How Routine Learners can Support Family Coordination

Scott Davidoff, John Zimmerman and Anind K. Dey
Carnegie Mellon Human-Computer Interaction Institute
{ scott.davidoff | johnz | anind } @ cs.cmu.edu

ABSTRACT
Researchers have detailed the importance of routines in how people live and work, while also cautioning system designers about the importance of people's idiosyncratic behavior patterns and the challenges they would present to learning systems. We wish to take up their challenge, and offer a vision of how simple sensing technology could capture and model idiosyncratic routines, enabling applications to solve many real world problems.

To identify how a simple routine learner can demonstrate this in support of family coordination, we conducted six months of nightly interviews with six families, focusing on how they make and execute plans. Our data reveals 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. With about 90% of their content concerning deviations, not routines, families do not rely on calendars to support them during these moments. We discuss how coordination tools, like calendars and reminder systems, would improve coordination and reduce stress when augmented with routine information, and how commercial mobile phones can support the automatic creation of routine models.

Author Keywords
Calendar, reminder, learning, location, mobile, planning.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design, Human Factors.

INTRODUCTION

People construct routines through the repeated performance of a set of sequenced actions. Routines are valuable because they allow people to complete their activities of daily living without attending to the details of any moment's activities, freeing their attention to focus on larger issues, challenges, and pleasures [30]. The development of many routines forms a sort of choreography of living that reduces stress and enhances confidence, competence, and control [15].

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 [3, 12, 17, 31, 32] and their incompatibility with the techniques of artificial intelligence [10, 28, 30]. We wish to take up this challenge. We offer a *vision* for how ubicomp systems, using only simple sensors, can learn a valuable subset of routines and act on this knowledge, making progress towards solving real problems.

Broadly speaking, routine learning systems could enable applications in ways that positively impact observed needs. For example, they might document work process, helping to train new workers or find opportunities for process improvements [4]. They can also reveal details of people's behavior so they can reflect on their actions, helping them to effect change in their lives [9]. We investigate the role of a routine learner with respect to dual-income families, a good target population because they rely heavily on routines to cope with the complex coordination of school, work, family, and enrichment activities [11, 17, 13].

We do not intend this work to be a demonstration of technical feasibility, but rather a discussion of conceptual feasibility. Because the value to families of detecting routines and exceptions to routines is currently unknown, we approach the situation looking first to understand what information families would find valuable. This information can better define the capabilities a technical system would need to provide. Accordingly, the work should serve as a road map for interested systems builders, identifying specific, novel technical targets, rather than implementation details or a technical exploration of practical feasibility.

As a first step in our investigation into how a practical routine learning system could directly benefit the lives of families, we conducted six months of field observations of family coordination. During this time, we interacted with six dual-income families to understand how they employ routines in their daily lives. The data collection allowed us to gain clarity on the structure behind the coordination breakdowns that families encounter. We find that *over 60%* of all family activities unfold in a non-routine fashion. We also find that during many of these situations, family members need but do not have accurate knowledge of one

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another's routines. Lastly, we find that family members cannot turn to their calendars for routine information, as over 90% of the events on calendars document non-routine activities.

These observations lead us to identify how 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. First, simply having access to routine information could help families more effectively create and execute coordination plans. Second, access to routine information could make calendars more useful for both planning new events and coping with unanticipated deviations in routine. Third, routine information could give reminder applications the capability to automatically create reminders in situations where the user did not anticipate a breakdown might occur.

In offering this vision for the role of routine learners in dual-income family life, we review the research on families and routines. Next we describe our data collection and describe the salient findings about routines, family support tools, and deviations. Finally, we detail the opportunities for ubicomp systems to add value to people's lives by leveraging knowledge of family routines.

RELATED WORK

Existing research has highlighted the value of routines in support of everyday living, and has noted the breakdowns that often occur when people must deviate from those routines. Working as a form of habituated memory [31], routines liberate human attention [33], helping people to feel more in control of their environment [3, 11, 30], and enabling the enjoyment of everyday experience [30]. Faced with complex logistical challenges to arrange the transportation and coordination of people and "equipment" related to school, work, family, and enrichment activities [3, 11, 17], dual-income families rely especially on routines to support the enactment of their dynamic schedules. The effortless mastery of this "busyness" through routine provides parents with a strong sense of control (as described by Bandura in [2]) over their environment [11].

Even well articulated, well-practiced and well-executed, plans and routines cannot help families respond to the many unexpected changes that often shape their day. 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.

Even more disruptive are *unscheduled deviations*, which are non-routine occurrences whose existence could not have been 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 [3, 12, 13, 32], and can degrade effective coordination practices [11, 16, 32], which can even trigger a cascade of coordination breakdowns [12].

In this work, we investigate the family experience where supportive routines confront less predictable situations, like role switches. These situated examples of coordination breakdowns describe a variety of ways in which the management of kids' activities requires sufficient attention to regularly compromise parents' sense of control. Our work then departs from the strictly ethnographic, using our observations of family life to consider the impact of a speculative routine learner. This work picks up that challenge by exploring how computational systems can leverage previously unavailable information resources, which can in turn free some of the attentional resources required to manage the background noise of 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. This work looks to advise system builders interested in the support of family life that is motivated by and grounded in observation, and in the wider application of routine as a capable and enabling abstraction.

A number of research systems have explored a variety of alternative approaches to supporting family coordination. Systems that share family member location [6], or even simply their status as "moving" or "not moving" [5] demonstrate that family members can leverage their rich knowledge of each other's routines to derive rich meaning out of only minimal information. Another approach looks to support family coordination by improving calendars or reminder systems. Digitized calendars can, for example, extend calendaring functions and accessibility to remote locations, and even throughout the home [24]. Digital reminder systems can deliver pre-defined information to mobile phones, or large displays at home [26], and can be triggered as people approach pre-specified places [22], or even when pre-specified situations unfold [23]. While these reminder systems do help coordination efforts to some extent [22], they require users to know in advance, what actions they might forget, and what information they would need at those times. Research on family routines, however, shows that many breakdowns are unanticipated [11, 17], or involve information that could have not been known beforehand [8, 12], making the task of manually creating an appropriate reminder in these situations effectively impossible.

Though models of routine have not been explored in support of family coordination, they are appearing in support of applications in various other domains.

Visualizations of the learned routines of office workers, for example, have been shown to help remote workers coordinate [4]. Learned models of transportation routines have been used to help people with cognitive impairments move about the city [21]. Routine patterns of communication have been used to generate social network graphs, helping model the spread of disease [15]. Our work advances this corpus by making a case for a routine learning system as an enabling technology, by bringing new capabilities and benefits to more traditional coordination tools such as calendars and reminder systems.

DATA COLLECTION 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. Quantitative methods employed included the following:

1. 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 interviews on family activities
4. GPS sampling for every family member (including children) at one-minute intervals.

Qualitative data collection included the following:

1. Evaluation of the knowledge of family members' routines
2. Identification of all calendar events as routine or non-routine

Participant selection was determined by several motivating factors. Looking to develop systems with the broadest possible impact, we chose to focus on the largest (61%) and fastest-growing family demographic in the United States – the dual-income nuclear family [18]. Seeking the most frequent and observable coordination issues, we selected families where both parents work full-time outside of their homes, and where children depend on their parents for transportation, limiting participation to families with children between the ages of 6 and 16. Within this demographic, we made an effort to recruit a wide cross-section, selecting families from a variety of ethnic and economic backgrounds, as well as expressing a variety of planning styles, child-rearing models, and transportation preferences. Table 1 provides an overview of the six families that participated in our data collection.

Quantitative data collection protocol

Every night 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.

Family Code	**Parents** Mom then Dad	**Income** in $1,000's	**Kids** Son/Daughter/Age	**Activities** Top 5 by rides given during study	**Rides per Week** From Nightly Interviews
P1	50, Procurement 52, Scientist	100+	D15, D12	Basketball, dance, altar service	
P2	51, Recruiter 50, Project Manager	80-100	S15, D10	Marching band, ski team, cheerleading, Leos	
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	

Table 1. Family and activity overview. Families P1 and P2 piloted the study for three months, followed by six months of data collection. 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.

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 [5, 7, 22], and that meaningful location [1], near-term-trajectory [23], and individual routines [21] 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.

Qualitative data collection protocol

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.

Towards this goal, we created a series of activities probing each family members on different aspects of routines. These activities were conducted as a series of biweekly interviews (referred to as activity-interviews) in family homes. All family members were asked to be present during the activity-interviews. 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 planned for and they enacted routines for various days of the week.

Looking to understand if family members had an accurate knowledge of the routines of others, one activity asked members to specify the routines for every other member for the coming calendar week, including the event start, end times, and travel times (see Table 2). To understand the level of detail with which family members could articulate one other's routines, 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 involved and any dependencies or constraints involved in the task such as remembering to wash a uniform before it is needed for a game. To understand if family members could describe their own routines with sufficient detail so that others could later enact them, 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" at the time of its placement on the calendar.

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, looking for some available form of documentation of missing routine information that families might be able to use, we turn to the artifacts used for coordination support, focusing on calendars. 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 later discuss how by learning family routines, a system could provide family members with the information they need but is currently not available.

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.

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. 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 their respective workplaces.

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 studies 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 the 10-minute bus ride to school every day, and after school head directly to track and color guard. Often home before Mom, 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 allows us to identify every activity occurrence by its location. Figure 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. Gaps in the dataset (caused by family or research team unavailability) have been condensed to accommodate space constraints imposed by this publication.

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 with both GPS and ground truth 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.

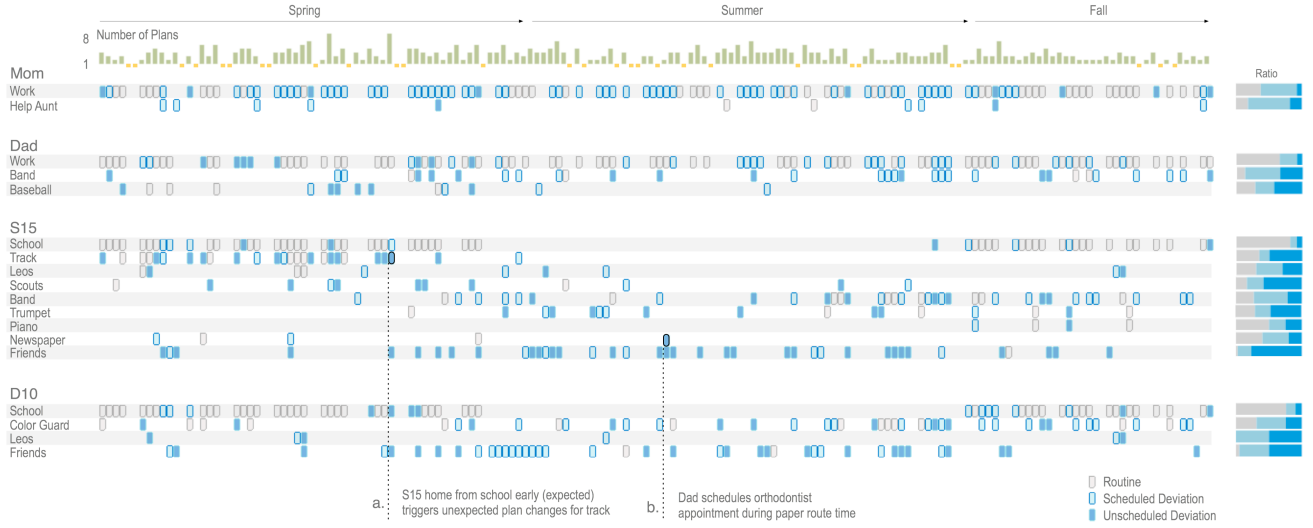


Figure 1. Six months of Family E's activities. Each dot represents an activity instance, ordered chronologically left to right, and classified as either routine, or scheduled or unscheduled deviation. Proportion bars to the right of each activity show the distribution of event types. Across the top is 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.

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. In this section, we offer evidence from our activity-interviews that family members often have beliefs about one another's routines that are, in small but important ways, incomplete and/or inaccurate. A look at routine awareness between family members hints at the causes of coordination failure.

As part of the ongoing bi-weekly interview process, we asked every member of every family to simply specify all the routine activities for every other family member in the coming week, with approximate start and end times. Examination of the lists shows that in almost all cases, family members descriptions are largely, *though not entirely*, complete or accurate. Family E's aggregated descriptions of S15's Wednesday routine (see Table 2) 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
Boy Scouts	Start		7:00 pm	7:00 pm
	End		8:30 pm	9:00 pm
Paper Route	Start	5:30 pm	5:30 pm	
	End	6:30 pm	6:00 pm	

Table 2. S15's 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 paper route inaccuracy 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 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.

In the absence of 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.

Calendars hold deviations not routines

Often employed as the principal coordination artifact [3, 25], 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 observational field 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 [33, 25, 29, 31], 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. Possible origins of this asymmetry become more clear if we consider how routines integrate into family life.

Since events on the calendar help families remember [3, 10, 25], we can reason that integrated and practiced routine

events require less, *if any*, reminding. Since previous studies have shown that many routines at one time were non-routine [32, 31], we can predict that calendars should show historical evidence of this gradual transition from non-routine to routine. Back-tracing various family routines shows this assertion to be valid. We observe the most legible example in family P1's calendar (see Figure 2).

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.

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 more significant and stressful coordination breakdowns that they can influence and even cause.

Family life will often evolve a division of labor. In family E, for example, Dad largely manages the pickups from color guard. Hectic dual-income family life, however, does not always accommodate a tidy division of labor. Unscheduled deviations (*e.g.*, working late or bad weather), scheduled deviations (*e.g.*, business trips), or even everyday chore negotiations can shift the ordinary division of labor, requiring a task's owner to hand over responsibility to the other parent. This *role switching* often brings to the foreground a variety of ways in which small gaps in routine knowledge can lead to coordination failure.

For example, in family F, Mom regularly calls the gymnastics carpoolers early in the day to confirm that D10 will attend gymnastics class. When out of town, Mom instructs Dad to make the call, but does not tell him that part of the call's routine is to discuss the pickup place. The carpoolers interpret no discussion of place to mean "the pickup will take place at school." When discussed directly, pickups can be at any location, but are usually from home. Unaware he has changed the plan, Dad picks D10 up from school, and she waits at home for the carpool, which is sitting in the school parking lot awaiting her arrival.

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 a very non-routine 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 plan creation 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 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 knowledge 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.

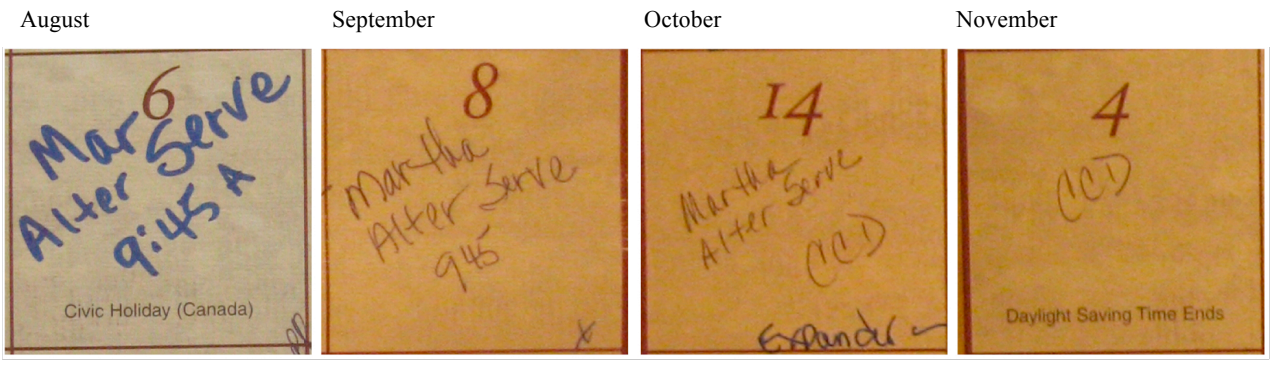


Figure 2. The disappearing routine. From August to November we can see that Altar Service slowly loses detail and eventually disappears. By November, even though the activity is ongoing, it has become routine, and disappears from the calendar.

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.

DISCUSSION AND DESIGN ARGUMENT

If a lack of accurate routine information can lead families to coordination breakdowns, we contend that the most direct solution is to *make routine information available* to families. The remainder of this work considers the capabilities computational systems can gain if provided with machine-interpretable access to routine information. We describe how these capabilities can ultimately enhance the efficacy and experience of family coordination, and minimize unnecessary stress.

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.*, [21]). Though full examination of its implementation is beyond the scope of this paper, our coordination examples require extensions of current models of routine movement to include multiple coordinating individuals and a larger numbers of destinations.

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. We start with an exploration of the calendar. Lacking routine information, current family calendars, if made accessible to Dad at the orthodontist's office, could not help him see S15's routine paper route. A calendar augmented with routine information could, however, make the paper route information visible to Dad as he scheduled the appointment and avoid double bookings.

We also explore contemporary research reminder systems. These systems perform admirably in situations where family members can create a reminder in advance. We observe, however, that in situations like where S15 assumes Dad can drive him to track, family members do not always see in advance the things they will not know or forget. Using routines as *input* can give reminder systems a variety of new capabilities. By monitoring family E's everyday routines, for example, a reminder system could both know that S15 is usually at track, and calculate that with Dad's absence he will probably have no transportation, helping with early detection of coordination breakdowns.

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

A calendar with knowledge of routines

While digital calendars as they are currently conceived give remote access to events entered on the home calendar, we reason that this access could not by itself have helped family E's Dad avoid situations like his orthodontist double booking. We observe that like many other routine events, S15's paper route is not listed on the calendar (see Figure 3a). Without evidence to inform him otherwise, these digital calendars could not have prevented Dad from scheduling the conflict because it is simply not visible to him. The burden instead lies entirely with Dad to recall S15's paper route.

Given computational access to S15's routines, the same digital calendar could, on demand, overlay S15's routines (Figure 3b), helping to provide Dad with a more accurate and global picture of S15's likely activities, and helping Dad check his assumptions. Even including the uncertainty that comes with sensor readings, the presence of a possible paper route changes Dad's fundamental memory task *from one of recall to one of recognition*. If Dad does not see the conflict and schedules the appointment, the same calendar could compare the entry with its model of S15's routine activities and make any potential overlap visually prominent (Figure 3c).

Models of routine can also be used as a resource to help calendaring applications assist S15 to avoid missing track on his school half day. As above, S15 could look to the calendar to display Dad's routine, gaining 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 [27]. Predicting, for example, that S15 needs to be at track at 3pm, and that Dad will arrive home at 5pm, planning algorithms (*e.g.*, [19]) could then be used to detect mutually exclusive conditions [6] 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.

A reminder system with knowledge of routines

All reminder systems require that users know beforehand what will be forgotten. In other words, these reminder systems can prove capable when helping to remember, for example, often-forgotten objects or facts that are hard to recall. The examples taken from our data collection illustrate an important breakdown in this systems approach to memory support: families cannot know in advance

enough information to create reminders for all the situations they will encounter. In other words, *families do not 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 the unpleasant situation of forgetting D4 at day care. Here, using only the GPS sensors included with our study participants, a system can learn (i) the time and location of D4's daily pickup, and (ii) that the pickup is usually Mom's responsibility. This should then create an environment in which to do anomaly detection. That is, when Mom is not nearby enough to make the pickup but the pickup is still necessary, the system can reason that the family is in a non-routine situation.

Whether by providing an ambient display to indicate perceived anomalies, or with more intrusive interruption, system designers can then 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 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 might be able 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.

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.

Routine learning systems and control

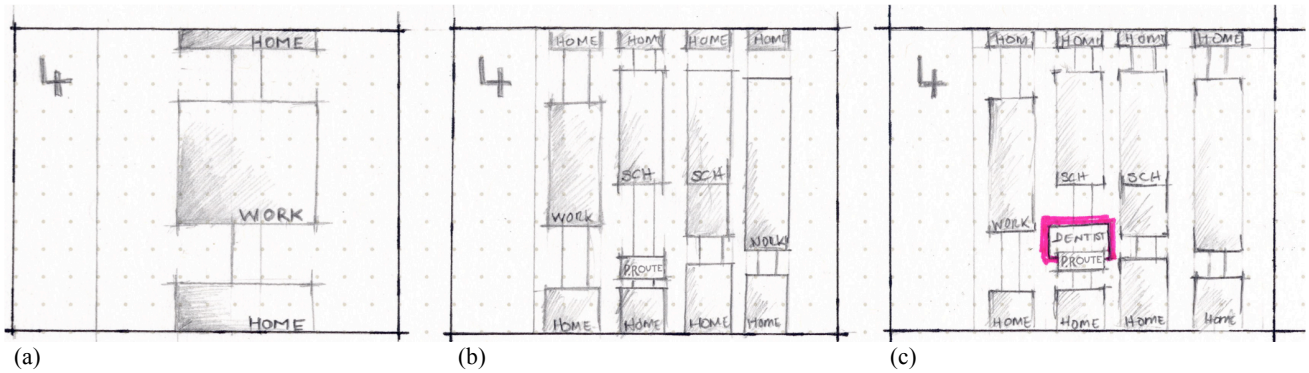
The sampling of coordination breakdowns indicates many ways in which gaps in routine information contribute to our families' experience of stress, which in turn erodes their experience of control over their lives. It also indicates ways in which our current approaches to the systems and artifacts that support coordination fail to buffer families from this experience of stress, reducing their quality of life.

Because we expect the effort required for their capture to be modest, learned models of routine present one path to low-cost stress relief for families. A layer of simple location sensing can be used to observe the performance of, and then to learn models of family routine. Enhancing the calendar, reminder systems, and location awareness systems can provide busy families with the information they need to make better-informed planning decisions, helping avoid scheduling mishaps, and ultimately address any number of incidents that inject stress into family life.

CONCLUSION

In this paper 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.

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.



(a) (b) (c)

Figure 3. Rough sketch showing family E's calendar augmented with family routine information. In (a), like with current calendars, Dad sees an overview of his day. In (b), to avoid a double booking, he compares his day with S15's expected routine. In (c), the calendar highlights a possible conflict with S15's expected paper route.

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. We plan to continue this research by using the data we have collected to build and test a routine learning system to help dual-income families to address the common coordination breakdowns that cause unnecessary stress in their lives.

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