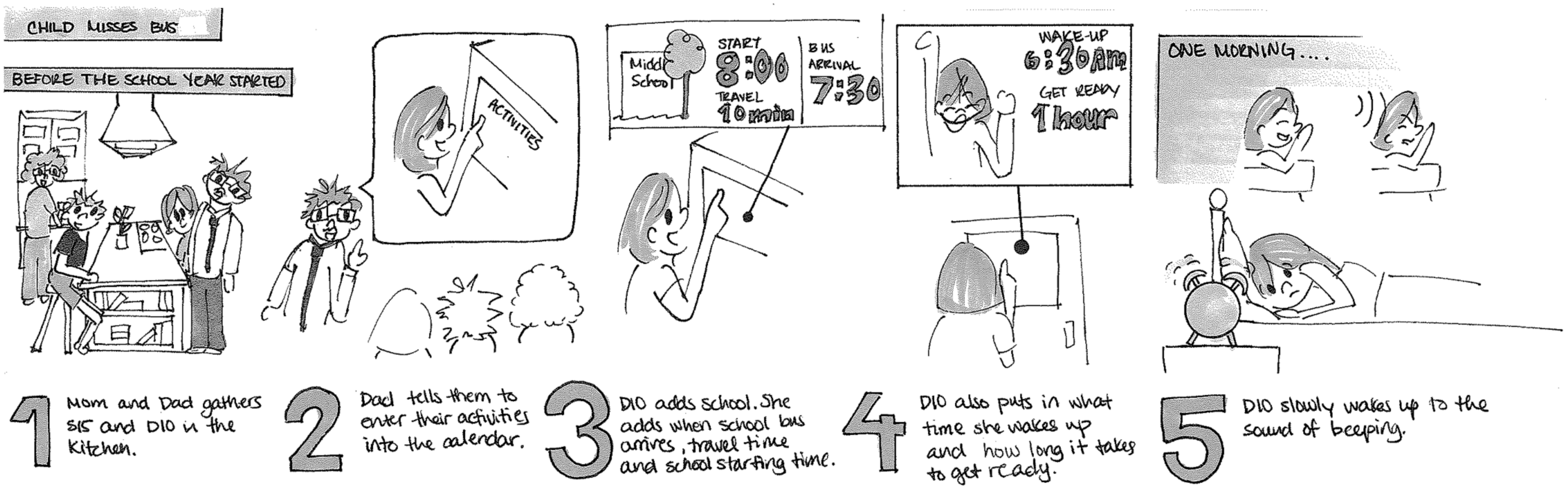

1-Child forgets equipment
We need to plan who needs what!
I have guard.
I have track and..
1 The family gathers to discuss the upcoming season's activities.
System
Activities? When? Ride? Where? Equipment?
2 Dad tells everyone to add their activities and the equipment they'll need to the system.
Guard Practice 8:00
flagpole.... shirts....
(red) guard bag....
3 DIO adds color guard practice. She lists her equipment and what bag she uses.
ONE DAY....
8:00pm
4 DIO sees that it is 7:00pm. She has color guard practice at 8:00pm.
5 She gets ready for color guard.
2-Child forgets equipment
6 While getting ready, DIO received a text from a friend.
flagpole
7 DIO replies. Distracted, she finishes getting ready but forgets a flagpole.
8 Meanwhile, Dad gets a reminder to check DIO's bag for all the equipment.
I'M READY
9 DIO tells Dad that she is ready to leave.
Where is your flagpole?
flag pole
10 Dad sees that she is missing a flagpole. He used the system as a guide.
11 They get the flagpole and leave for color guard practice.

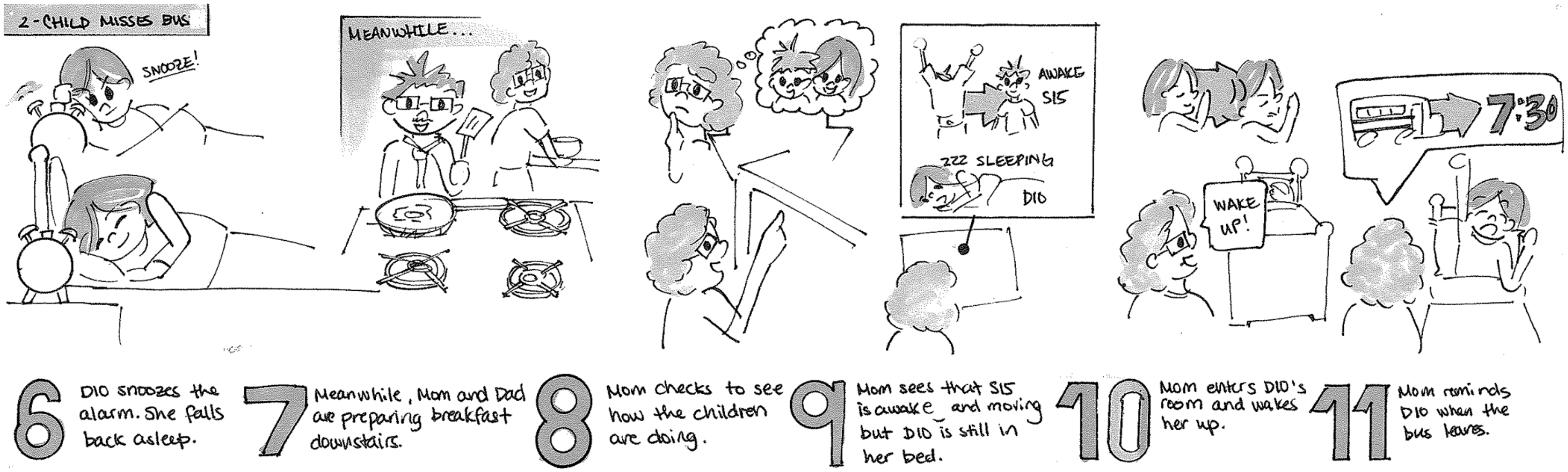

3- CHILD MISSES BUS
MORNING!
MIDDLE SCHOOL
MIDDLE SCHOOL
12 DIO gets ready and joins the family for breakfast.
13 DIO leaves for the bustop.
14 The bus arrives at the school. DIO gets to school on time.
15 Mom's phone beeps.
16 Mom sees that DIO is on the bus and arrived at school on time.
Child forgets equipment
8:00pm
I'll wait in the car.
Missing
1 DIO sees that it is 7:30. She has color guard in half an hour.
2 DIO gets ready for color guard. Dad tells her that he will wait in the car.
3 While getting ready, DIO receives a text from her friend.
4 DIO replies and finishes getting ready.
5 DIO leaves the house but forgets her compact.

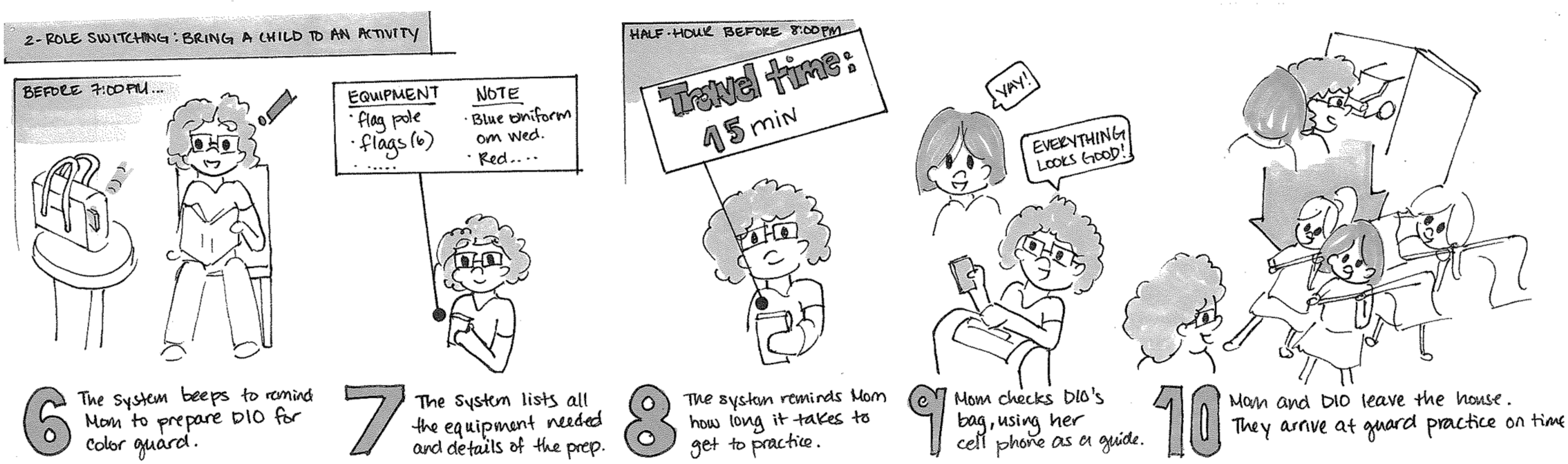

Bring child to Activity
Tonight!
OK.
1 Dad asks Mom to bring D10 to guard practice.
Yes mom!
8:00!
2 At 7:30, Mom reminds D10 to get ready for color guard practice.
3 But D10 gets ready in a rush and leaves some things behind.
School
4 Mom drives D10 to school in a hurry. They are late.


ROLE SWITCHING : BRING CHILD TO AN ACTIVITY
1 Dad takes D10 to guard practice regularly.
AT THE BEGINNING OF THE SEASON...
Guard! : 8:00PM middle school
2 Dad filled in details about the activity.
Equipment
TRAVEL TIME: 15 MIN
Prep time
3 He also put in specifics, like equipment needed, how long it takes to prepare, etc.
ONE NIGHT...
TONIGHT!
OK
4 Dad asks Mom to bring D10 to color guard practice that night.
Guard! : 8:00PM MIDDLE SCHOOL
(DRIVER: DAD)
TRAVEL: 15 MIN
EQUIPMENT: ~
TODAY, I WILL DRIVE!
5 Mom checks the system to see all the activity details. She transfers the ride responsibility from Dad to herself

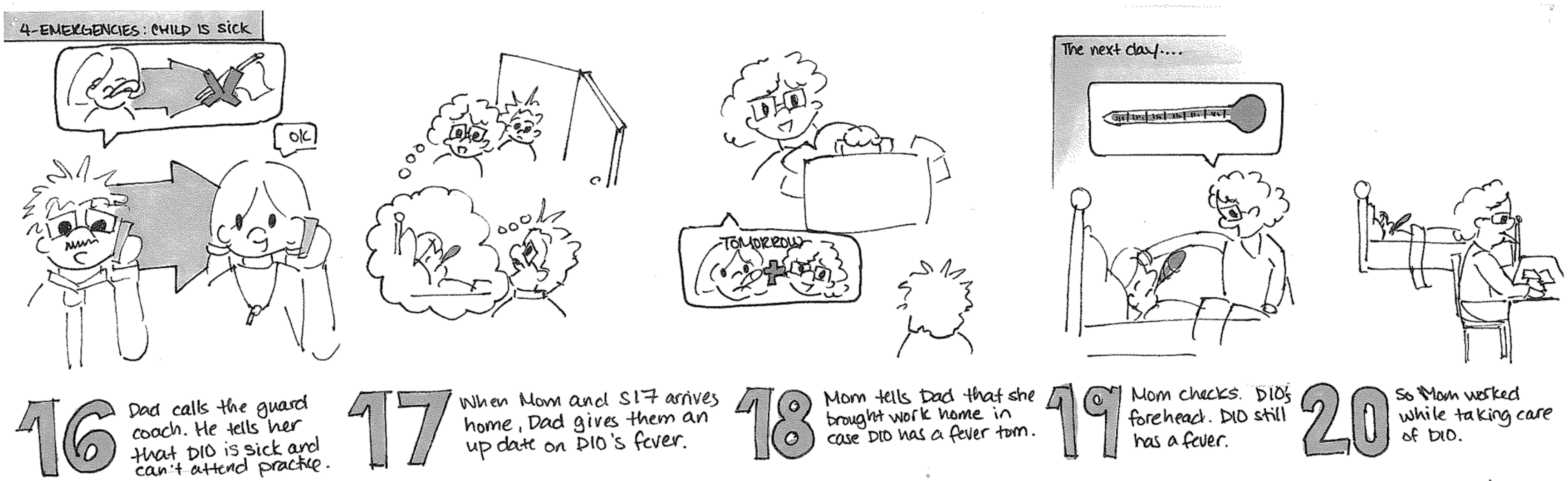

Child misses the bustop
Bye Mom!
I'm leaving kids!
1 DIO woke up late.
2 DIO quickly gets ready. She sees that Mom is headed out the door.
3 DIO sees that the school bus will leave soon. She hurries out the door.
4 But DIO was too late. The bus left without her.

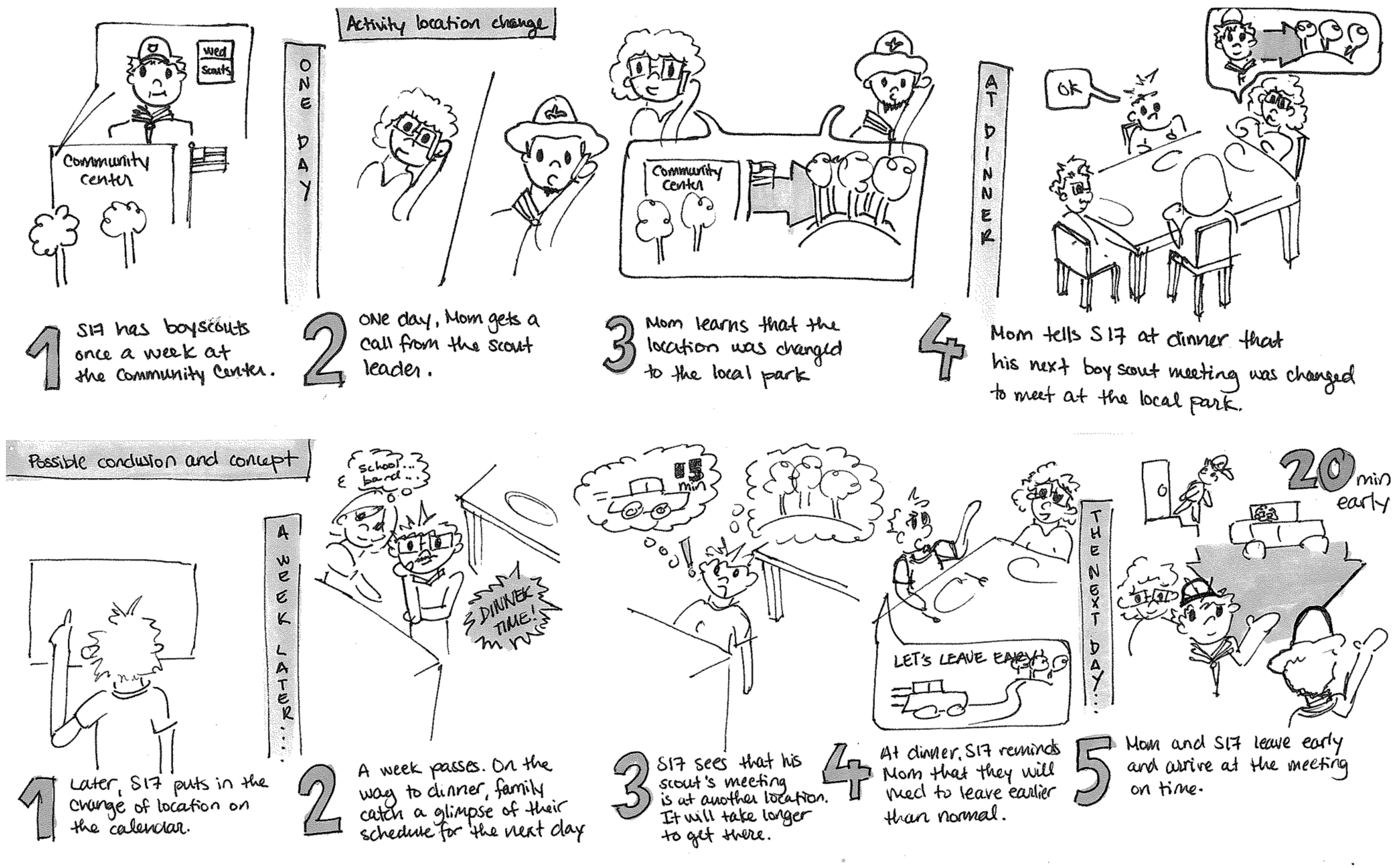

CHILD MISSES BUS
BEFORE THE SCHOOL YEAR STARTED
ACTIVITIES
Middle School
START 8:00
TRAVEL 10 min
BUS ARRIVAL 7:30
WAKE-UP 6:30 Am
GET READY 1 hour
ONE MORNING....
1 Mom and Dad gathers SIS and DIO in the Kitchen.
2 Dad tells them to enter their activities into the calendar.
3 DIO adds school. She adds when school bus arrives, travel time and school starting time.
4 DIO also puts in what time she wakes up and how long it takes to get ready.
5 DIO slowly wakes up to the sound of beeping.


2-CHILD MISSES BUS
SNOOZE!
MEANWHILE...
AWAKE
SIS
zzz SLEEPING
DIO
WAKE UP!
7:30
6 DIO snoozes the alarm. She falls back asleep.
7 Meanwhile, Mom and Dad are preparing breakfast downstairs.
8 Mom checks to see how the children are doing.
9 Mom sees that SIS is awake and moving but DIO is still in her bed.
10 Mom enters DIO's room and wakes her up.
11 Mom reminds DIO when the bus leaves.

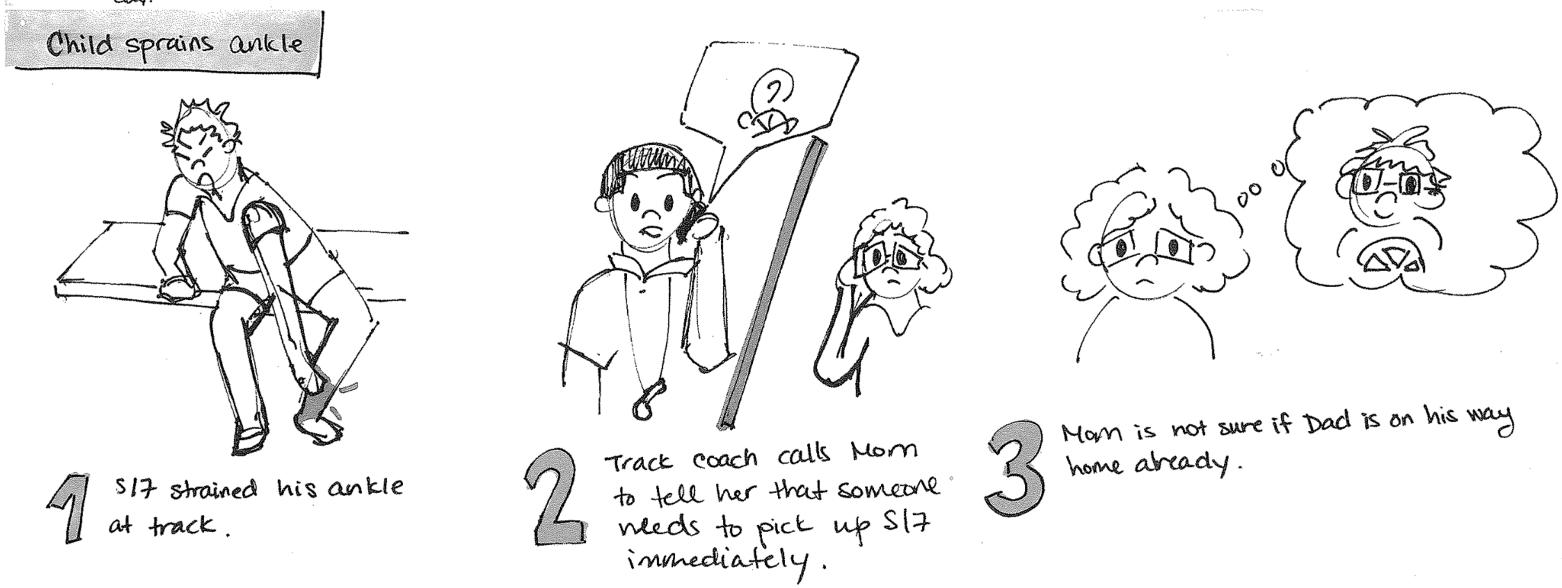

2-ROLE SWITCHING: BRING A CHILD TO AN ACTIVITY
BEFORE 7:00PM...
EQUIPMENT
· flag pole
· flags (6)
· .....
NOTE
· Blue uniform on Wed.
· Red...
HALF-HOUR BEFORE 8:00PM
Travel time:
15 min
YAY!
EVERYTHING LOOKS GOOD!
6 The system beeps to remind Mom to prepare DIO for color guard.
7 The system lists all the equipment needed and details of the prep.
8 The system reminds Mom how long it takes to get to practice.
9 Mom checks DIO's bag, using her cell phone as a guide.
10 Mom and DIO leave the house. They arrive at guard practice on time

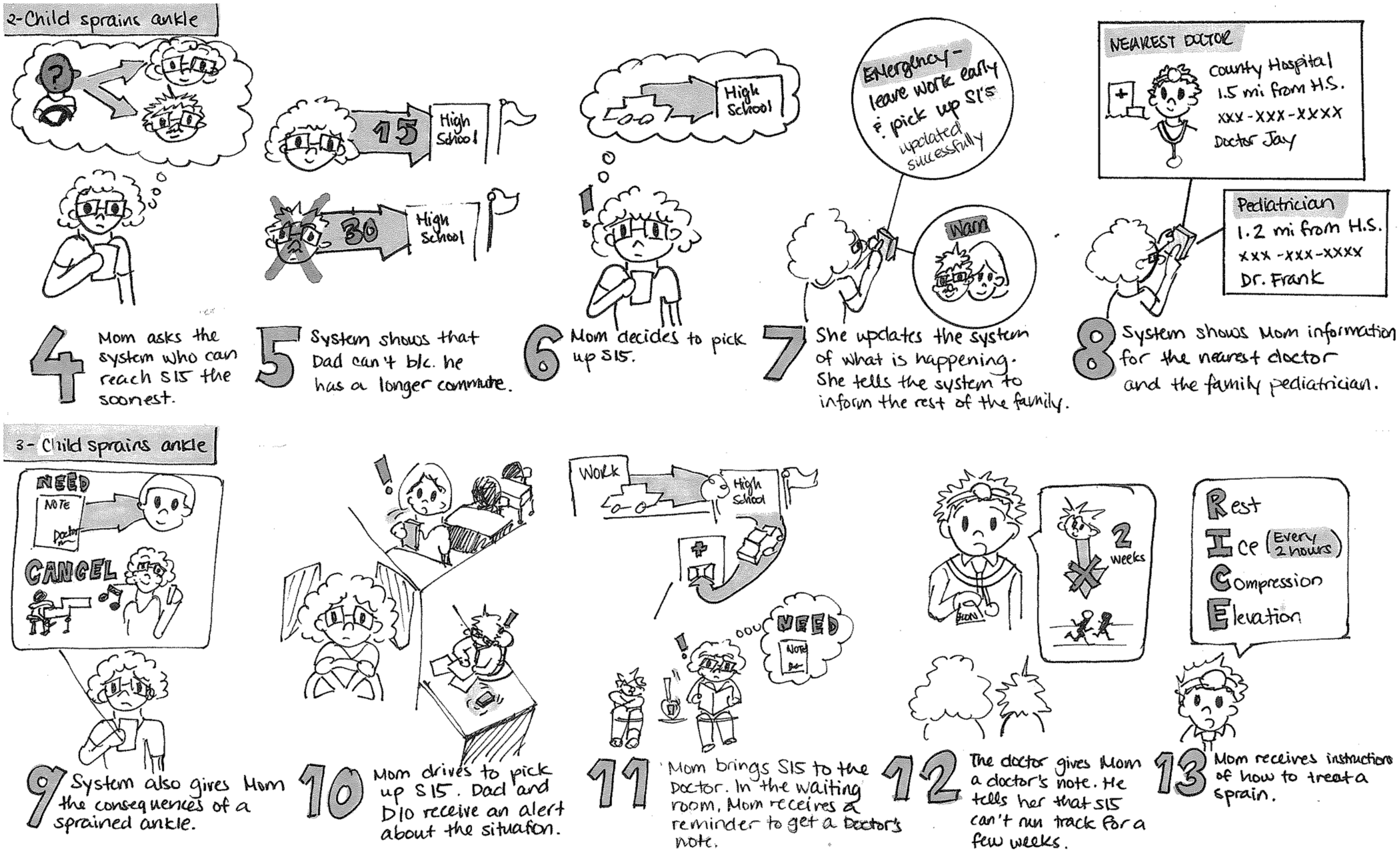

3-EMERGENCIES : CHILD IS SICK
REMIND ME
HOME
LATER....
MIDDLE SCHOOL
FEVER
HEADACHE
HOME
CALL COACH!
XXX - XXX - XXXX
11 Mom puts in a reminder to bring work home.
12 Dad drives to the Middle School to pick up DIO.
13 The nurse tells Dad that DIO has a fever and a headache.
14 Dad takes DIO home and makes her comfortable.
15 The system beeps to remind Dad to contact the guard coach


4-EMERGENCIES : CHILD IS SICK
OK
TOMORROW
The next day....
16 Dad calls the guard coach. He tells her that DIO is sick and can't attend practice.
17 When Mom and SI7 arrives home, Dad gives them an up date on DIO's fever.
18 Mom tells Dad that she brought work home in case DIO has a fever tom.
19 Mom checks. DIO's forehead. DIO still has a fever.
20 So Mom worked while taking care of DIO.

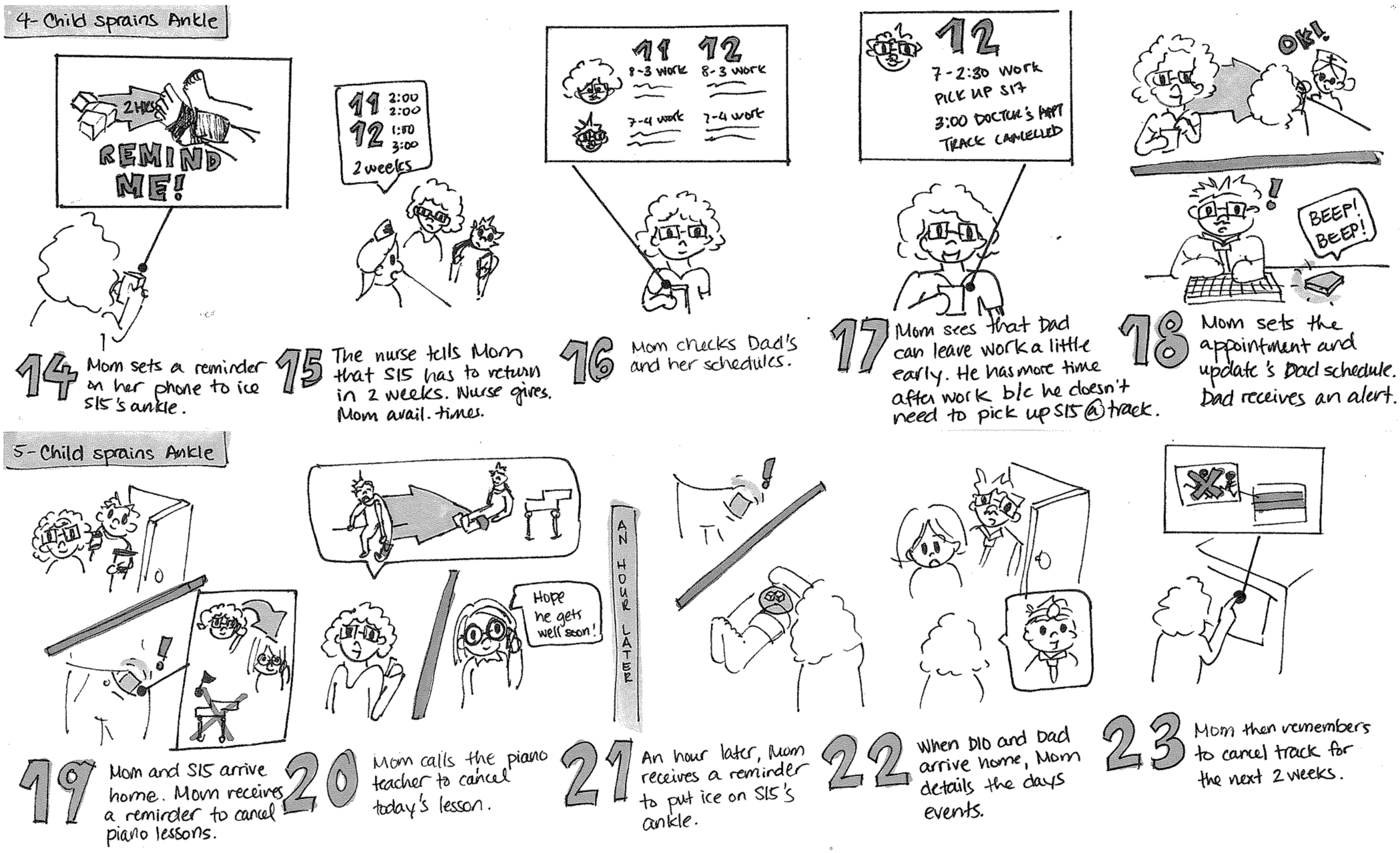

Activity location change
wed Scouts
Community center
ONE DAY
1 S17 has boyscouts once a week at the community center.
2 ONE day, Mom gets a call from the scout leader.
Community center
3 Mom learns that the location was changed to the local park
AT DINNER
OK
4 Mom tells S17 at dinner that his next boy scout meeting was changed to meet at the local park.
Possible conclusion and concept
A WEEK LATER...
1 Later, S17 puts in the change of location on the calendar.
school board...
DINNER TIME!
2 A week passes. On the way to dinner, family catch a glimpse of their schedule for the next day
15 min
3 S17 sees that his scout's meeting is at another location. It will take longer to get there.
LET'S LEAVE EARLY!
THE NEXT DAY...
4 At dinner, S17 reminds Mom that they will need to leave earlier than normal.
20 min early
5 Mom and S17 leave early and arrive at the meeting on time.

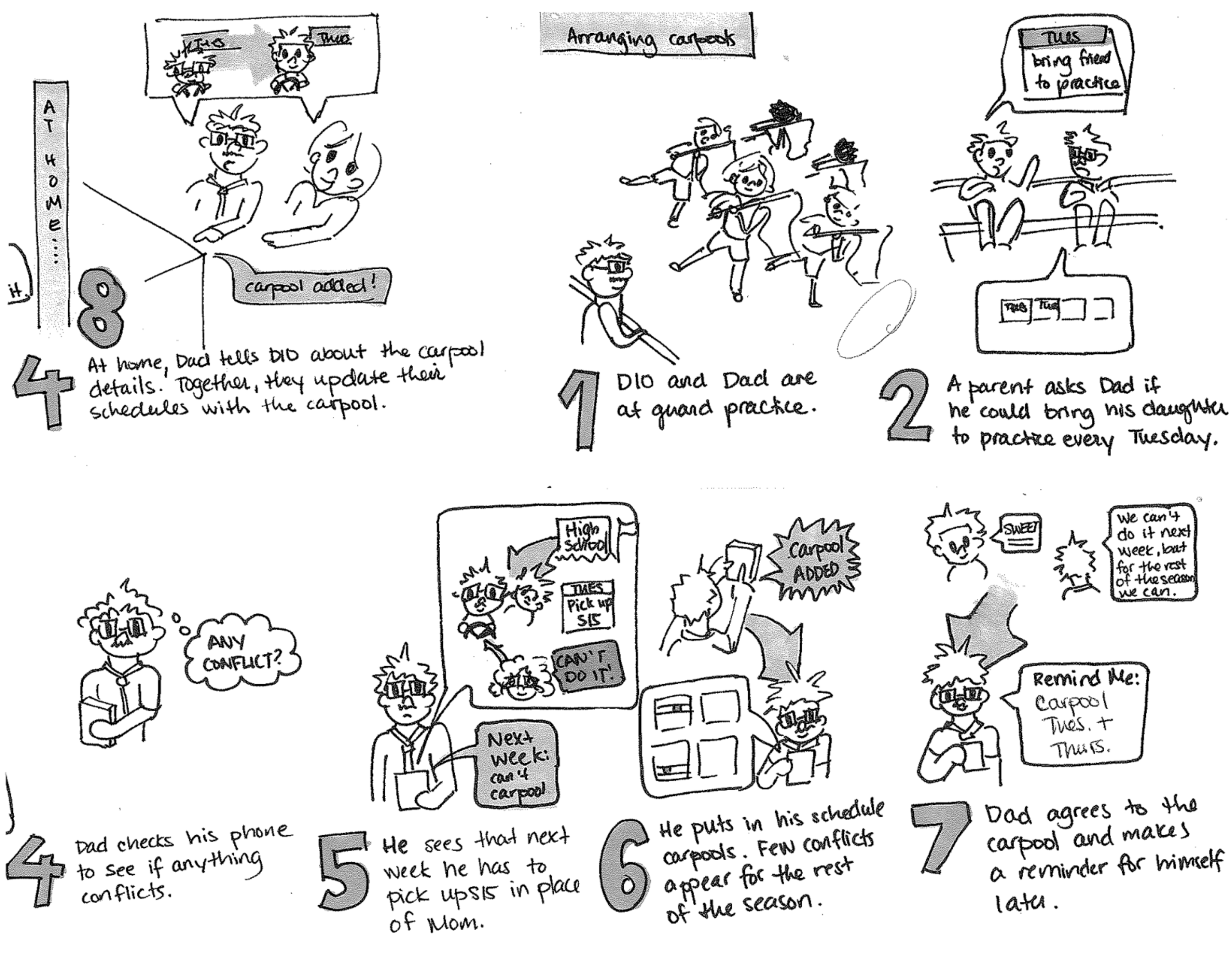

2- Scheduled Cancellation
4
Dad updates the calendar. The calendar tells Dad that he doesn't need to pick up and drop off DIO that day.
WEDNESDAY MORNING
FRee TIME
5
Dad checks his calendar and sees that he has more free time b/c guard practice was canceled.
THURSDAY MORNING
!
REMIND ME!
6
Dad sees on his daily schedule that he needs to bring DIO to practice. He sets a reminder.
1 HOUR BEFORE PRACTICE
7
The system beeps and reminds Dad to bring DIO to practice.
8
Dad falls into his routine. He gets DIO ready and brings her to color guard practice ontime.


Child sprains ankle
1
S17 strained his ankle at track.
2
Track coach calls Mom to tell her that someone needs to pick up S17 immediately.
3
Mom is not sure if Dad is on his way home already.

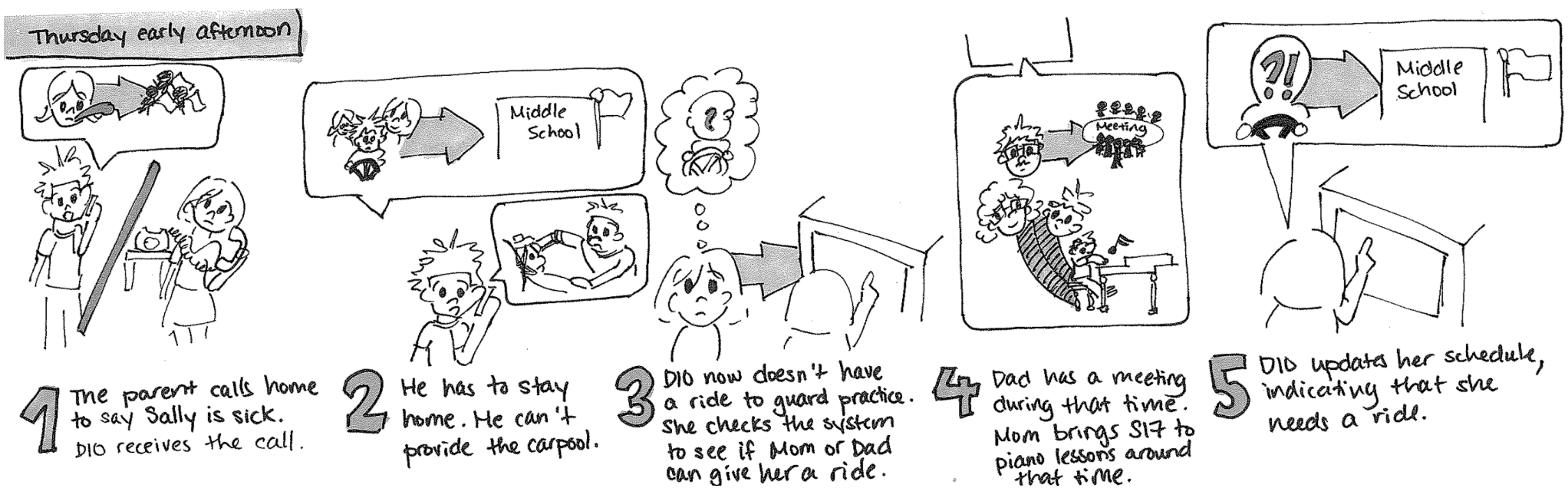


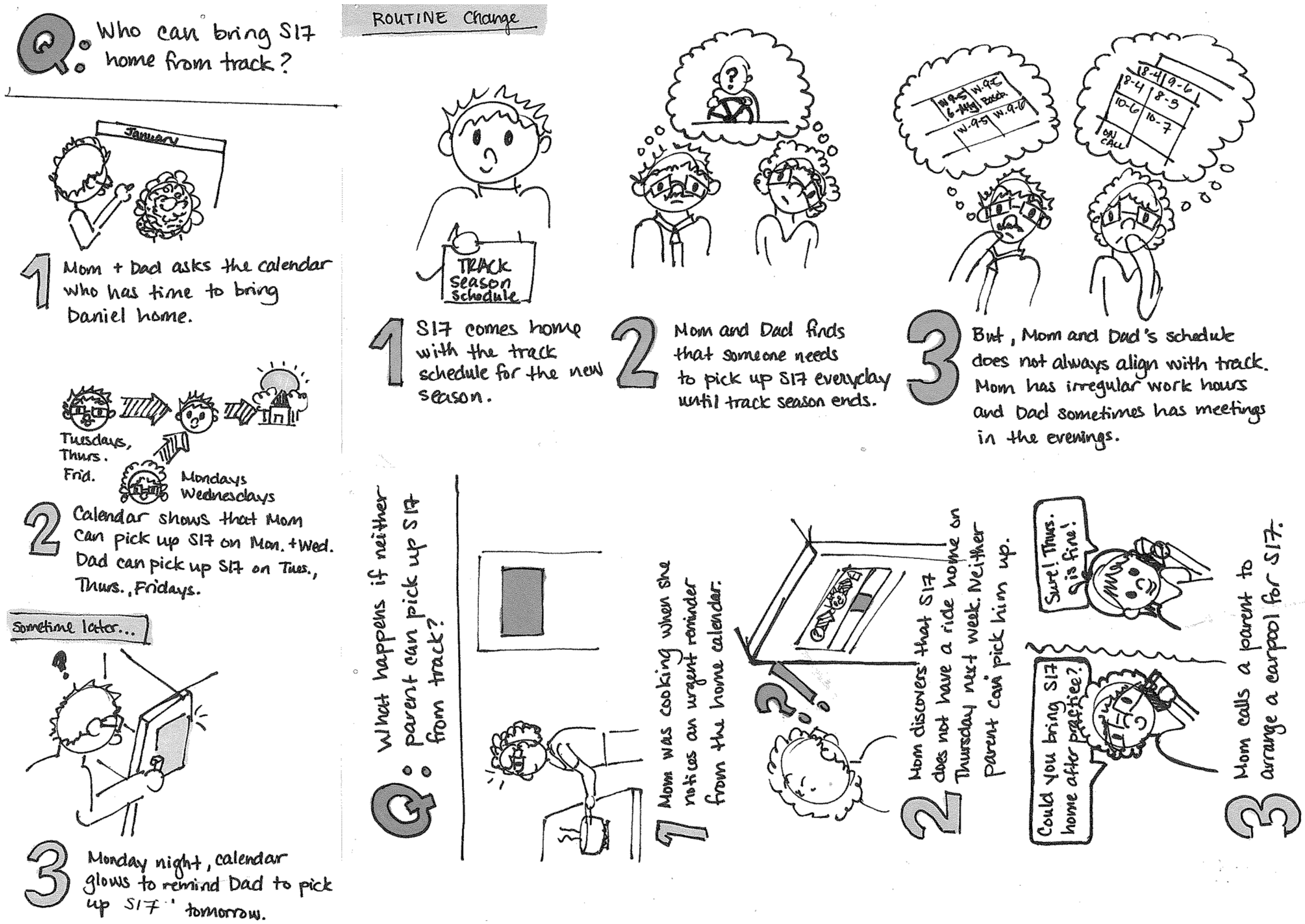
2-Child sprains ankle
4 Mom asks the system who can reach S15 the soonest.
15
High School
30
High School
5 System shows that Dad can't b/c. he has a longer commute.
High School
6 Mom decides to pick up S15.
Emergency - leave work early & pick up S1's
updated successfully
Mom
7 She updates the system of what is happening. She tells the system to inform the rest of the family.
NEAREST DOCTOR
County Hospital
1.5 mi from H.S.
xxx-xxx-xxxx
Doctor Jay
Pediatrician
1.2 mi from H.S.
xxx-xxx-xxxx
Dr. Frank
8 System shows Mom information for the nearest doctor and the family pediatrician.
3- Child sprains ankle
NEED
NOTE
Doctor
CANCEL
9 System also gives Mom the consequences of a sprained ankle.
10 Mom drives to pick up S15. Dad and D/0 receive an alert about the situation.
WORK
High School
NEED
11 Mom brings S15 to the Doctor. In the waiting room, Mom receives a reminder to get a Doctor's note.
2 weeks
12 The doctor gives Mom a doctor's note. He tells her that S15 can't run track for a few weeks.
Rest
Ice (Every 2 hours)
Compression
Elevation
13 Mom receives instructions of how to treat a sprain.

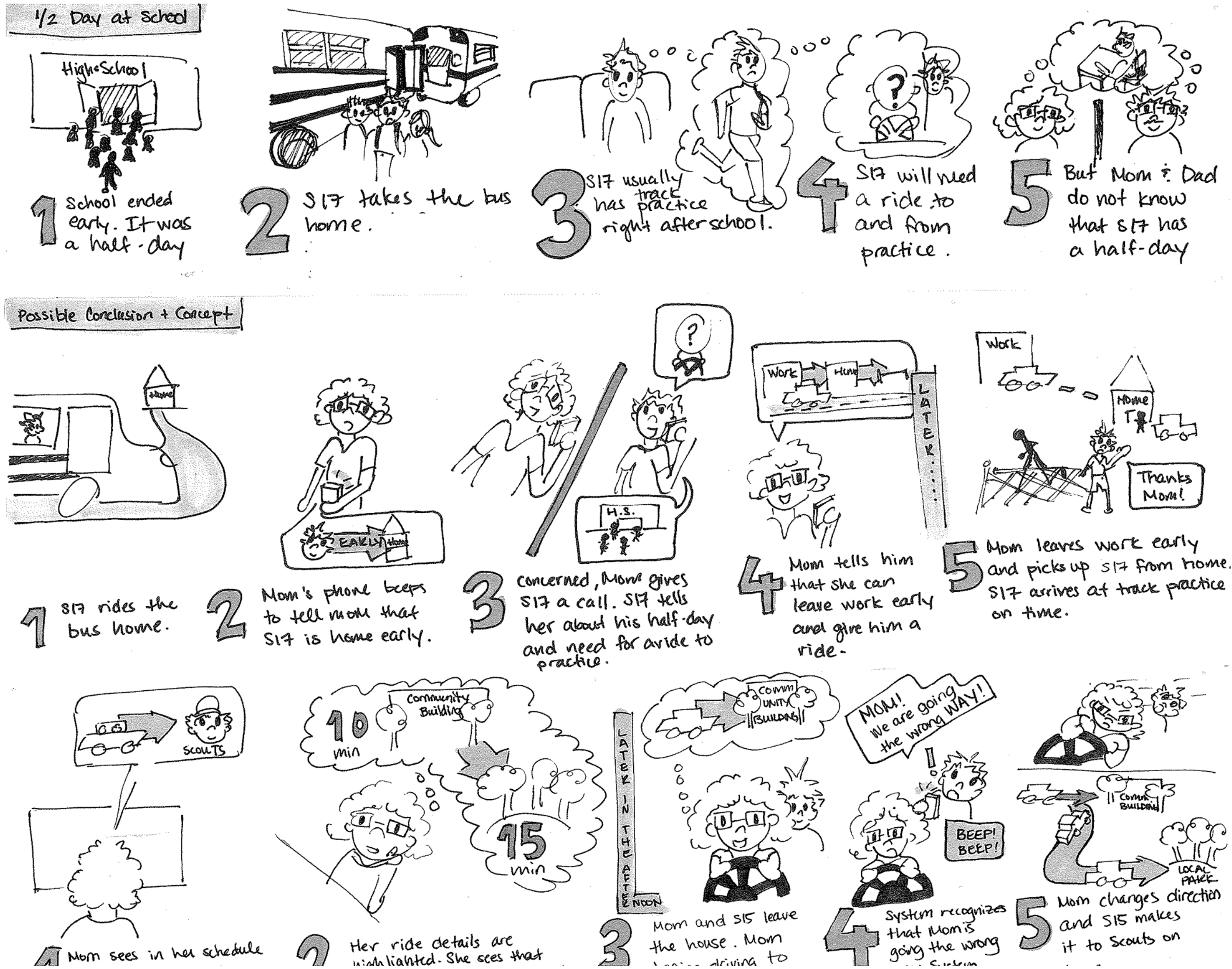

4- Child sprains Ankle
2HRS
REMIND ME!
14 Mom sets a reminder on her phone to ice S15's ankle.
11 2:00 2:00
12 1:00 3:00
2 weeks
15 The nurse tells Mom that S15 has to return in 2 weeks. Nurse gives Mom avail. times.
11 12
8-3 work 8-3 work
7-4 work 7-4 work
16 Mom checks Dad's and her schedules.
12
7-2:30 WORK
PICK UP S17
3:00 DOCTOR'S APPT
TRACK CANCELLED
17 Mom sees that Dad can leave work a little early. He has more time after work b/c he doesn't need to pick up S15 @ track.
OK!
BEEP! BEEP!
18 Mom sets the appointment and update's Dad schedule. Dad receives an alert.
5- Child sprains Ankle
19 Mom and S15 arrive home. Mom receives a reminder to cancel piano lessons.
Hope he gets well soon!
20 Mom calls the piano teacher to cancel today's lesson.
AN HOUR LATER
21 An hour later, Mom receives a reminder to put ice on S15's ankle.
22 When D10 and Dad arrive home, Mom details the days events.
23 Mom then remembers to cancel track for the next 2 weeks.

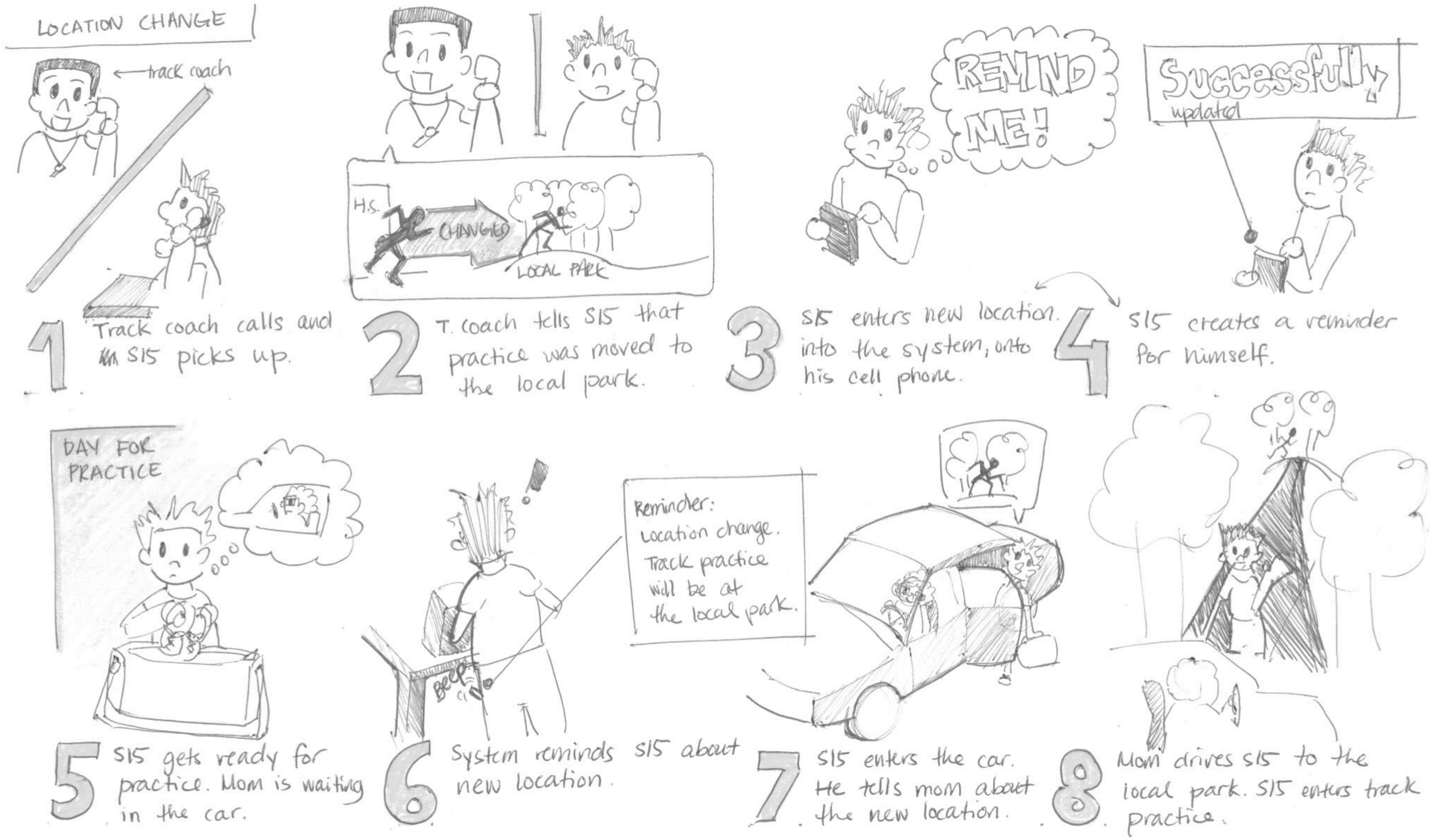

A T H O M E . . . .
8
carpool added!
4 At home, Dad tells DIO about the carpool details. Together, they update their schedules with the carpool.
Arranging carpools
1 DIO and Dad are at guard practice.
TUES
bring friend to practice
2 A parent asks Dad if he could bring his daughter to practice every Tuesday.
ANY CONFLICT?
4 Dad checks his phone to see if anything conflicts.
High school
TUES Pick up SIS
CAN'T DO IT!
Next week: can't carpool
5 He sees that next week he has to pick up SIS in place of Mom.
Carpool ADDED
6 He puts in his schedule carpools. Few conflicts appear for the rest of the season.
SWEET
We can't do it next week, but for the rest of the season we can.
Remind Me: Carpool Tues. + Thurs.
7 Dad agrees to the carpool and makes a reminder for himself later.

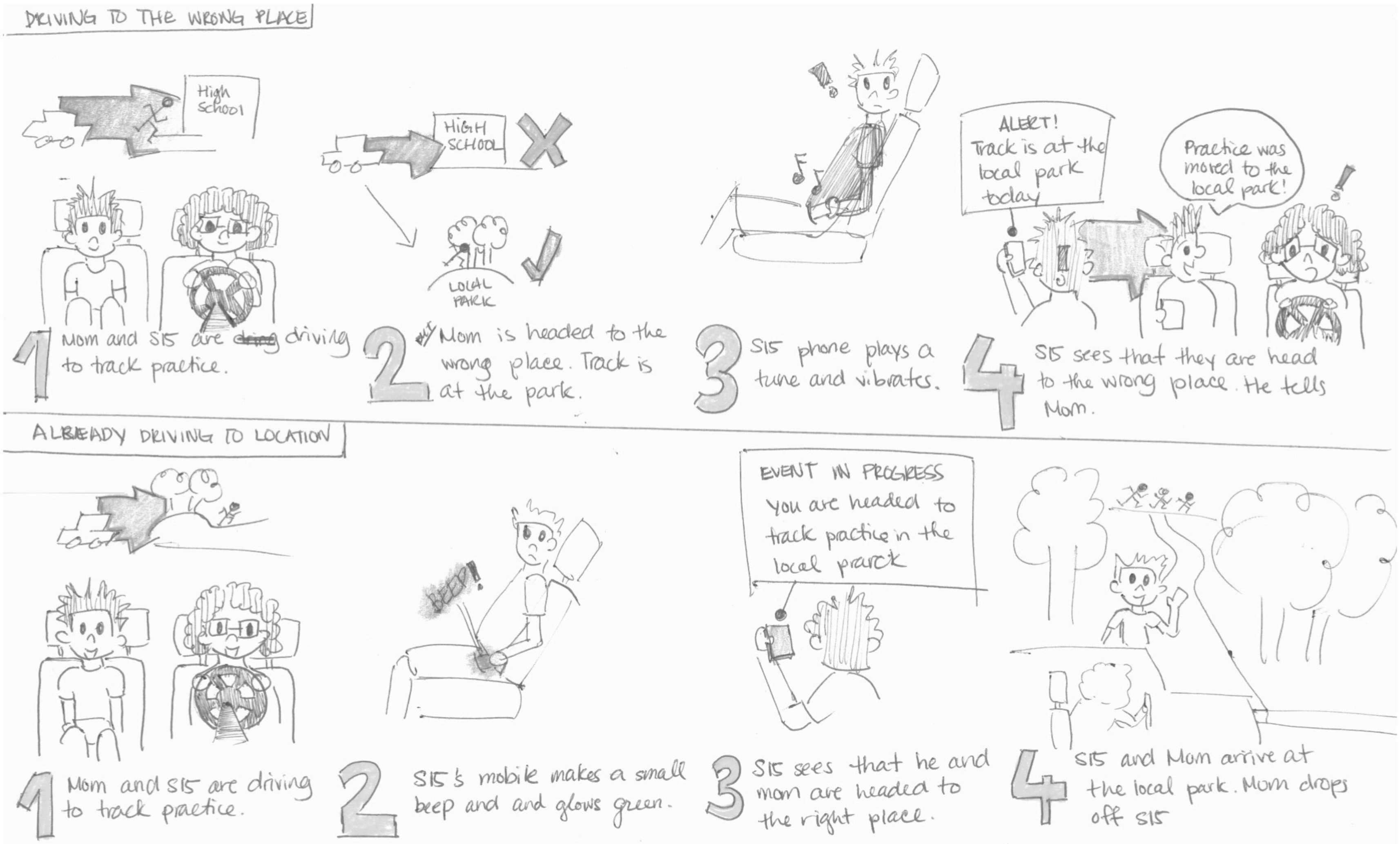

Possible conclusion + concept
ON TUESDAY...
10min
Sally's
10min
WE'LL PICK YOU UP AT 7:45?
OK!
30
min before practice
7:30
Home
7:45
Sally
Practice
8:00
1 Dad and DIO discuss carpool responsibilities. DIO volunteers to confirm carpool details w/ Sally each week.
2 On Tuesday, Dad receives a reminder to pick up Sally. It lists expected travel time and carpool details.
3 DIO receives a reminder to confirm carpool details. She calls Sally to confirm.
4 Dad + DIO leave 30 minutes before practice.
5 They pick up Sally and arrive at guard practice on time.


Thursday early afternoon
Middle School
Meeting
?!
Middle School
1 The parent calls home to say Sally is sick. DIO receives the call.
2 He has to stay home. He can't provide the carpool.
3 DIO now doesn't have a ride to guard practice. She checks the system to see if Mom or Dad can give her a ride.
4 Dad has a meeting during that time. Mom brings S17 to piano lessons around that time.
5 DIO updates her schedule, indicating that she needs a ride.

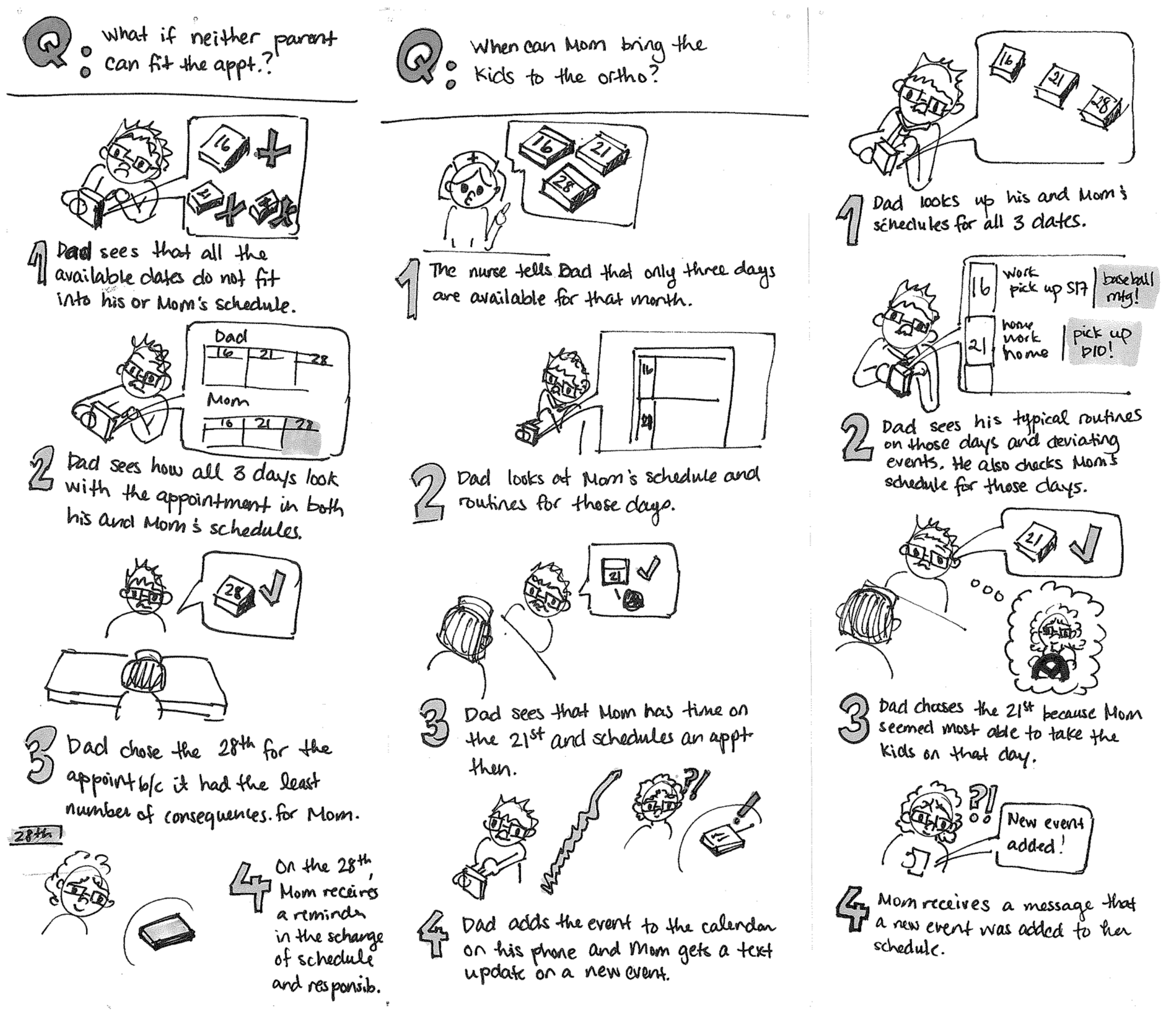

Q: Who can bring S17 home from track?
January
1 Mom + Dad asks the calendar who has time to bring Daniel home.
Tuesdays, Thurs. Frid.
Mondays Wednesdays
2 Calendar shows that Mom can pick up S17 on Mon. + Wed. Dad can pick up S17 on Tues., Thurs., Fridays.
Sometime later...
3 Monday night, calendar glows to remind Dad to pick up S17 tomorrow.
ROUTINE Change
TRACK Season Schedule
1 S17 comes home with the track schedule for the new season.
2 Mom and Dad finds that someone needs to pick up S17 everyday until track season ends.
3 But, Mom and Dad's schedule does not always align with track. Mom has irregular work hours and Dad sometimes has meetings in the evenings.
Q: What happens if neither parent can pick up S17 from track?
1 Mom was cooking when she notices an urgent reminder from the home calendar.
2 Mom discovers that S17 does not have a ride home on Thursday next week. Neither parent can pick him up.
Sure! Thurs. is fine!
Could you bring S17 home after practice?
3 Mom calls a parent to arrange a carpool for S17.


1/2 Day at School
High School
1 School ended early. It was a half-day
2 S17 takes the bus home.
3 S17 usually has track practice right after school.
4 S17 will need a ride to and from practice.
5 But Mom & Dad do not know that S17 has a half-day
Possible Conclusion + Concept
Home
1 S17 rides the bus home.
EARLY Home
2 Mom's phone beeps to tell mom that S17 is home early.
H.S.
3 Concerned, Mom gives S17 a call. S17 tells her about his half-day and need for a ride to practice.
Work Home
LATER....
4 Mom tells him that she can leave work early and give him a ride.
Work
Home
Thanks Mom!
5 Mom leaves work early and picks up S17 from home. S17 arrives at track practice on time.
SCOUTS
1 Mom sees in her schedule
Community Building
10 min
15 min
2 Her ride details are highlighted. She sees that
LATER IN THE AFTERNOON
COMMUNITY BUILDING
3 Mom and S15 leave the house. Mom
MOM! We are going the wrong WAY!
BEEP! BEEP!
4 System recognizes that Mom is going the wrong
COMM BUILDING
LOCAL PARK
5 Mom changes direction and S15 makes it to Scouts on


LOCATION CHANGE
track coach
1 Track coach calls and S15 picks up.
H.S.
CHANGED
LOCAL PARK
2 T. coach tells S15 that practice was moved to the local park.
REMIND ME!
3 S15 enters new location into the system, onto his cell phone.
Successfully updated
4 S15 creates a reminder for himself.
DAY FOR PRACTICE
5 S15 gets ready for practice. Mom is waiting in the car.
Reminder: Location change. Track practice will be at the local park.
BEEP
6 System reminds S15 about new location.
7 S15 enters the car. He tells mom about the new location.
8 Mom drives S15 to the local park. S15 enters track practice.


DRIVING TO THE WRONG PLACE
High School
HIGH SCHOOL
LOCAL PARK
ALERT! Track is at the local park today
Practice was moved to the local park!
1 Mom and S15 are ~~dring~~ driving to track practice.
2 Mom is headed to the wrong place. Track is at the park.
3 S15 phone plays a tune and vibrates.
4 S15 sees that they are head to the wrong place. He tells Mom.
ALREADY DRIVING TO LOCATION
BEEP!
EVENT IN PROGRESS You are headed to track practice in the local parck
1 Mom and S15 are driving to track practice.
2 S15's mobile makes a small beep and and glows green.
3 S15 sees that he and mom are headed to the right place.
4 S15 and Mom arrive at the local park. Mom drops off S15


1/2 Day
Half day here
day off thursday
1 Mom and Dad updates the calendar on school closings once a month.
MARCH
1/2
2 S15 has a 1/2 day on Wednesday.
March
Beep! Beep!
3 A week before, system sees that S15 needs a ride to track b/c he has a half day. System alerts Mom + Dad.
High School
4 Mom + Dad sees who can fit it in their schedule.
Work
EARLY
Dead line!
NO!
5 Dad sees that he would need to leave work much earlier than normal. He has an important deadline so Dad can't leave early.
Possible solution + concept
H.S.
6 Mom sees if she can give S17 a ride.
Meeting
4:00
3:30
7 Mom sees that she has a meeting at 4:00 and track begins at 3:30.
work
3:00
H.S
4:00
work
8 System tells her that she can leave work at 3:00, pick up and drop off S15 and make it to the meeting.
REMIND ME!
Set Reminder: 2:00
"Leave Work at 3:00!"
9 Mom sets a reminder to leave work early.
WEDNESDAY
2:00
Work
3:00
Work
4:00
Home
3:30
High School
10 That day, Mom receives a reminder. She leaves work early and was able to accomplish everything as planned
Scheduling for someone else
Sure!


Q: What if neither parent can fit the appt.?
16
1 Dad sees that all the available dates do not fit into his or Mom's schedule.
Dad
16 21 28
Mom
16 21 28
2 Dad sees how all 3 days look with the appointment in both his and Mom's schedules.
28
3 Dad chose the 28th for the appoint b/c it had the least number of consequences. for Mom.
28th
4 On the 28th, Mom receives a reminder in the schange of schedule and responsib.
Q: When can Mom bring the kids to the ortho?
16 21 28
1 The nurse tells Dad that only three days are available for that month.
2 Dad looks at Mom's schedule and routines for those days.
3 Dad sees that Mom has time on the 21st and schedules an appt then.
4 Dad adds the event to the calendar on his phone and Mom gets a text update on a new event.
16 21 28
1 Dad looks up his and Mom's schedules for all 3 dates.
16 work pick up S17
baseball mtg!
21 home work home
pick up D10!
2 Dad sees his typical routines on those days and deviating events. He also checks Mom's schedule for those days.
21
3 Dad choses the 21st because Mom seemed most able to take the kids on that day.
?!
New event added!
4 Mom receives a message that a new event was added to her schedule.

Appendix F Temporal + Spatial Visualization Examples

Carnegie Mellon

Visual research report

Family Routines Project - Fall 2009

V.1.1 February 2010

This report follows the research conducted during the 2009 fall term. It covers the various stages of visual explorations done in tandem and inspired by the research being conducted by Scott Davidoff on his Project on Family, Control, and the Smart Home.

Section 1

Looking at the current solutions

Scott's research focuses currently on using data to create a routine that an intelligent system could then tap to help parents plan their day to day activities. The visualization of this type of interaction between the system and the user has multiple types of possible outcomes, and the groups initial insitinct was to start with the ideas based on existing systems and see where there was room to improve and expand, based on the data we were gathering. The initial steps where to look at other scheduling systems, more importantly things that dealt with both time and space(location) and if possible other types of dependencies. An ideal present solution would be to find something that was successful as scheduling people places and objects, as these are commonalities shared with parents looking to map their days with kids events, the event needs and their own schedules.

Scheduling systems

The search began on the internet, primarily because the proliferation of scheduling tools has seen its biggest growth in industries that conduct a lot of work over the internet. These tools whose primary function is based on the idea of easily tracking and editing content specific to a day or a series of dates takes its cues from more traditional methods of achieving the same task, such as traditional wall calendars.

The search began by first typing in words like “calendar” and “scheduling tools” into Google. This initial query resulted in literally thousands of results, which were slowly reviewed. In most cases the goal was to try and find key elements in each of the implementations and options. These key elements were; tools that tracked time wether by day or hour, things that tracked multiple types of focuses (people, places, objects), also tools that showed shifts in focus; not just something that would show a persons schedule but perhaps a person schedule as he or she moved locations. In most cases these types or tools exist for very specific uses, like employee tracking and facility scheduling. In the end profiling some of the more interesting ones proved to be essential in understanding the strengths and in some case weaknesses of each of these tools.

While doing this initial search, it was also important to take some time to look at the visual style of the tools being displayed. Carefully identifying patterns in the current tools, would later serve to qualify standards to how different aspects of the tools were treated. These types of observations where key in trying to determine the existence of paradigms in visual languages when it comes to calendering systems. These paradigms would then begin to serve as the foundational guidelines for our own visual explorations.

Scheduling systems

As these images were being pulled off the web and into folders, there was a realizations that there needed a better way to track and display these samples, simply so that there was an easier way to access them visually, without having to resort to viewing them in list form and having to search each image one by one. As a result of these need, the samples were uploaded into a Flickr.com account, that would serve as a database of sorts, that would allow each image to be tagged labeled and grouped if necessary. While doing this, each image was also tagged with visual attributes such as how the information was being read by the user, which overall direction was implemented, how many levels of information where contained, what kind of information was being compared and methods of how they were separating the data.
Bellow is a list of all the possible attributes that could be used to tag any specific image.

Account Info

Login:
hcireasearch

Password:
282112

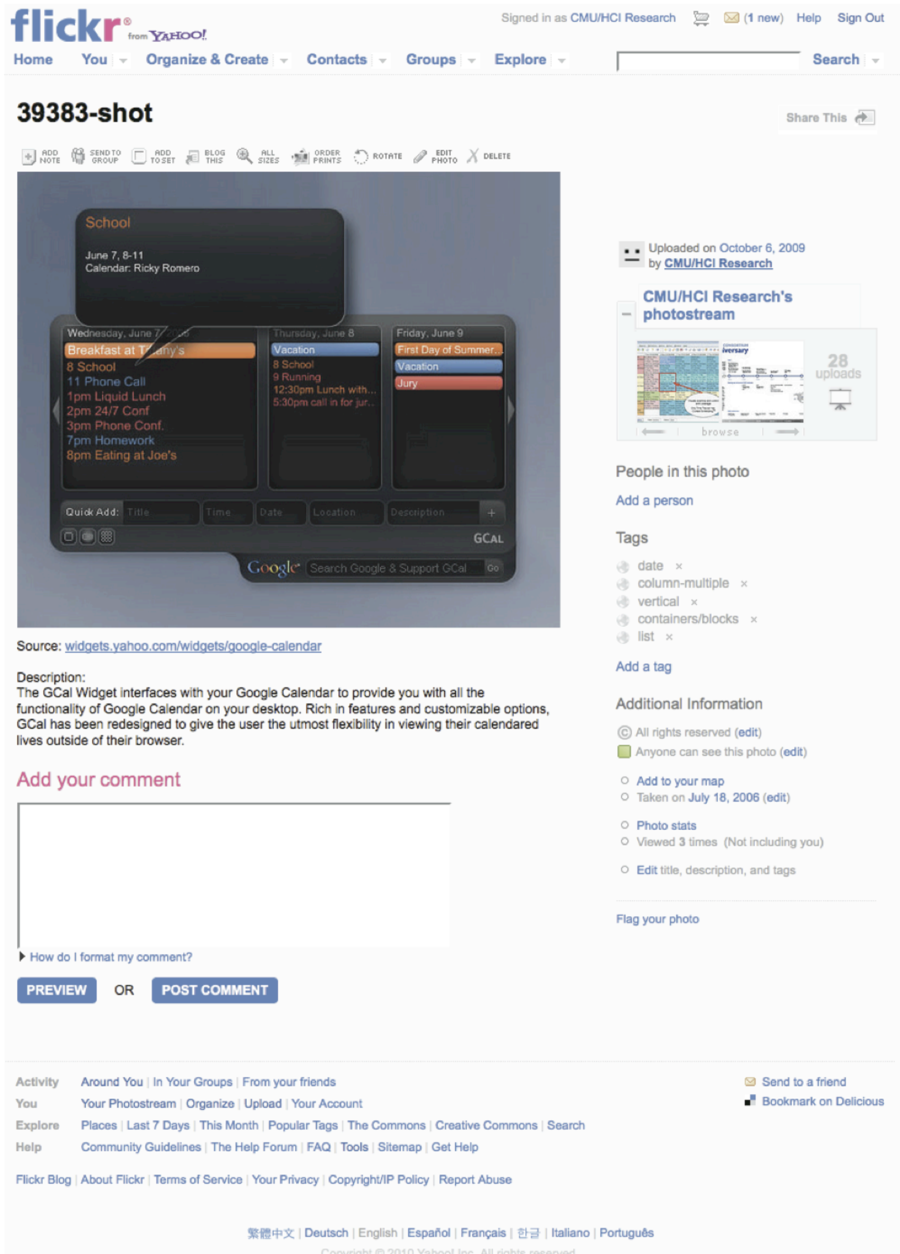
Data Tags

Location
Time
Date
People/Person
Tools

Visual Tags

Structure - Column-Multiple
Structure - Column-Single
Structure - Grid
Structure - List
Read - Vertical
Read - Horizontal
Read - Multiple-paths
Read - Single-paths
Visuals - Markers
Visuals - Containers/Blocks

The flickr account also provided an important place to archive the source of the images we were finding. By keeping this online it also became significantly easier to view the live site/product that we used to pull the image source from.


flickr from YAHOO!
Signed in as CMU/HCI Research (1 new) Help Sign Out
Home You Organize & Create Contacts Groups Explore Search
39383-shot
Share This
ADD NOTE SEND TO GROUP ADD TO SET BLOG THIS ALL SIZES ORDER PRINTS ROTATE EDIT PHOTO DELETE
School
June 7, 8-11
Calendar: Ricky Romero
Wednesday, June 7
Breakfast at Tiffany's
8 School
11 Phone Call
1pm Liquid Lunch
2pm 24/7 Conf
3pm Phone Conf.
7pm Homework
8pm Eating at Joe's
Thursday, June 8
Vacation
8 School
9 Running
12:30pm Lunch with...
5:30pm call in for jur...
Friday, June 9
First Day of Summer...
Vacation
Jury
Quick Add: Title Time Date Location Description
GCAL
Google Search Google & Support GCal Go
Uploaded on October 6, 2009
by CMU/HCI Research
CMU/HCI Research's photostream
28 uploads
browse
Source: widgets.yahoo.com/widgets/google-calendar
Description:
The GCal Widget interfaces with your Google Calendar to provide you with all the functionality of Google Calendar on your desktop. Rich in features and customizable options, GCal has been redesigned to give the user the utmost flexibility in viewing their calendared lives outside of their browser.
People in this photo
Add a person
Tags
date
column-multiple
vertical
containers/blocks
list
Add a tag
Additional Information
All rights reserved (edit)
Anyone can see this photo (edit)
Add to your map
Taken on July 18, 2006 (edit)
Photo stats
Viewed 3 times (Not including you)
Edit title, description, and tags
Flag your photo
Add your comment
How do I format my comment?
PREVIEW OR POST COMMENT
Activity Around You | In Your Groups | From your friends
You Your Photostream | Organize | Upload | Your Account
Explore Places | Last 7 Days | This Month | Popular Tags | The Commons | Creative Commons | Search
Help Community Guidelines | The Help Forum | FAQ | Tools | Sitemap | Get Help
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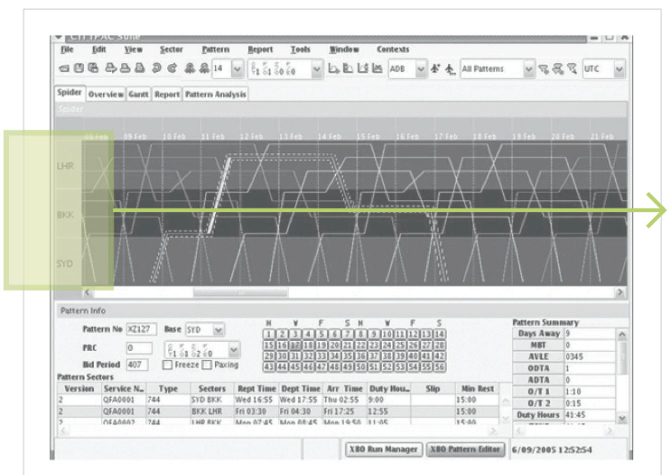
Tagging

I created these tags to allow to find commonalities amongst the visual samples I was finding. In most cases most samples will be defined by multiple descriptive features. There are two distinct ways at looking at the categories; The first is based on layout and the second is based on data points. Layout focuses on commonalities in the way that the data is being displayed, while data points focuses on the type of information patterns that are being displayed.

In terms of layout, as a sample tries to show more data points, the layout will start to be defined by multiple types of descriptive tags. For example a system that is trying to display Time, Location, People and Date, will most always have a grid, multiple column layouts and multiple paths by which it can be read.

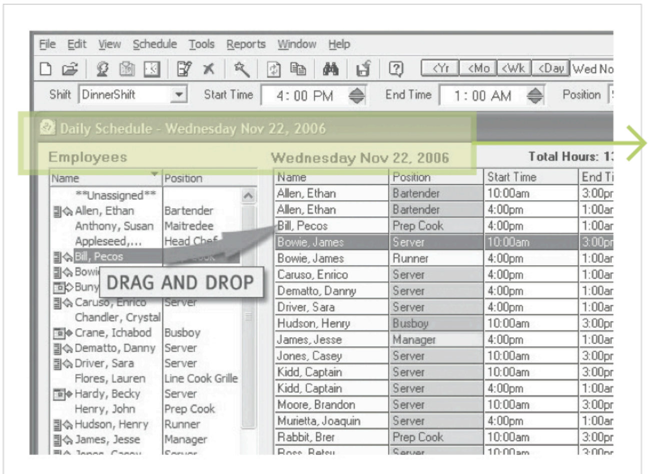
Breakout of the tags

Data tags



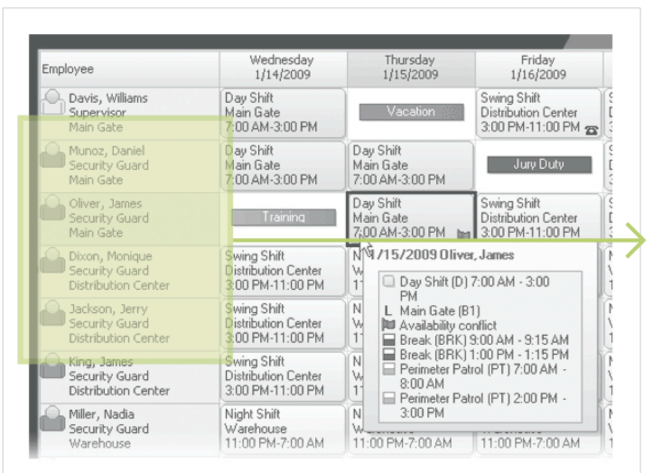
Location

Sample of location data points. This sample shows plane movement between airports over time.



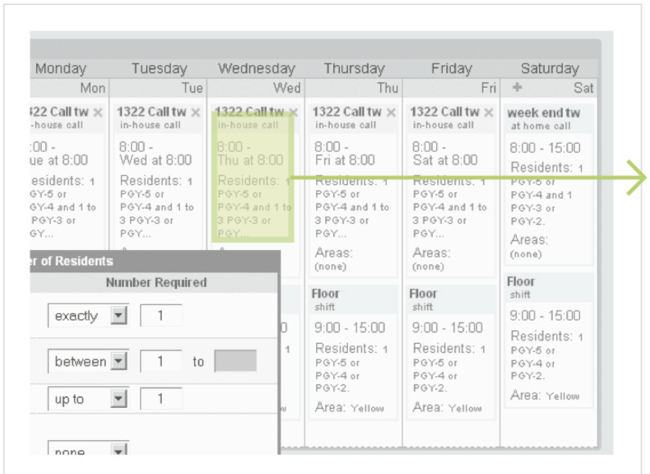
Date

Sample of a date data point. This sample shows people's schedule in a specific day.



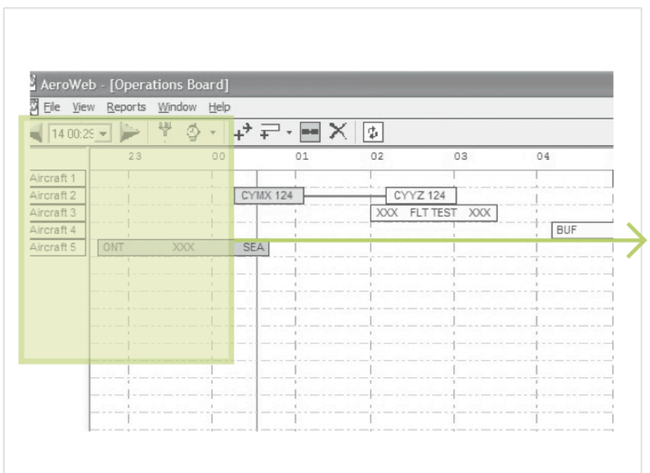
People

Sample of people data points. This sample shows people's shifts organized by employee.



Time

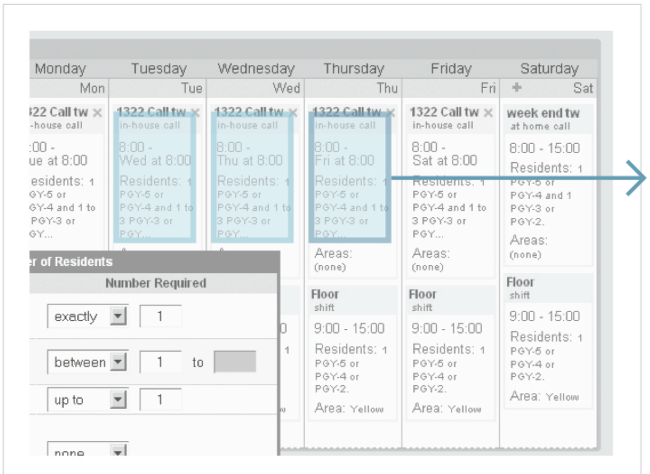
Sample of time data points. This sample shows time specific shift in a day.



Tools

Sample of tool data point. This sample shows the schedule of use of a tool (airplanes) .

Visual tags

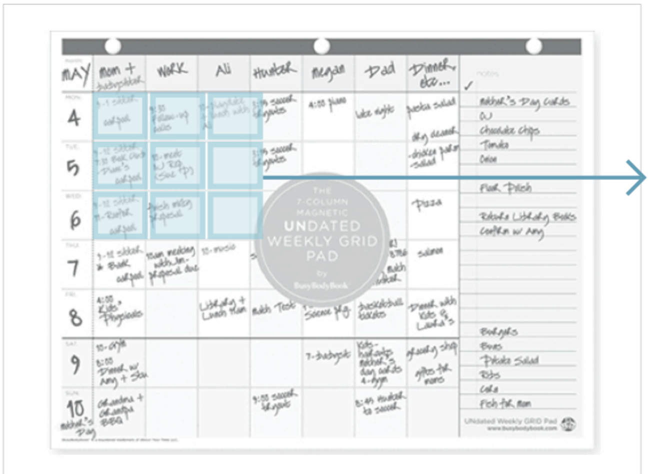


Structure - *Column multiple*

Data is divided into multiple columns repeating more than once. Focus is on multiple columns.

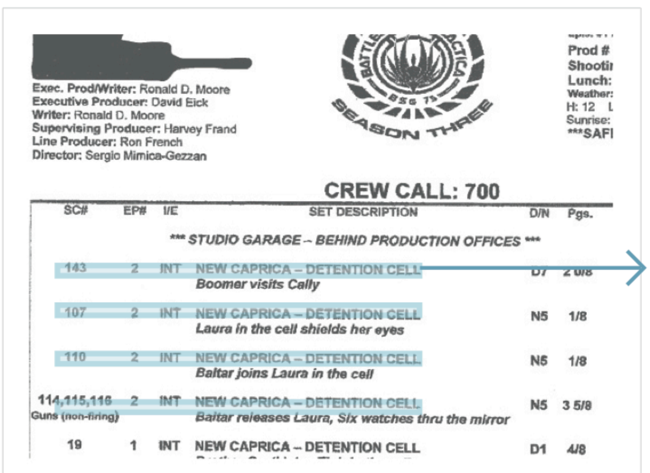
Structure - *Column single*

Data is displayed in once primary column. Focus is on one column at a time.



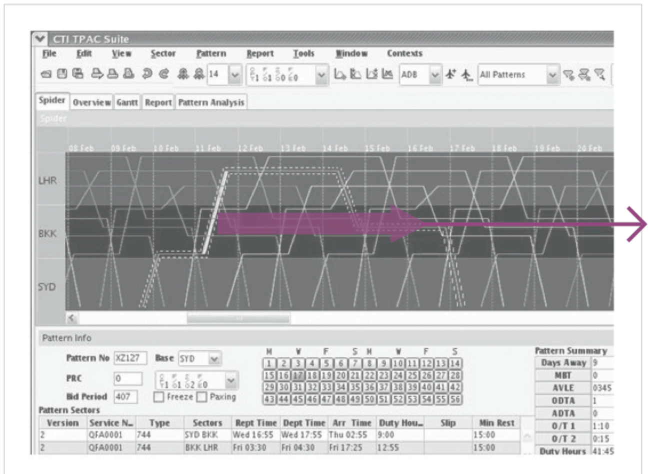
Structure - *Grid*

Data is divided into a grid system where each axis serves a point of reference for a specific data point.



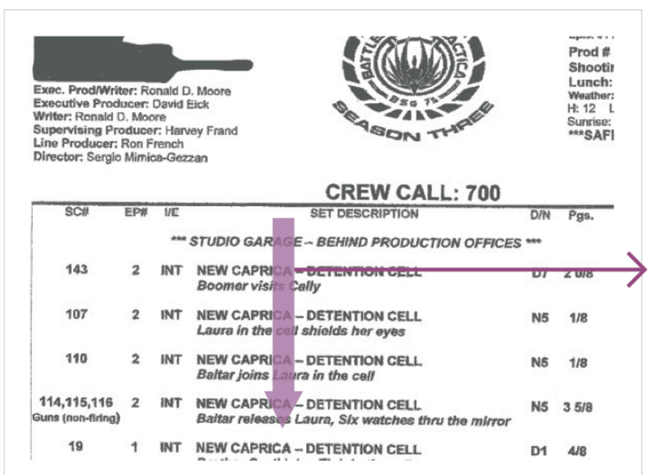
Structure - *Column single*

Data is displayed as a set of listed items, sometimes with multiple instances per line.



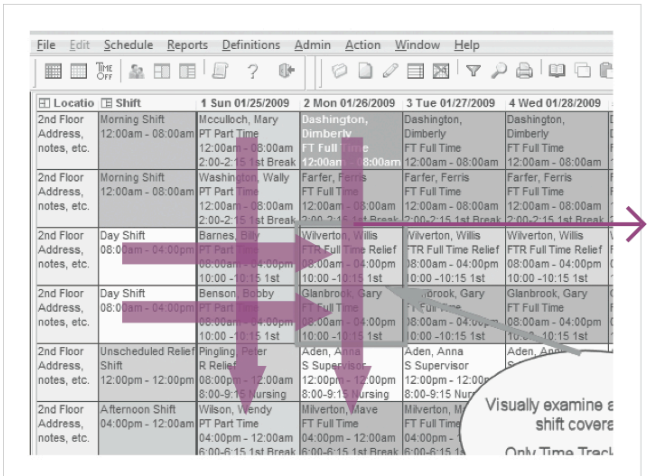
Read - *Horizontal*

The main focus of the display or layout is read in a horizontal fashion.



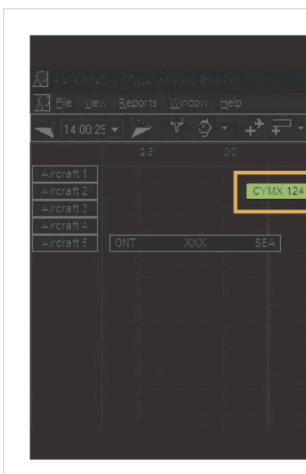
Read - *Vertical*

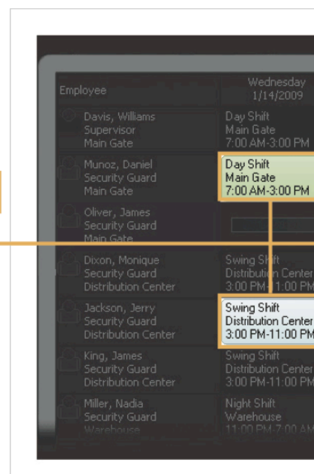
The main focus of the display or layout is read in a vertical fashion.



Read - *Multiple Paths vs Single paths*

The main focus of the display or layout is read in both a vertical, and horizontal fashion.





Visuals - *Containers & Markers*

Containers serve as a separation of information among common things while markers serve as a specific flag that serves to inform about a unique highlighted element

Image Results

Location
9 Results

Location is mapped as
-As a primary axis (i.e.: left axis)
-As a data point (i.e.: column header)

3 Read - Horizontal Samples
6 Read - Vertical Samples
3 Structure - Grid (primary layout)
4 Structure - Column
2 Structure - List

Time
16 Results

Time is mapped as
- 3 As a primary axis (top & left axis)
- 5 As a data point (column header)
- 1 As time line
- 7 as a subset of DATE

9 Read - Horizontal Samples
6 Read - Vertical Samples
7 Structure - Grid (primary layout)
8 Structure - Column-Multiple
1 Structure - Column-Single
5 Structure - List
1 Visuals - Blocks/Containers

Date
13 Results

Date is mapped as
- 11 As a data point (column header)
- 2 Subset of Primary Data point

9 Read - Horizontal Samples
4 Read - Vertical Samples
5 Structure - Grid (primary layout)
7 Structure - Column-Multiple
1 Structure - Column-Single
1 Structure - List
2 Visuals - Blocks/Containers

People/Person
23 Results

Date is mapped as
- 7 As a primary axis (top & left axis)
- 15 As a data point (column header)
- 1 As time line

13 Read - Horizontal Samples
6 Read - Vertical Samples
2 Read - Single Path
1 Read - Multiple path
7 Structure - Grid (primary layout)
11 Structure - Column-Multiple
1 Structure - Column-Single
5 Structure - List
5 Visuals - Blocks/Containers

Section 2

Experimenting with layout

Once we realized how various other tools managed to visualize schedules, it was our time to try and begin to think of how to bring the data collected by Scott, to an interface. Some initial hurdles that continue to plague us are deciding what people want to see. Is it predictions, is it actual schedules, is it conflicts only, dependencies or a combinations of all of those.

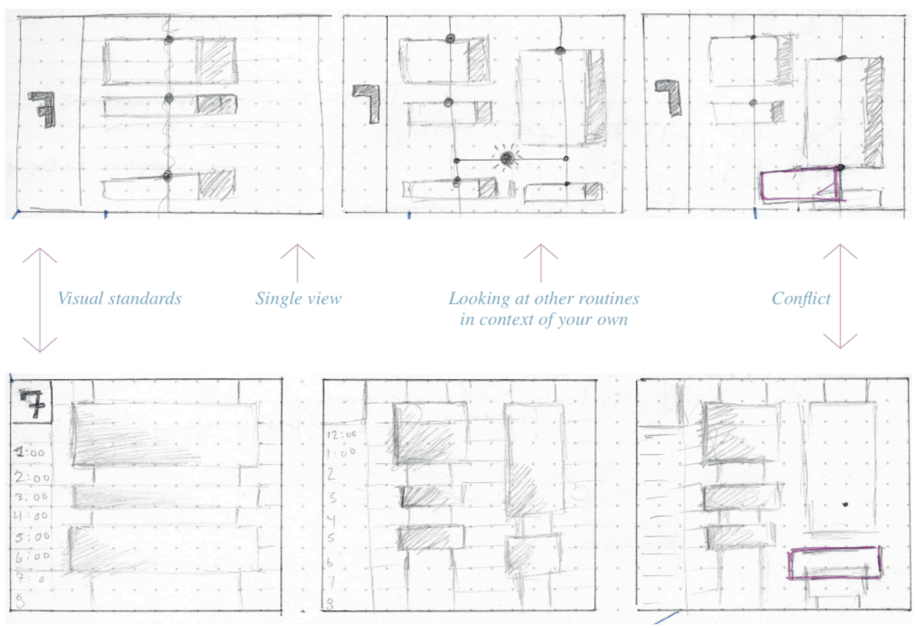
Idea sketching

We identified certain scenarios that would best show the power of the tool. The ideal situation is a schedule that has a significant conflict or issue that requires some form of solution. The idea is that in the root of the conflict, the tool is going to help its user not only to identify the problem in a timely manner, but provide some measure of control as to how to solve for the problem.

Approach 1 - Showing conflict

The first stab at the visualization efforts were done focusing in on looking at a single user view and comparing it to someone else's view and identifying any sort of conflict that would occur in those spaces. Below you see sketches that begin to map a persons day events and then a secondary track line of a "family members" schedule to compare against the personal view.

Sketches for routine mapping and schedule comparison.

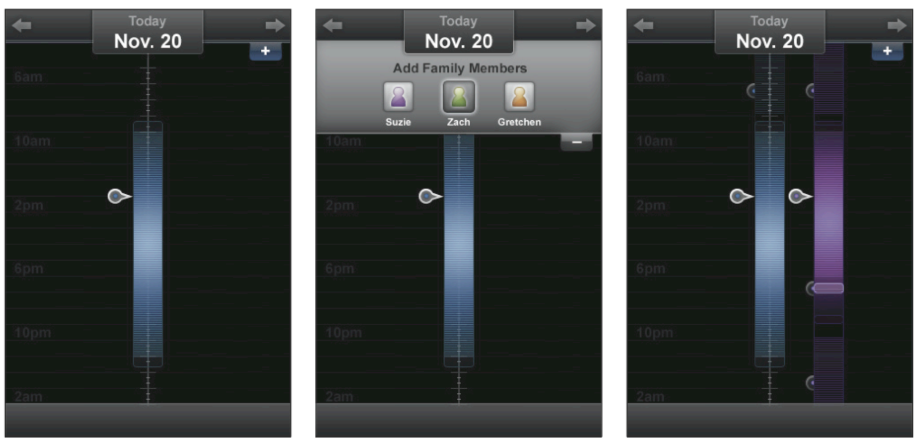


Approach 2 - Predicting location

These three screens take the idea of being able to encase the location of the person in a light frame. As the system becomes more confident that you are in fact in that location the color becomes denser and brighter. The first two Screens ***(A. & B.)*** show the single person view plus the tool to add a second. The third screen ***(C.)*** shows how a second person would be seen in tandem with the main user. The third screen also attempts to conceptualize how an intervening event scheduled for a time that is regularly reserved for a different activity may begin to show.

However the problems with this current system is that routines vary in length of time, therefore being able to clearly juxtapose a long routine underneath a shorter unscheduled or conflicting routine is a scenario that perhaps does not occur often enough. In most cases overbooking a time occurs not in the middle of an activity but either at the beginning or end of one and its this minor overlap that leads to problems.

These diagrams show how color can be used to manifest a systems ability to predict location.



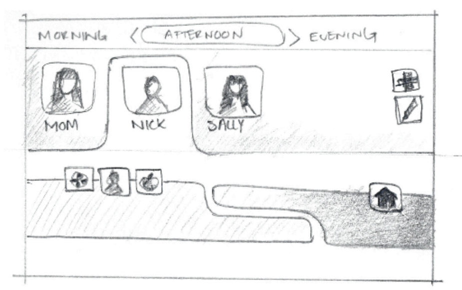
Screen A *Screen B.* *Screen C*

Also the paradigm for this system is based on the idea of being able to predict location by density in color, however in screen ***(C.)*** the paradigm is broken as the brightest element is a conflict in the system that has a unknown outcome, rather than a highly predictable event. Since the overlapping appointment is not routine but rather occasional, its visualization should be under the color paradigm, much lighter if not invisible in comparison to the routine event. But for some obvious reasons having an almost invisible conflict defeats the purpose of showing it at all.

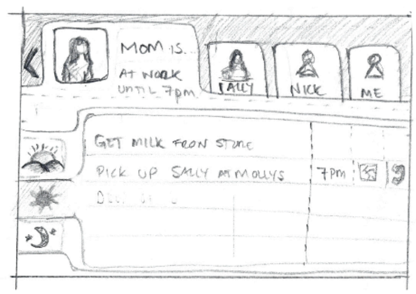
Approach 3 - Viewing events

The next set of visual incursions took the shape of attempts at trying to look at how events would be seen along the span of a day. These could be either manifested as individual segmented blocks, as listed items or as icons. Some of these brief attempts try to capture what you could do as a user and how you can begin to categorize the information in a more engaging way or more rational or useful way. In the following set of screens, Screen ***(D.)*** shows how a user can select a person, and subsequently view that persons day. The activities would map to a time line that would show icons for the corresponding type of event and would show any sort of travel time

These sketches show different ways to deal with visualizing events along a specific users time line.



Screen D



Screen E.

between activities and locations, demonstrated by the overlapping sections of each activity. This taps into two major functions of Scott's intended goal for the application. The first being location and routine mapping the second is a visualization of the travel time between events which is an important component of the tool.

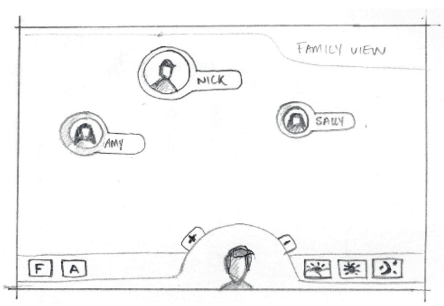
In screen ***(E.)*** the type of interaction to maneuver through people is similar to that in screen ***(D.)***, the difference here is that events appear as a list of events with some added icons that help the user identify the needsassociated with the event at quick glance.

Screens *(D.)* and *(E.)* have some advantages, but they also have significant drawbacks that pop up almost immediately after looking at the sketches. Most notably, in each screen you suffer from basic minor problems. In screen *(D.)* you run the risk of having events that are simply too short to be tagged with identifying icons. In screen *(E.)* the major problem comes from deciding which information is important enough to be listed, should errands, or to do's be part of that initial list? How does the information get ranked? And how do you show more important events vs. Perhaps simple to do's?

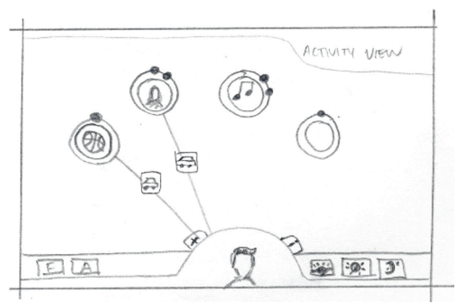
Approach 3 - User relationships

As part of the various visual experiments I was trying out, it seemed somewhat interesting to try and visualize the person as a focal point and then map the events and responsibility of the person around them as a set of orbs or shape that would create links and ties or relationships as the events came closer to happening. The Screens *(F.01)* and *(F.01)* show how the system or application could begin to show you two types of views relating to this concept of a central focal point. The user situated at the bottom of

These sketches show different ways to deal with visualizing events in contect of how the relate to a person.



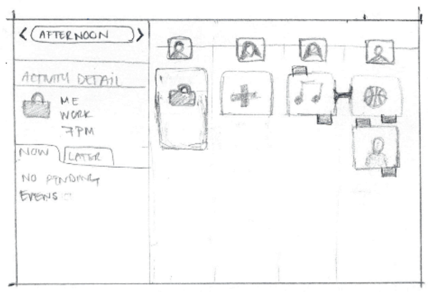
Screen F.01



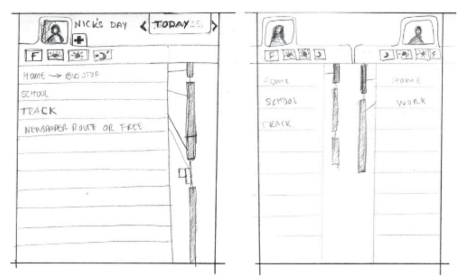
Screen F.02

the frame, sees other member of the family as well as events in context to him or her. The member of the family could be smaller or bigger depending on distance from each other or if there was an event that would soon take place with a specific person. In the case of the events view you could actually link the event to you and then use icons to tie the type of responsibility you would have to that event. As with the people view, the more pressing the event the closer the orb would move toward the main user. While perhaps not the most effective method of conveying large quantities of data, this view does do a unique thing, and tries to show data in a less linear manner and by means of positioning on the screen aims to also inform the user of its value and importance.

In the same effort as the previous sketches, the following screens ***(G.)*** and ***(H.)*** also try to begin to show potential ways of viewing events, persons and locations, though this time the focus is more on the event and not on the person. This shift in focus allows me to give the event or set of events a more prominent position in the overall hierarchy. In screen ***(G.)*** we can



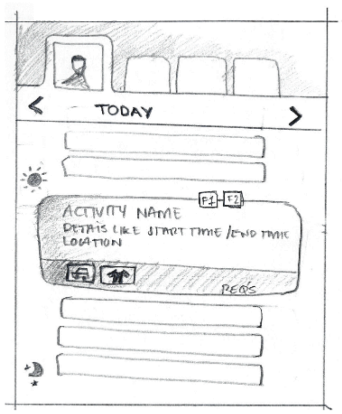
Screen G.



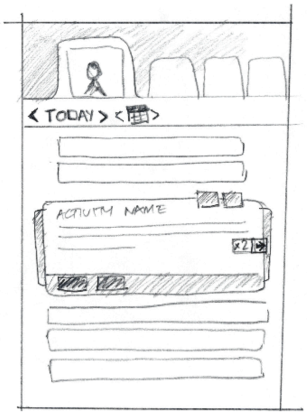
Screen H.

dedicate more space to a global view of the family calendar without having to waste space to showing that the user is the point of reference. In screen ***(G.)*** the events in family members lives are reduced to blocks and icons that show the type of event. These icons are meant to be tools to create quick glances and obtain basic information in less time. The size of the blocks do correspond slightly to the time they are occurring in, they also have these "teeth " like features which signal when an event requires involvement, for example a mother taking her child to a basketball game and then to a friends house. The "to" and "from" distinctions are created by these tab like teeth. Screen ***(H.)*** uses a simple list based system. Here each event is given equal weight in he list, however the right hand side of the screen opens up into a more visual and accurate representation of the events over time. The idea is that you see what you have to do and then see the context of the activity in terms of the rest of your day. Both ***(G.)*** and ***(H.)*** suffer from significant problems , primarily that they scale poorly, and run the risk of simply having too much information being put forth at any given time.

As something of a backlash to the previous version of sketches, I decided to try something a bit more controlled with screens ***(I.01)*** and ***(I.02.)*** Instead of seeing all events at once, I opted for one event or time at any given mo-



Screen I.01



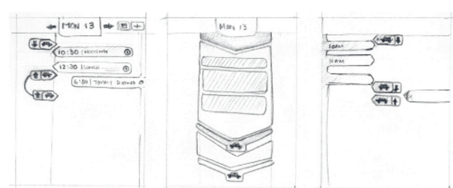
Screen I.02

The magnifying glass effect is used in these sketches to highlight one specific event and all the dependencies associated with the event.

ment. This way the focus would be on the current specific needs without jumping ahead or behind. The “magnifying glass” approach came from a discussion we had in a group session, and one I think carries merit, as the sole focus approach serves a very clear purpose of identifying the events with clarity. However like other sketches it suffers from scalability concerns as well as managing events that are taking place at the same time and comparing family member schedules.

Round 2 - Defining needs of the interface

Once we had gone through some of these initial rounds of sketching, we started to really focus on what needed to be shown. Creating and defining these needs is key in creating the information hierarchy that the application should have . The main focus of the screens is to try and show how your everyday normal schedule starts to deal with the various dependencies that are created as a result of being tied to events other members in your family have to partake in. Parents have to deal with kids events by ad-

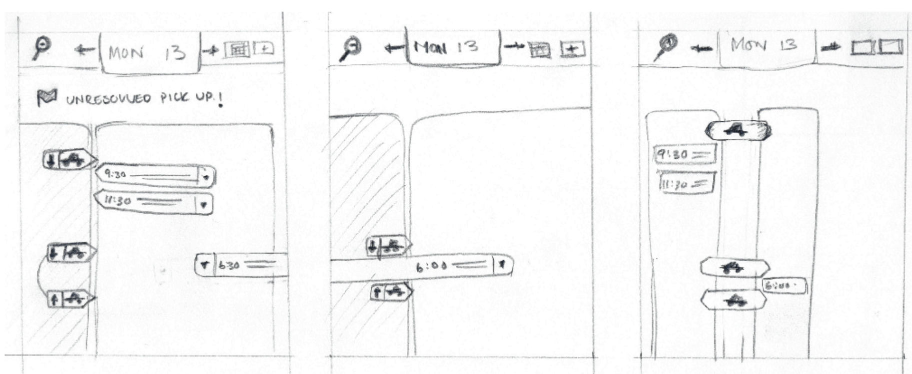


Screen J. *Screen K.*

dressing multiple types of responsibilities, ranging from drop-offs and pick ups to meals for events and other type of physical requirements needed by the kids. Screen ***(J.)*** begins to tap into this idea of creating a two track approach to visualizing the users information. The first track highlights in a quick fashion those things which are dependencies. While its not shown as an event, the marker serves to identify a responsibility that the person must address. With the development of Scott's data, the system should be able to determine that the kids have and activity occurring at a certain hour and that they are dependent on mom or dad to get them there. The second track is the persons normal calendar view. This exist so that the person can keep a contextual view of how this responsibility fits into their day. Also the sketch conceptualizes the idea that an event that does not belong to you can be shown as a container that extend of the far right edge, signifying it does not belong or is not part of this users active schedule.

Screen ***(K.)*** starts to tackle a similar visual marking system, but instead of seeing events in a separate track it works as a stacked system where individual responsibility items appear as these arrow like features, while routine is mapped as a large parent container and then smaller meeting type events that take place within the span of your routine time in the office appear as blocks inside the parent routine item. This screen simply adds too much

A two track systrem can help seperate tasks by type of priority or type of involvement.



Screen L.01

Screen L.02

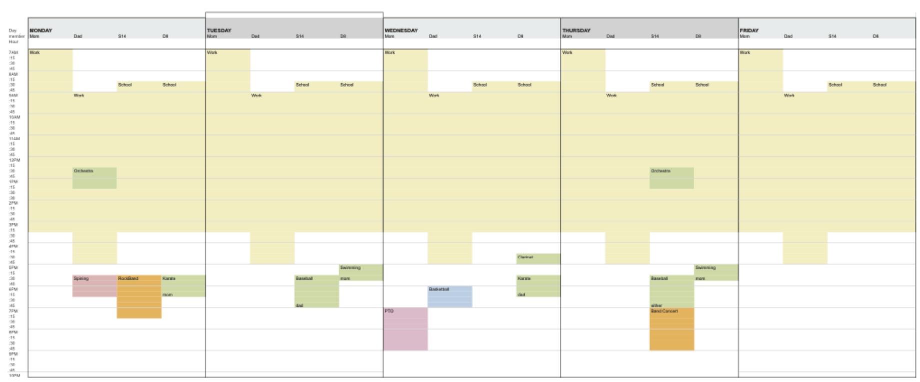
confusion to the mix, but the concept of being able to map multiple layer items is intriguing, since routine is one thing but actual schedule is another.

In screens ***(L.01)*** and ***(L.02)*** we expand on the idea of the two track approach. This seems to be hitting closer to the potential for what Scott's system is trying to do, which is highlight the responsibilities of the parent in terms of the child, but still in context of where the parent is. The idea is that the icon on the first responsibility track can change according to the need of the responsibility. As the technology becomes stronger this becomes the element of manipulation. Another interesting feature that is being shown in the ***(L.)*** screens is the idea that a hand gesture on a touchpad type surface could potentially trigger access to the calendar of that family member who has a dependency based on you, or basically accessing the event that is protruding from the side. This could be a in interesting way to link events to other family members.

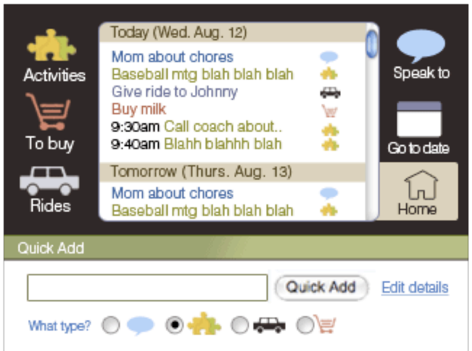
Next steps

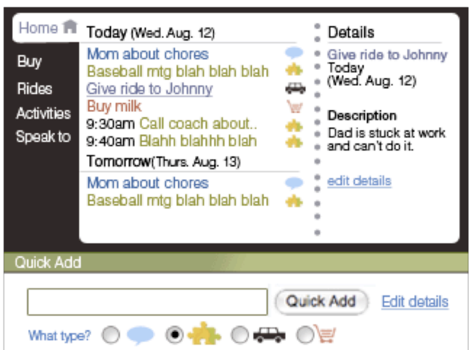
After these various explorations we realized the next step was to solidify what a families week may look like. With this basis, we would be able to quickly identify the conflicts that might arise, but more importantly it gives us a location, time and set up of events that can begin to be represented within the sketches and further interface development. By having these factual schedules in the mix, we are able to accurately portray what the holes and needs of visualization are not only through scenarios but by basic needs.

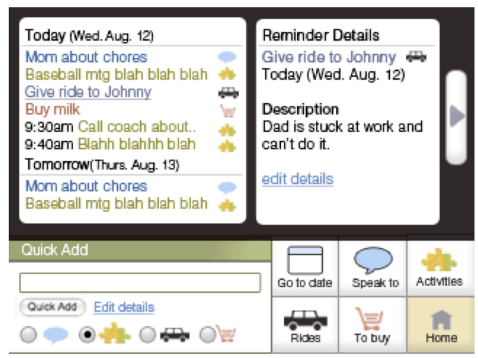
The following is a quick graphic showing the family calendar as it stands for the future of the interface development.



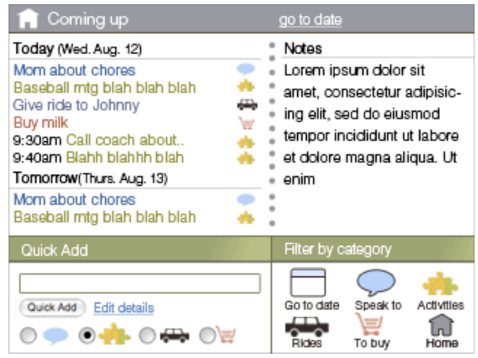
Appendix G Family Coordination Application Sketches

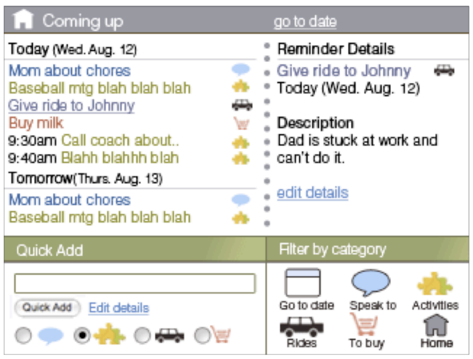




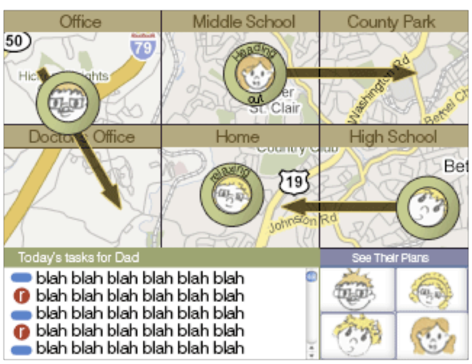


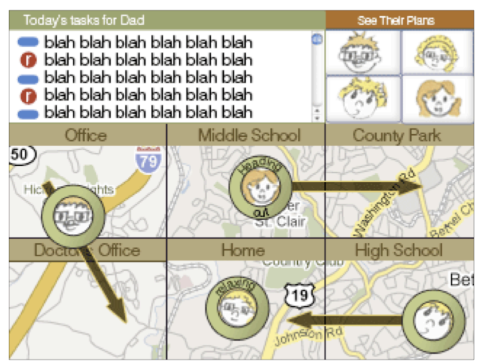

Quick Add
Quick Add
Edit details
Go to date
Speak to
Activities
Rides
To buy
Home
Today (Wed. Aug. 12)
Mom about chores
Baseball mtg blah blah blah
Give ride to Johnny
Buy milk
9:30am Call coach about..
9:40am Blahh blahhh blah
Tomorrow(Thurs. Aug. 13)
Mom about chores
Baseball mtg blah blah blah
Reminder Details
Give ride to Johnny
Today (Wed. Aug. 12)
Description
Dad is stuck at work and can't do it.
edit details

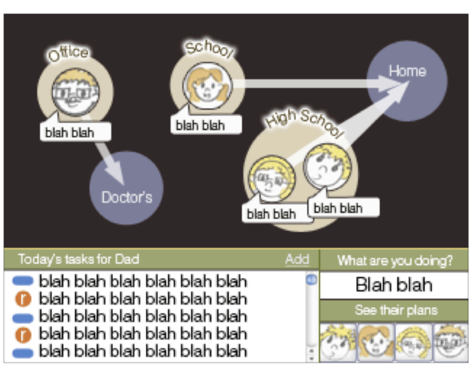

Coming up
go to date
Today (Wed. Aug. 12)
Mom about chores
Baseball mtg blah blah blah
Give ride to Johnny
Buy milk
9:30am Call coach about..
9:40am Blahh blahhh blah
Tomorrow(Thurs. Aug. 13)
Mom about chores
Baseball mtg blah blah blah
Notes
Lorem ipsum dolor sit amet, consectetur adipisic-ing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim
Quick Add
Quick Add
Edit details
Filter by category
Go to date
Speak to
Activities
Rides
To buy
Home

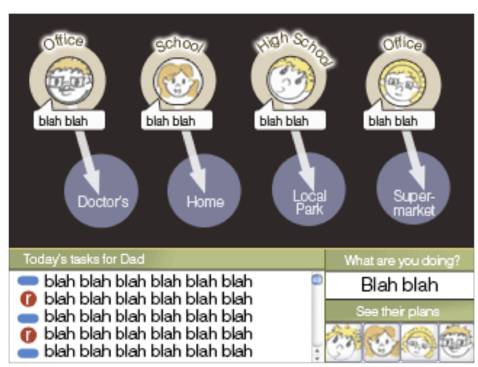

Coming up
go to date
Today (Wed. Aug. 12)
Mom about chores
Baseball mtg blah blah blah
Give ride to Johnny
Buy milk
9:30am Call coach about..
9:40am Blahh blahhh blah
Tomorrow(Thurs. Aug. 13)
Mom about chores
Baseball mtg blah blah blah
Reminder Details
Give ride to Johnny
Today (Wed. Aug. 12)
Description
Dad is stuck at work and can't do it.
edit details
Quick Add
Quick Add
Edit details
Filter by category
Go to date
Speak to
Activities
Rides
To buy
Home

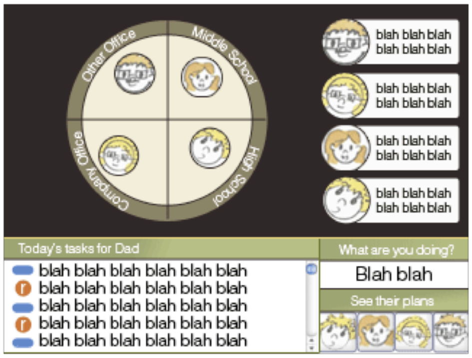

Coming up
go to date
Today (Wed. Aug. 12)
Mom about chores
Baseball mtg blah blah blah
Give ride to Johnny
Buy milk
9:30am Call coach about..
9:40am Blahh blahhh blah
Tomorrow(Thurs. Aug. 13)
Mom about chores
Baseball mtg blah blah blah
August 2009
Quick Add
Quick Add
Edit details
Filter by category
Go to date
Speak to
Activities
Rides
To buy
Home

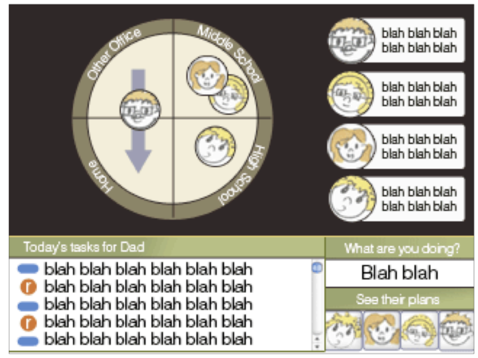

Office
Middle School
County Park
Doctor's Office
Home
High School
Today's tasks for Dad
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
See Their Plans

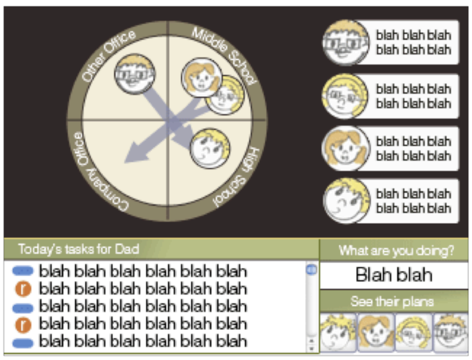

Today's tasks for Dad
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
See Their Plans
Office
Middle School
County Park
Doctor's Office
Home
High School

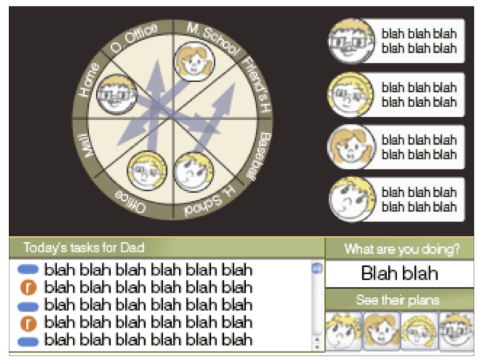

Office
School
Home
High School
blah blah
blah blah
Doctor's
blah blah
blah blah
Today's tasks for Dad
Add
What are you doing?
Blah blah
See their plans
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah

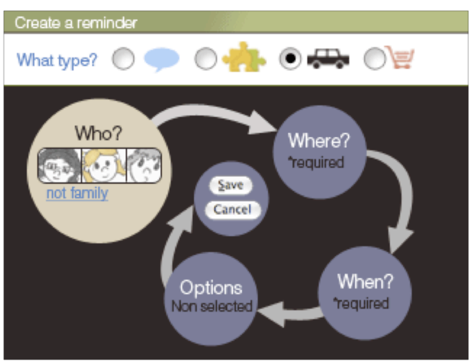

Office
School
High School
Office
blah blah
blah blah
blah blah
blah blah
Doctor's
Home
Local Park
Super-market
Today's tasks for Dad
What are you doing?
Blah blah
See their plans
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah

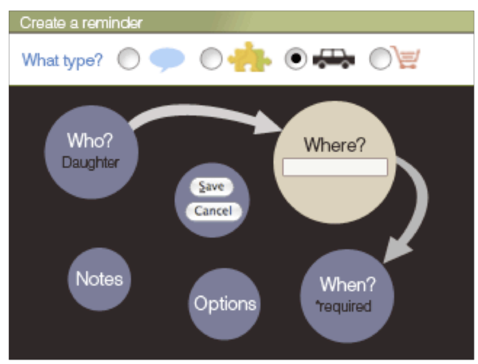

Other Office
Middle School
Company Office
High School
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
Today's tasks for Dad
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
What are you doing?
Blah blah
See their plans

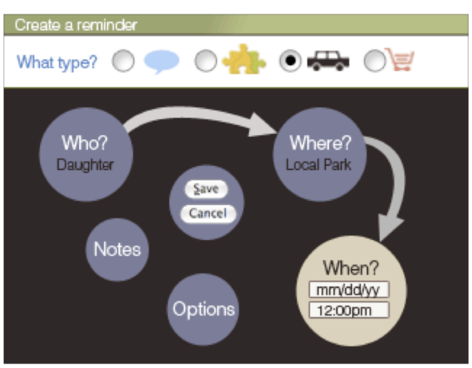

Other Office
Middle School
Home
High School
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
Today's tasks for Dad
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
What are you doing?
Blah blah
See their plans

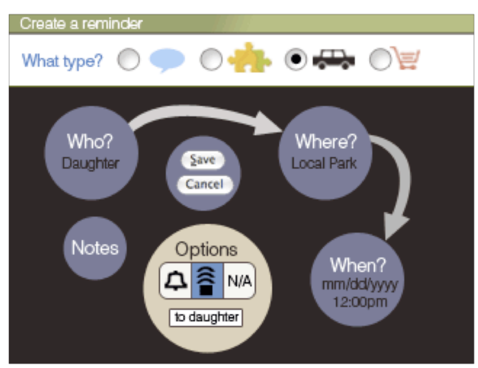

Other Office
Middle School
Company Office
High School
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
Today's tasks for Dad
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
What are you doing?
Blah blah
See their plans


O. Office
M. School
Home
Friend's H
Mall
Baseball
Office
H. School
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
Today's tasks for Dad
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
blah blah blah blah blah blah
What are you doing?
Blah blah
See their plans

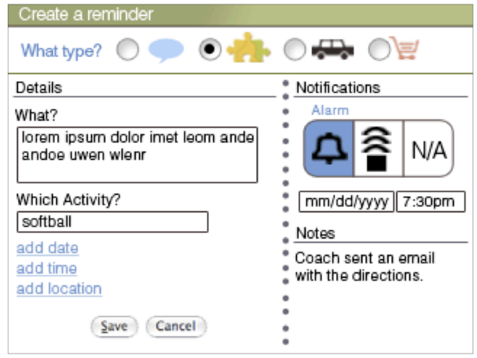

Create a reminder
What type?
Who?
not family
Where?
*required
Save
Cancel
Options
Non selected
When?
*required

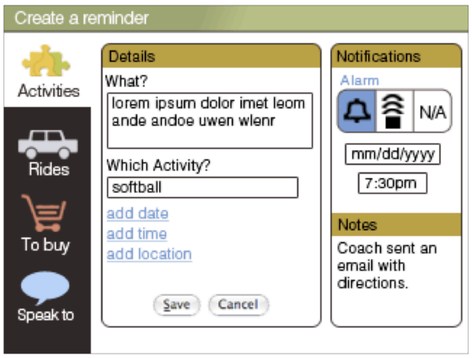

Create a reminder
What type?
Who?
Daughter
Where?
Save
Cancel
Notes
Options
When?
*required

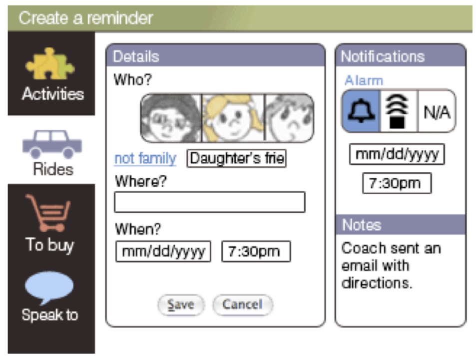

Create a reminder
What type?
Who?
Daughter
Where?
Local Park
Save
Cancel
Notes
Options
When?
mm/dd/yy
12:00pm


Create a reminder
What type?
Who?
Daughter
Save
Cancel
Where?
Local Park
Notes
Options
N/A
to daughter
When?
mm/dd/yyyy
12:00pm


Create a reminder
What type?
Details
Who?
not family
Daughter's frie
Where?
When?
mm/dd/yyyy
7:30pm
Save
Cancel
Notifications
Proximity
N/A
close to
daughter
Notes
Dad has a meeting after work and can't make it.

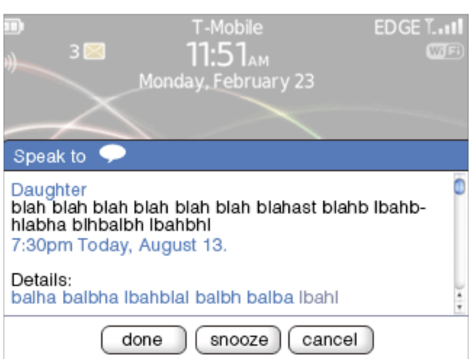

Create a reminder
What type?
Details
What?
lorem ipsum dolor imet leom ande andoe uwen wlenr
Which Activity?
softball
add date
add time
add location
Save
Cancel
Notifications
Alarm
N/A
mm/dd/yyyy
7:30pm
Notes
Coach sent an email with the directions.


Create a reminder
Activities
Rides
To buy
Speak to
Details
What?
lorem ipsum dolor imet leom ande andoe uwen wlenr
Which Activity?
softball
add date
add time
add location
Save
Cancel
Notifications
Alarm
N/A
mm/dd/yyyy
7:30pm
Notes
Coach sent an email with directions.


Create a reminder
Activities
Rides
To buy
Speak to
Details
Who?
not family
Daughter's frie
Where?
When?
mm/dd/yyyy
7:30pm
Save
Cancel
Notifications
Alarm
N/A
mm/dd/yyyy
7:30pm
Notes
Coach sent an email with directions.

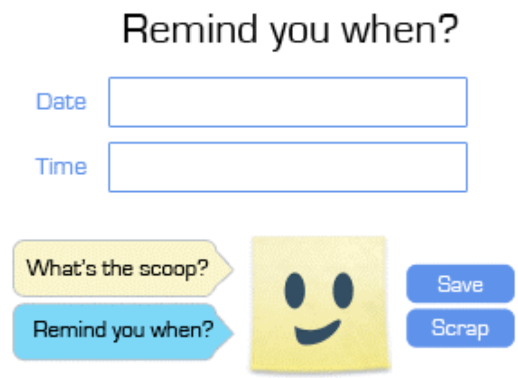

Give a ride
Daughter and daughter's friend to unknown location.
7:30pm Today, August 13.
Details:
Coach sent an email with directions.
done
snooze
cancel

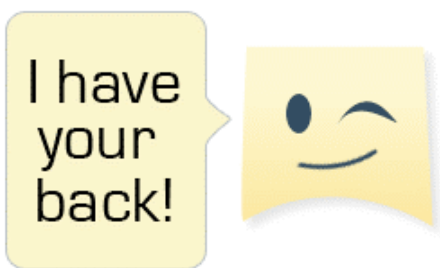

Speak to
Daughter
blah blah blah blah blah blah blahast blahb lbahbhlabha blhbalbh lbahbhl
7:30pm Today, August 13.
Details:
balha balbha lbahblal balbh balba
done
snooze
cancel


T-Mobile
EDGE
3
11:51AM
Monday, February 23
WiFi
Speak to
Daughter
blah blah blah blah blah blah blahast blahb lbahb-hlabha blhbalbh lbahbhl
7:30pm Today, August 13.
Details:
balha balbha lbahblal balbh balba lbahl
done
snooze
cancel


Speak to
Daughter
blah blah blah blah blah blah blahast blahb lbahb-hlabha blhbalbh lbahbhl
7:30pm Today, August 13.
Details:
balha balbha lbahblal balbh balba lbahl
done
snooze
cancel


What's the scoop?
What
Where
When
What's the scoop?
Remind you when?
Save
Scrap


Remind you when?
Date
Time
What's the scoop?
Remind you when?
Save
Scrap


I have your back!


Title:
Where:
Date:
Time:
Date:
Time:


Saved


Remind About ?
about -- when -- where -- alert -- save
When is it ?
Date
Time
about -- when -- where -- alert -- save
Where is it ?
about -- when -- where -- alert -- save
Alert when ?
Date
Time
about -- when -- where -- alert -- save
SAVED
about -- when -- where -- alert -- save

Appendix H Data Collection Study Nightly Protocol

1. Review today
    a. Movement, for each person
        i. From
        ii. To
        iii. Time
        iv. Transport
        v. Objects: school bag, soccer uniform
    b. Forgetting
        i. Did you forget anything?
            1. What
            2. Where?
        ii. Did you help anybody remember their things? Jobs?
            1. What?
            2. When?
            3. Where?
    c. The Plan
        i. Plan steps
            1. Person
            2. To
            3. Transportation
                a. What: School bus
                b. Who drives?
            4. When
            5. For what?
            6. Individual or coordinated decision?
        ii. Changes
            1. Cause: late meeting, traffic
            2. Consequences
                a. Who found out about stimulus
                b. Who made plan? Alone?
                c. Who had to be told about changes?
            3. Exchange media?
        iii. Explain updates
            1. Planned/unplanned
            2. Cause
            3. Major/minor
            4. Would you have wanted to know
            5. How would you have wanted to know
            6. When would you have wanted to know
    d. Calendar
        i. Get images
        ii. What changes were made
        iii. Who?
        iv. When?
        v. Where?
        vi. What info included and what not included?
    e. Notes
        i. Get images

        ii. What changes lists were made
        iii. Who?
        iv. When?
        v. Where?
2. Tomorrow's Plan
    a. Plan steps
        i. Person
        ii. To
        iii. Transportation
            1. What: School bus
            2. Who:
        iv. When
        v. Activity
            1. School
    b. Mark any changes made to plan during interview
3. Schedule tomorrow
4. Nightly Interview Technical Support
    1. Scrape phone
        a. Check minutes
        b. Check SMS totals
    2. Scrape accutracking
    3. Scrape weather
    4. Transcribe data from nightly interviews: calendar images, interview notes

Appendix I Data Collection Study Activity Interview Questionnaire

Please answer these questions about ***your last 2 weeks***

	About how often did this happen?					About how stressful was the experience?				
	Never 1	1 or 2 times 2	A few times 3	Pretty often 4	Very often 5	Not at all 1	A little 2	Somewhat 3	Pretty 4	Really 5
I found my dinner plans changed.										
My plans to pick up the kids changed										
I wasn't sure where the kids were										
My kids acknowledged my efforts kids										
I struggled to find things while rushing out the door										
My carpool plans changed										

About how often did this
About how stressful was the

	happen?					experience?				
	Never	1 or 2 times	A few times	Pretty often	Very often	Not at all	A little	Somewhat	Pretty	Really
	1	2	3	4	5	1	2	3	4	5
I needed my spouse’s help to buy something	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
The kids changed plans at the last minute	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I needed the kids to tell me what to buy	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I couldn’t find a note I wrote	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
My spouse was late for something	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I lost communication with my spouse	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
My spouse reminded me to do something	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	About how often did this happen?					About how stressful was the experience?				

	Never 1	1 or 2 times 2	A few times 3	Pretty often 4	Very often 5	Not at all 1	A little 2	Somewhat 3	Pretty 4	Really 5
I raised my voice at my kids	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I made a to do list	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
It was hard to stay on top of dinner plans	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
My spouse asked me to buy something for them	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I reminded my spouse to do something	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I left a list at home when I went shopping	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I forgot to write something on the calendar	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	About how often did this happen?					About how stressful was the experience?				
	Never	1 or 2 times	A few times	Pretty often	Very often	Not at all	A little	Somewhat	Pretty	Really

	1	2	3	4	5	1	2	3	4	5
I didn’t have a phone number while out	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A kid forgot something for school	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I left something I needed at work	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I wasn’t sure what time a kids’ activity started/ended	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I didn’t know who was picking up one of the kids	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A kids forgot something for an activity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A carpooler cancelled	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Never	1 or 2 times	A few times	Pretty often	Very often	Not at all	A little	Somewhat	Pretty	Really

About how often did this happen?

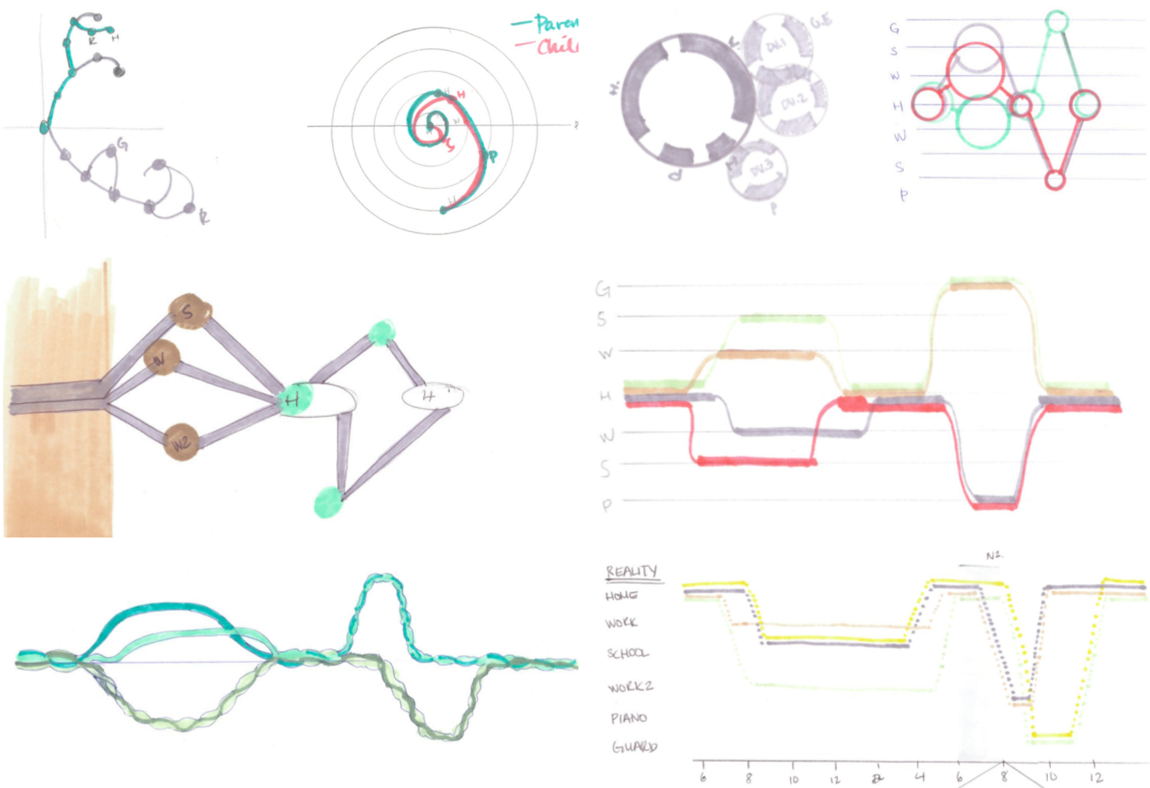
About how stressful was the experience?

	1	2	3	4	5	1	2	3	4	5
I did a last-minute task for my a kids' activity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A kid forgot their lunch (or money)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I lost track of time and left late	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I helped out my spouse with one of their jobs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A kid told me something at the last minute	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I had no idea how to get hold of a kid	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I got stuck in traffic during activity pickup/dropoff	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	About how often did this happen?					About how stressful was the experience?				
	Never	1 or 2 times	A few times	Pretty often	Very often	Not at all	A little	Somewhat	Pretty	Really
	1	2	3	4	5	1	2	3	4	5

I misunderstood coordination plans with my spouse	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I had no idea how to get hold of my spouse	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

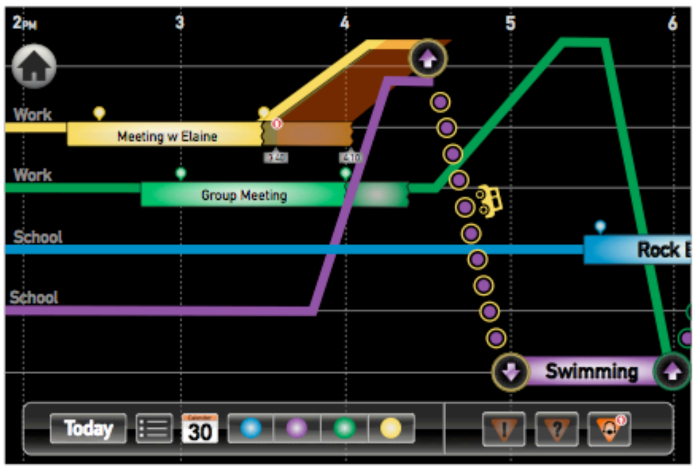
Appendix J Prototyping the Family Time-Flow (FTF)

With the decision to keep place as nominal, we began to sketch interface prototypes. Explorations include the use of spirals and circles (top row) as well as more organic expressions of space and time (middle row). The dots that represent co-travel originated in exploration of the visual metaphor of thread. When family members were together, we drew them as intertwined (bottom left). We also explored a way to compress the visualization by using the diameter of circles to represent time at a place, instead of a linear representation (top, left).

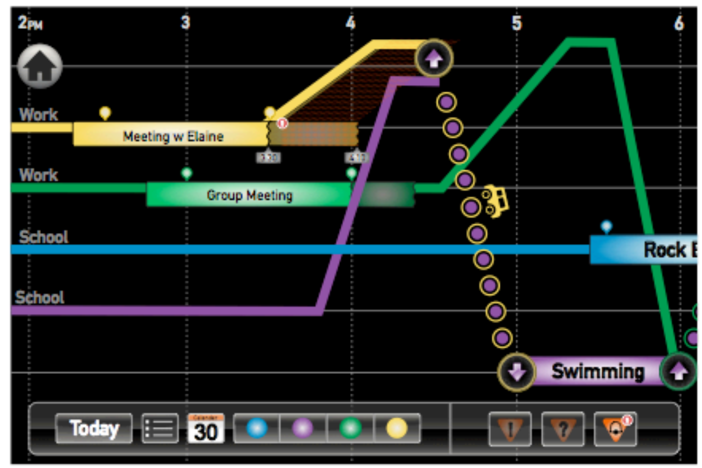


Appendix K FTF Visualization Standards

Case 1. Dad attendance: certain. Location: At work. Other attendees: Elaine. Starting time: 2:30 pm. Ending time: 3:30 pm. Arrival time: 2:20 pm Departure time: ranges from 3:30 pm to 4:00 pm (not certain)



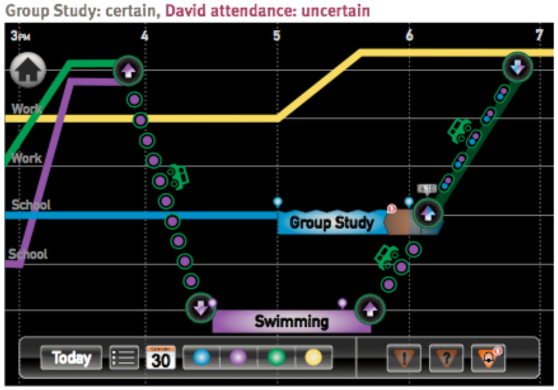
zigzag line + translucency: undecided (arriving/departing) time
translucent area: transporting area related to undecided (arriving/departing) time
translucent orange area: routes related to undecided (arriving/departing) time, which may cause conflicts
number in a red circle: indicates numbers of conflicting/unresolved/alarming issue



zigzag line + translucency: undecided (arriving/departing) time
translucent area: transporting area related to undecided (arriving/departing) time
dotted- orange area: routes related to undecided (arriving/departing) time, which may cause conflicts
number in a red circle: indicates numbers of conflicting/unresolved/alarming issue

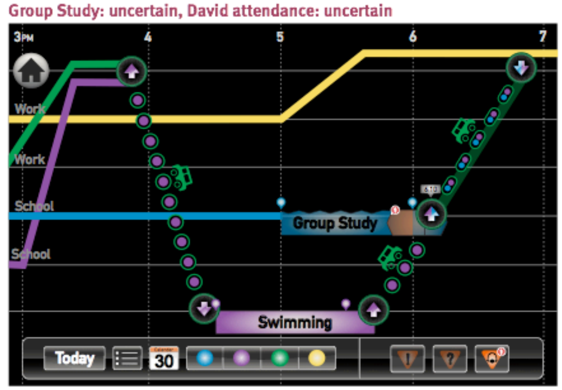
Case 2. Event: Group Study Location: At David's school Starting time: 5:00 pm Ending time: 6:15 pm Arrival time: 5:00 pm Departure time: ranges from 6:00 pm to 6:30 pm (not certain)

Group Study: certain, David attendance: uncertain



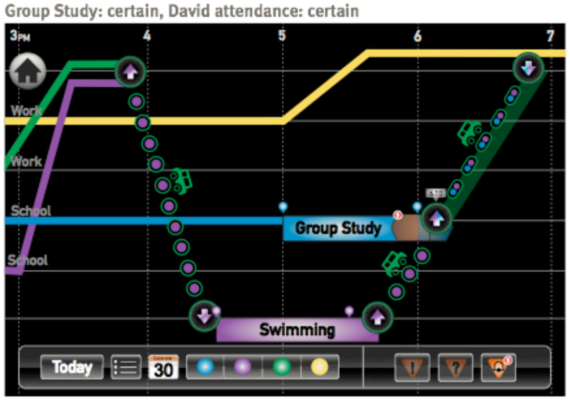
solid box + zigzag line: event is decided + the person's attendance is undecided
pointed line + translucency: undecided (arriving/departing) time
pointed line + translucency+ orange area: routes related to undecided (arriving/departing) time, which may cause conflicts
translucent area: transporting area related to undecided (arriving/departing) time
number in a red circle: indicates numbers of conflicting/unresolved/alarming issue

Group Study: uncertain, David attendance: uncertain



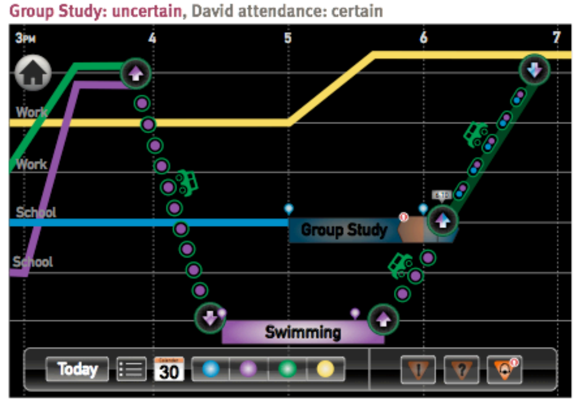
translucent box + zigzag line: event is undecided + the person's attendance is undecided
pointed line + translucency: undecided (arriving/departing) time
pointed line + translucency+ orange area: routes related to undecided (arriving/departing) time, which may cause conflicts
translucent area: transporting area related to undecided (arriving/departing) time
number in a red circle: indicates numbers of conflicting/unresolved/alarming issue

Group Study: certain, David attendance: certain



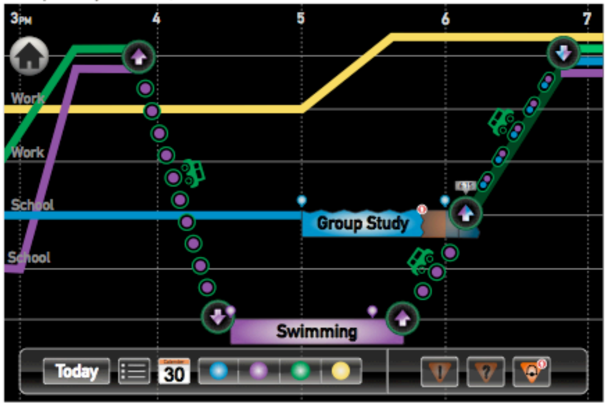
solid box: event in decided
pointed line + translucency: undecided (arriving/departing) time
pointed line + translucency+ orange area: a range of undecided(arriving/departing) time, which may cause conflicts
translucent area: transporting area related to undecided (arriving/departing) time
number in a red circle: indicates numbers of conflicting/unresolved/alarming issue

Group Study: uncertain, David attendance: certain



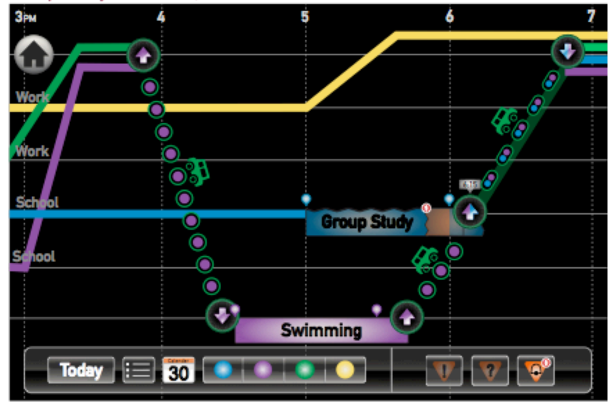
solid box + zigzag line: event is decided + the person's attendance is undecided
pointed line + translucency: undecided (arriving/departing) time
pointed line + translucency+ orange area: a range of undecided (arriving/departing) time, which may cause conflicts
translucent area: transporting area related to undecided (arriving/departing) time
number in a red circle: indicates numbers of conflicting/unresolved/alarming issue

Group Study: certain, David attendance: uncertain



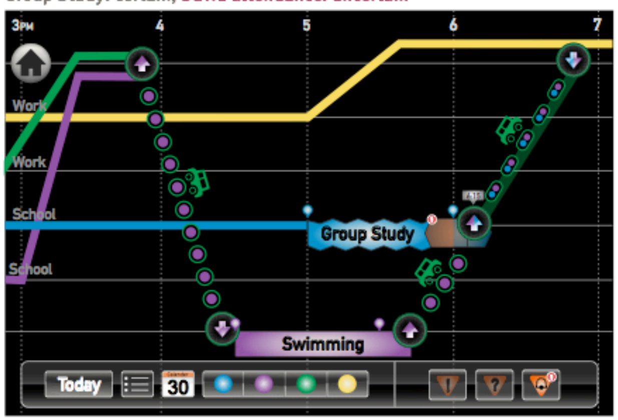
solid box + zigzag line: event is decided + the person's attendance is undecided
zigzag line + translucency: undecided (arriving/departing) time(arriving/departing) time, which may cause conflicts
translucent area: transporting area related to undecided (arriving/departing) time
number in a red circle: indicates numbers of conflicting/unresolved/ alarming issue

Group Study: uncertain, David attendance: uncertain



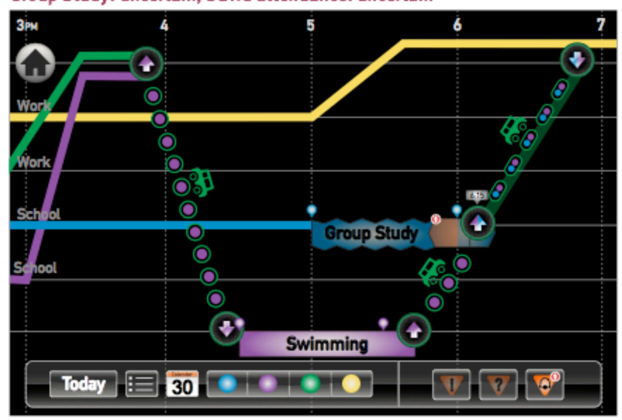
translucent box + zigzag line: event is undecided + the person's attendance is undecided
zigzag line + translucency: undecided (arriving/departing) time(arriving/departing) time, which may cause conflicts
translucent area: transporting area related to undecided (arriving/departing) time
number in a red circle: indicates numbers of conflicting/unresolved/alarming issue

Group Study: certain, David attendance: uncertain



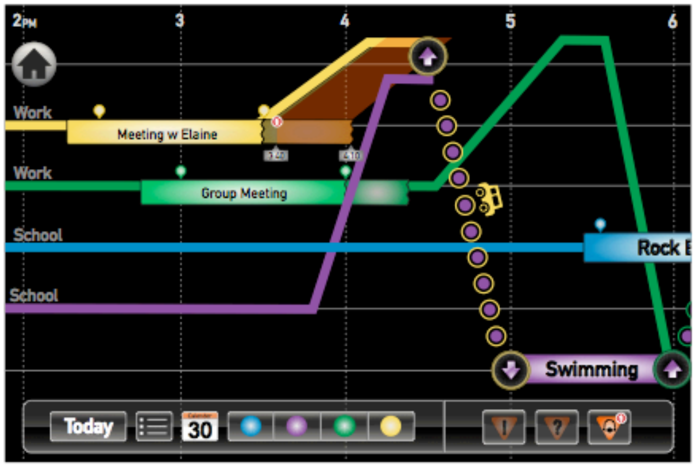
solid box + zigzag line: event is decided + the person's attendance is undecided
pointed line + translucency: undecided (arriving/departing) time(arriving/departing) time, which may cause conflicts
translucent area: transporting area related to undecided (arriving/departing) time
number in a red circle: indicates numbers of conflicting/unresolved/alarming issue

Group Study: uncertain, David attendance: uncertain

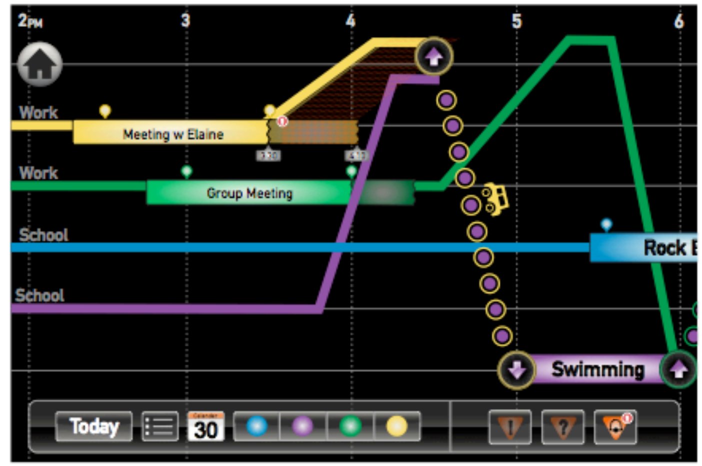


translucent box + zigzag line: event is undecided + the person's attendance is undecided
pointed line + translucency: undecided (arriving/departing) time (arriving/departing) time, which may cause conflicts
translucent area: transporting area related to undecided (arriving/departing) time
number in a red circle: indicates numbers of conflicting/unresolved/alarming issue

Case 3. Event: Parent & student meeting at Jane's school. Mom/Jane attendance: certain Location: At Jane's school Starting time: 4:00 pm School Ending time: 5:00 pm School Mom's arrival time: 3:45 pm (not certain) Jane's arrival time: 3:45 pm Departure time: 5:10 pm (not certain)



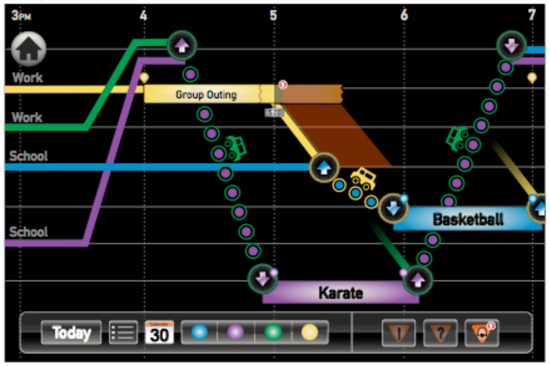
zigzag line + translucency: undecided (arriving/departing) time
translucent area: transporting area related to undecided (arriving/departing) time
translucent orange area: routes related to undecided (arriving/departing) time, which may cause conflicts
number in a red circle: indicates numbers of conflicting/unresolved/alarming issue



zigzag line + translucency: undecided (arriving/departing) time
translucent area: transporting area related to undecided (arriving/departing) time
dotted- orange area: routes related to undecided (arriving/departing) time, which may cause conflicts
number in a red circle: indicates numbers of conflicting/unresolved/alarming issue

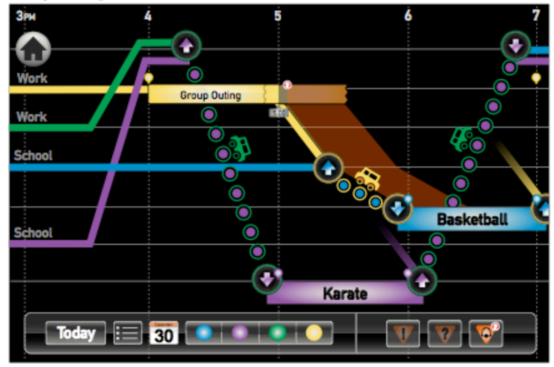
Case 4. Event: Group Outing. Dad attendance: certain / not certain. Location: At downtown Starting time: 4:00 pm Ending time: 7:00 pm Arrival time: 4:00 pm Departure time: not certain

Group Outing: certain, Dad attendance: certain



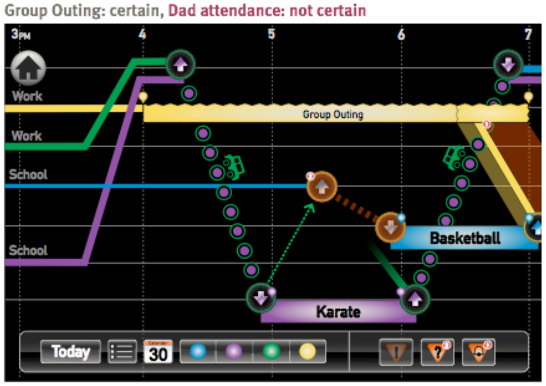
zigzag line + translucency: undecided (arriving/departing) time
translucent area: transporting area related to undecided (arriving/departing) time
translucent orange area: alarming event, which may cause conflicts
route line + gradation: do not know where a person in charge comes from
number in a red circle: indicates numbers of conflicting/unresolved/alarming issue

Group Outing: certain, Dad attendance: certain



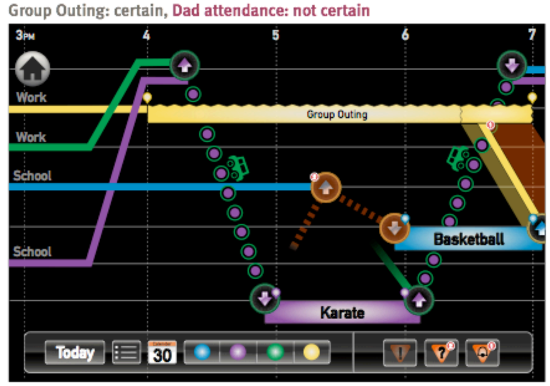
zigzag line + translucency: undecided (arriving/departing) time
translucent area: transporting area related to undecided (arriving/departing) time
translucent orange area: alarming event, which may cause conflicts
route line + gradation: do not know where a person in charge comes from
number in a red circle: indicates numbers of conflicting/unresolved/alarming issue

Group Outing: certain, Dad attendance: not certain



solid box + zigzag line: event is decided + the person's attendance is undecided
zigzag line + translucency: undecided (arriving/departing) time
translucent area: transporting area related to undecided (arriving/departing) time
translucent orange area: alarming event, which may cause conflicts
number in a red circle: indicates numbers of conflicting/unresolved/alarming issue
dotted line: transporting line related to unresolved pick-up or drop-off

Group Outing: certain, Dad attendance: not certain



solid box + zigzag line: event is decided + the person's attendance is undecided
zigzag line + translucency: undecided (arriving/departing) time
translucent area: transporting area related to undecided (arriving/departing) time
translucent orange area: alarming event, which may cause conflicts
dotted line: transporting line related to unresolved pick-up or drop-off
number in a red circle: indicates numbers of conflicting/unresolved/alarming issue

Appendix L Validation Study Instruments

We adapted the Technology Adoption Model 3 (TAM-3) survey (Venkatesh et al. 2003), itself an adaptation of the original TAM survey (Venkatesh & Davis 2000), to the context of family logistics. Wherever appropriate workplace issues, vocabulary, and roles were transformed to be more appropriate to family logistics

Perceived Usefulness
Using the system would improve my performance in my job as a parent
Using the system would enhance my effectiveness in my job as a parent
Using the system would increase my productivity as a parent
I think the system would be useful in my job as a parent

Result Demonstrability
I would have difficulty explaining why using the system may or may not be beneficial
I believe I could communicate to others the consequences of using the tool
I would have no difficulty telling others about the result of using the tool
If I used the tool, the results would be apparent to me

Behavioral Intention
If it were available, I would plan to use the tool in the next 3 months
If I had access to the tool, I predict that I would use it
Assuming I had access to the tool, I would intend to use it

Computer Playfulness
When using computers I characterize myself as spontaneous
When using computers I characterize myself as creative
When using computers I characterize myself as playful
When using computers I characterize myself as unoriginal

Computer Anxiety
Computers do not scare me at all
Working with a computer makes me nervous
Computers make me feel uncomfortable
Computers make me feel uneasy

Perceived Enjoyment
I would imagine using this tool to be enjoyable
I would imagine that the actual process of using the tool is pleasant
I think I would have fun if I used this tool

Computer Self-Efficacy
I could complete my job as a parent using this tool…
…if there was no one around to tell me what to do as I go
…if I had a built-in help facility for assistance

…if someone showed me how to use it first
…if i had used similar tools before this one to perform the same task

Output Quality
If I used this tool, I would have no problem with the quality of the tool's output
I imagine that the quality of the output that I would get from using this tool would be high
The quality of the output I would get from the tool is high
If I used this tool, I would imagine that the results from the tool would be excellent

Perception of Control
Given the resources, opportunities, and knowledge it takes to use this tool, it would be easy for me to use
I would feel control over the tool if I used it
This tool is not compatible with other tools that I use

The survey also included two scales that probed dimensions of family logistics, focusing on planning and awareness.

Help with awareness
The tool would help me know more about what other family members plan to do.
The tool would help me know more about what other family members are doing.

Help with planning
The tool would help me make plans easier.
The tool would help me make plans that I would be less likely to need to change.
The tool would help me improvise when I need to change plans.