# designing for a frictionless mobile lifestyle

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HPL-2003-143
July 17th , 2003*

planning,
scheduling,
coordinating

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This exploration started by defining the concept of a mobile lifestyle and by identifying families with working parents as a relevant examp le population. User studies in this population led to a rich picture of their lifestyles. Examination and definition of the concept of friction, using mechanical friction as a metaphor, provided the tools to interpret these user studies.
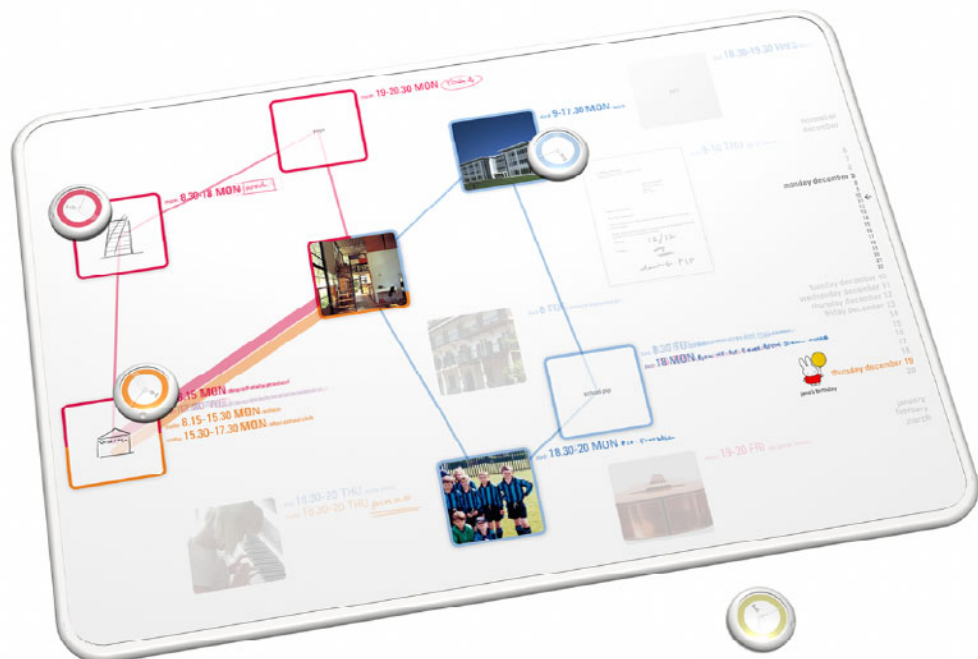
Scheduling and coordination activities, with a focus on the usage situations of scheduling a new appointment and staying synchronized in a changing reality, emerged from the user studies as resonating most clearly with the concepts of friction. This report presents two products that embody this resonance through their design. The "long-term planner" is a large dynamic display that visualizes entangled family schedules and provides shared tangible interaction when scheduling a new appointment. The "coordination watch" is a mobile device that provides awareness of and distributed haptic interaction with changes in routines.

This project shows how a metaphorical interpretation of a real-world concept such as friction can be used throughout the design process to provide fresh ways of looking at usage situations and to provide direction in product and interaction design.

# designing for a frictionless mobile lifestyle

Graduation Project in Industrial Design Engineering, Delft University of Technology, Hewlett-Packard Labs   Stephan Hoefnagels, February 2003

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"Designing for a Frictionless Mobile Lifestyle"

February 2003

## Acknowledgements

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*Abstract*

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# 1
## *Introduction*

The User Studies and Design Group at HP Labs draws on a wide range of methods from both the social sciences and design to gain new insights in the interaction between people and technologies. User research helps to better understand current and potential customers. Design helps generate new concepts and ideas and to render these concepts in ways that help evaluate them. In this context, established and emerging technologies are mainly used as boundary conditions in a user-centered design process and as a way to give designs realism and plausibility.

This Master's Thesis project in Industrial Design Engineering is part of the "Frictionless Mobile Lifestyle" initiative at HP Labs. Initially, this name was adopted to stress the fact that the research program at HP Labs should be focused on using technology to try to reduce friction in people's day-to-day mobile lives.

Although this is a catchy header, there is much ambiguity on what the concepts of friction and mobile lifestyle can imply for user-centered product design. My project aims to critically explore the theme of a "frictionless mobile lifestyle", to identify and express the meanings this theme may have in a user-centered design process.

I approach this exploration through researching and defining the concept of a mobile lifestyle and introducing a relevant example population of working parents with dependent children (chapter 2). This example population embodies many of the concepts explored in the definition of a mobile lifestyle. The introduction of this population helps in keeping the project in focus. After this, I investigate the concept of friction through using mechanical friction as a metaphor in the domain of a mobile lifestyle (chapter 3). The insights gained in this process are then used to set-up and interpret several user studies in the example population (chapter 4). This leads to the identification and description of relevant usage situations in which the concept of friction plays a meaningful role. These usage situations are not inherent solely to the example population; however, they are clearly expressed in this population. Of these, scheduling and coordination activities have the clearest resonance with the concept of friction (chapter 5). Not only does application of the concept of friction identify these activities, it provides a fresh way of looking at these activities by indicating some unique focus points. I then express these focus points through the product and interaction design of two information appliances in the scheduling and coordination domain: the long-term planner and the coordination watch (chapter 6). Finally, I evaluate the meaning of this approach and its results (chapter 7). Figure 1 depicts this process.
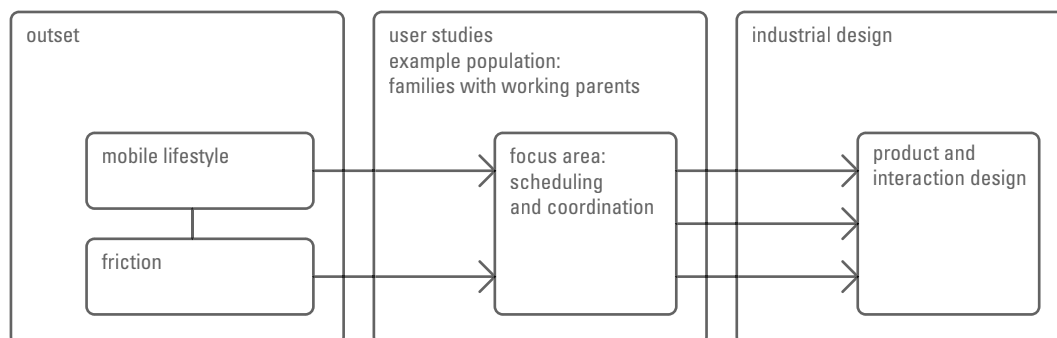


Figure 1 Approach

The challenge in this process is to follow through the concept of friction from its definition, to the identification of relevant usage situations and focus points in these situations, to the expression of these focus points in product and interaction design.

# 2
## *Mobile Lifestyle*

To get a handle on the theme of a "frictionless mobile lifestyle" I first need to create a clear picture of what the concept of a "mobile lifestyle" means, or more broadly, what "mobility" exactly means. The goal is to create a comprehensible picture of and insight in the concept of mobility, to chart the many different aspects of mobility, to analyze and define the concept of a mobile lifestyle. This critical exploration is useful in its own right. In addition, it is a vital step in exploring the notion of friction.

## *2.1  Physical Mobility*

**Static and dynamic mobility**[1]
Traditionally, mobility is associated with the physical displacement of items, be it persons, objects or information. I will refer to this classic notion of mobility as "physical mobility". Focusing on persons, physical mobility encompasses two main aspects, the act of persons traveling between two discreet locations, which I will refer to as "dynamic mobility", and, seen from a wider perspective, the act of persons actually residing in a number of different places over a certain period of time, "static mobility" (figure 2). These dimensions exist simultaneously. They are an inseparable part of mobility. The interest in making this distinction lies in the recognition of the fact that mobility has an added aspect besides actually being in motion. It has very relevant static aspects to it.



dynamic mobility                    static mobility
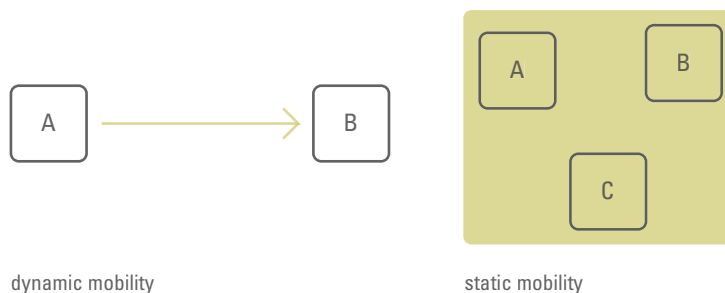
Figure 2 Left: dynamic mobility implies being in motion. Right: static mobility implies residing in different locations over time.

Looking at these notions from a practical point of view, the static and dynamic aspects of mobility each have their own specific implications concerning product design, their own preferred modes of interaction and functionality. Take for example two different mobile devices: the mobile phone and the laptop. The mobile phone is typically a device that caters for the dynamic aspect of mobility: the aspect of actually being in motion. People literally use

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the device when "on the move", when walking or driving their car. The laptop however, is much more a device that is used in discrete, physically separated, but *static* situations [32]. Generally, people will sit down at a desk to use their laptop. The purpose of a laptop is more about transporting relevant information to different places and working on this information when static, than actually using the device while in transport. As an extreme, one person I interviewed as part of this project did not tend to move her laptop at all. She used her laptop as her main home PC and only moved it in rare instances, such as when visiting her mother over the weekend [second working parents interview study (chapter 4)].

In short, what I am saying here is that different mobile devices cater for different mobile situations. This difference is very relevant when deciding on the interaction design of a mobile device. For example, interaction with a product in static situations can pose more cognitive demands on the user than interaction in dynamic situations. Furthermore, occupation of hands, eyes and ears for other activities lead to design considerations for dynamic situations.

### Active and passive dynamic mobility
The above examples presuppose that dynamically mobile persons are actively engaged in their mobility; they walk or drive their car. They are actively mobile. Riding the bus or being a passenger in the car are examples of a different situation. In these instances, the user is passively mobile. Passive mobility has a big overlap with static mobility in that interaction with a mobile device in this situation can pose high cognitive demands on the user and hands, eyes and ears are free. Nevertheless, there are important differences between static mobility and
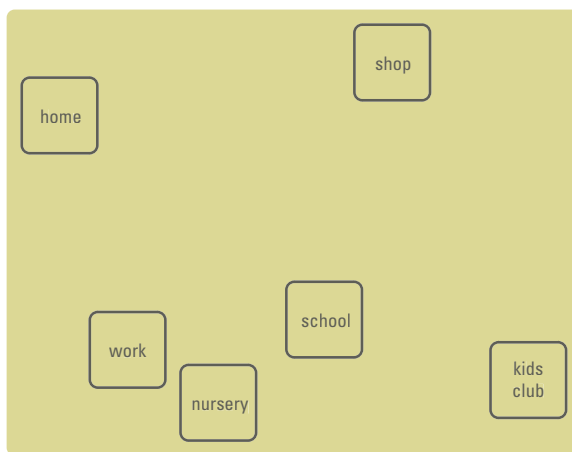


Figure 3 Typical places a working parent travels between in a normal day [first working parents interview study (chapter 4)]

passive, dynamic mobility. For example, working on a report in a work environment with reference books and papers nearby is very different from working on the train where these resources are not readily available [48]. In essence, the different environments vary in their suitability for the activity that is pursued. The synergy between environment and activity is an important notion. It is extended and elaborated upon in the next section.

### The extent of physical mobility
To what extent are persons physically mobile? Between what places do people generally travel? An extreme exponent of physical mobility occurs during holidays when people travel long distances and expose themselves to new locations. However, holidays are not part of most people's day-to day lives, the focus of this project. Another popular scenario is that of the mobile professional moving from location to location and airport to airport to conduct business. However, this project does not focus on professional situations. The above examples therefore may be good examples of mobility, but they are not part of the focus area of this project.
So, when are people usually mobile in their day-to-day home lives? The answer is not that spectacular. Working parents, for instance, visit and travel between a limited number of locations on a typical day (figure 3).

Looking more closely at the number of different places people travel between in a typical day is useful to get a feel for the extent of their physical mobility. However, of primary interest are the differences that exist between these various places, since each of these places has its own different set of characteristics that influences product use, interaction possibilities and, more general, activities that can be pursued at these places (section 2.2). In short, each different environment influences the activities pursued in that environment and the choice of products used to do so.

**Reasons for physical mobility**
Why do people travel between different places? Considering this question is of interest because it provides insight into the attitudes persons have to mobility, the things they expect and the things they do not expect from mobility. Looking at the goals that people have when they are mobile, two essentially different reasons for physical mobility emerge. The first category consists of mobility for the sake of mobility. Mobility is in this case the goal a person pursues. Examples in this category are recreational walks or cycling trips. In these cases, the person wants to experience the fact of being mobile. Products in this area may enhance this experience, similar to binoculars to fully take in the environment. Products and services should at least not distract users from their mobility. In my project, I will not focus on this area of physical mobility.

The second category consists of mobility with the aim to arrive at specific location. The main goal is to get somewhere else. The reason is usually to pursue an activity at a place that is more suited to that specific activity than the current location. A person that travels to the shop to do shopping for example. Primarily, mobility is a
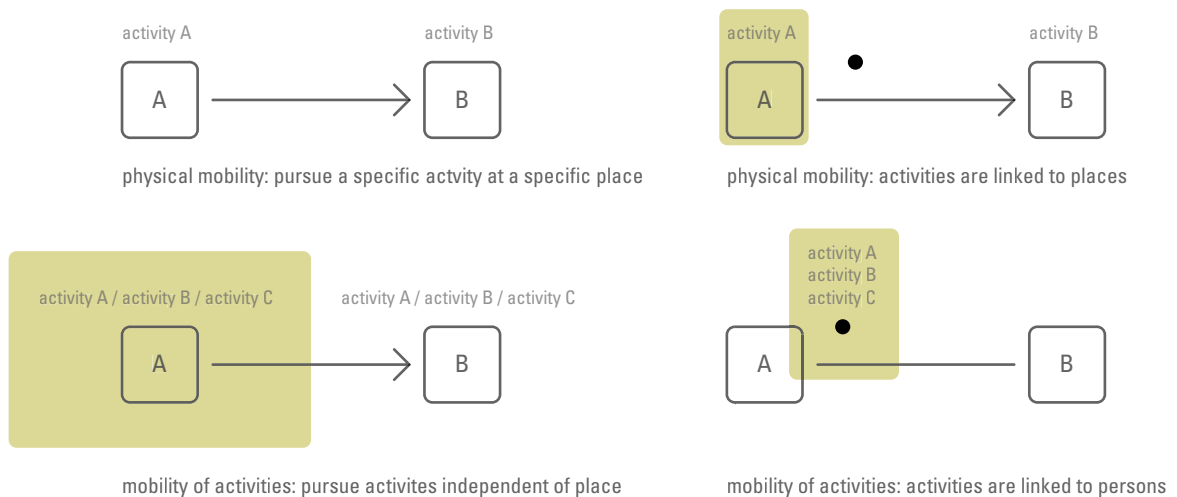


Figure 4 Top: activities linked to specific locations. Bottom: mobility of activities over different locations.

means to an end: pursue a certain activity. People in this area generally do not particularly care about experiencing the fact of being mobile, as opposed to the category mentioned above. This is the area that I will focus on. It opens up intriguing possibilities to make activities mobile, as is explained in the next section.

## 2.2   Mobility of Activities

**Activities are spread over locations**
While it is likely that the locations that people travel between in a normal day have remained the same for a long period of time, some change has occurred in the activities that are pursued at these different locations. Traditionally, specific locations are linked to specific activities. People sleep at home, work at the office and shop at the shopping center (figure 4, top left). This is changing. In the late seventies, the Sony Walkman freed the activity of listening to music from having to be at specific locations. The current advent of mobile communications is continuing along this direction, separating more activities from their location. People now have the ability to pursue more and more activities that were previously location specific, anywhere they happen

to be (figure 4, bottom left). Coordinating a family appointment while commuting for example. While it is likely that over the past decades the number of places that people travel between has remained the same, there has occurred a difference in the fact that activities are spread over these places as opposed to being connected to a specific location. Activities are not so much linked to locations anymore, as they are to persons (figure 4, right). The very concept of "place" as a platform for activities or as a historically accreted complex of practices and meanings [for this definition of place, see [1]] is changing.

Activities are becoming more fluid. This fluidity opens up very remarkable product and service design opportunities. Mobile phone operator Orange's experiments in their fully networked home provide some examples [25]. Orange's home is a test-bed for mobile services. It allows for mobile activities. One example is monitoring people calling at the door and letting them in remotely. Although families living in the home perceived some mobile activities as useful, the most striking example is of an activity that was not:

> "The ability to use voice commands and a mobile phone to turn on the washing machine and other domestic appliances was a neat trick for a while, but not terribly useful.
> Richard Harper, head of the Digital World Research Centre at the University of Surrey, was closely involved with the project. He says: "Being able to turn on the washing machine remotely over the phone is not really relevant. There's no point switching it on unless you put the washing in."
> And to do that you have to be standing beside the machine – in which case you might as well switch it on at the same time."

This example illustrates the fact that certain activities tend to be more strongly coupled to locations than others are. Activities are mobile, but some are more mobile than others. And for good reasons. For example, in their take on mobility of activities, Siemens envisions a world where activities are completely separated from location [47]. In one of their scenarios, persons are happily interrupted to engage in work activities during their vacation on the beach. Personally, I do not believe in a mobility of activities that is this widespread and obvious. I will use a more subtle interpretation of this concept as explained in the next section.

Continuing along the above line of reasoning, spreading activities over locations implies the possibility of carrying out all activities from one location. In this case, mobility of activities will actually decrease physical mobility. There have been experiments in the past where people lock themselves in a space and try to survive relying solely on communication technology [see for instance [45]]. These are rightfully considered extreme situations. Mobility of activities might be convenient, but in most cases, convergence of that mobility to a single location is probably not a good idea.

### Locations influence the character of activities
Although the coupling between activities and locations is becoming less strong, locations do still influence the character of activities. Consider teleworking for example. Persons that I interviewed for this project articulated that when they work from home, their work activities have a very distinct and different character from when they work at the office [second working parents interview study (chapter 4)]. At home, the focus is more on tasks that require constant attention such as writing reports; at work, the emphasis shifts to communicating with others in the workplace. This is due to differences in character of home and office environments. The environment clearly influences the character of their work activities.

I will use Agre's [1] effort to rethink architecture in the context of ubiquitous computing to explain this further. In his research, Agre investigates the relationship between architecture and human institutions. Human institutions are the persistent structures of human relationships. Examples of institutions are the norms of public politeness and the rules and conventions of driving on the highway. Architecture and institutions, once established, are relatively long-lived and impersonal, and they provide the boundary conditions for the constant negotiation and evolution of practices. Practices are the ensemble of embodied routines that a particular community of people has evolved for doing particular things in a particular place. An example is the customary greetings and debriefings that a married couple engages in when they arrive home from work.

Buildings typically conform to standardized types because of the way they map the institutions they house. Nearly every building is designed with an institution in mind: the family home for example, with its distinction between the master bedroom and the other bedrooms. Buildings thus posit identities, roles that persons live out. Hospitals make us into patients, courtrooms into jurors and restaurants into diners. Having been defined in this way, people certainly retain a broad freedom of action. But they conceptualize and strategize their action upon a terrain that the institution has created. The environment thus very clearly influences the character of the activity that is pursued.

### Locations influence the requirements of products used

Taking the previous rationale one step further exposes the implications for product design. An activity that changes character over different locations requires different products in these environments. Take an activity as scheduling for example. Working parents I interviewed, report doing home related scheduling both at home and at the office. At the office, they will typically use their electronic diary on their PC for this activity. At home, this is far less likely. They use paper diaries and wall calendars [user studies (chapter 4)]. Thus, different products are used in different environments for the same activity; different products cater for different characteristics of a single activity. This is partly due to the difference in suitability of these products for the different characteristics of the activity. In addition, it is due to boundary conditions posed by the environment. At home, a PC is not likely to be switched on all day, making it less useful for scheduling purposes.

### Implications

Severing the link between location and activities has several meaningful implications.

Firstly, for an activity to be pursued independent from location, access to the items and persons necessary for that activity is needed. An example of this in the mobile activity of coordination is the clearly articulated need of families with working parents to have location independent access to their kitchen calendar to coordinate domestic appointments when not at home [first working parents interview study (chapter 4)].

Secondly, as people pursue different activities at different locations, the awareness of other persons' activities and location becomes an important consideration. Activities that are pursued "as and when" create an increased need to be aware of what others are up to.
A clear illustration of this notion is the fact that many mobile phone conversations still start with the question "Where are you now?" This can be interpreted as an explicit attempt to establish some notion of the context of the other person. The fact that artifacts are no longer linked to specific locations has an effect on the contextual information that is transmitted by these artifacts. Before the advent of mobile phones for example, when making a phone call at night, it would be clear to the other person which phone you were using and that you were probably at home. When activities are pursued linked to specific locations, this specific context information is implicitly available. However, it would not necessarily be clear that it was you who was calling; this would have to be explicitly established. A mobile phone being a personal device linked to a particular individual does provide this information implicitly. Mobile devices and fixed devices thus provide different contextual information.

Thirdly, and most interestingly, as people are pursuing different activities in the same location, these activities can start to interfere with one another. Consider a holiday on the beach that is interrupted by a mobile phone call concerning a work activity. When activities become mobile, activities are likely to start to interrupt one another. This might be very cognitively demanding and people could perceive these interruptions as highly stressful [working parents questionnaire study (chapter 4)].
A characteristic of the use of a mobile device is that the user is likely to be engaged in a primary activity and their mobile device intrudes on that activity. Think for instance of when you are having a conversation with someone and you receive a call on your mobile phone. You now have to decide where to focus your attention. You have to choose between two activities, continuing the conversation you were having, or focusing your attention on your phone call. Alternatively, you could decide to juggle your attention between the two. In effect, you are asked to be in two places at once.
More generally, it can be said that the mobile device creates a context and activity that intrudes on the existing context and activity. The user might perceive this as problematic, especially when both activities are important at the same time.

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For example, in their study of PDA guides in a science museum with interactive exhibits, Semper and Spasojevic [49] found that the use of a handheld device tended to distract people from interacting with the exhibits. They suggest the reasons for this are both mechanical and cognitive. Holding the handheld device prevents people from freely using their hands to manipulate the exhibits. Moreover, reading content from the handheld device distracts from interacting with the exhibit. Furthermore, they suggest that the use of handheld devices may disrupt normal social interactions between members of social groups, because each visitor could get lost in the world of the device and pay less attention to the rest of their group.

## 2.3  Networked Devices and Mobile Lifestyles

**Networked devices enable mobile lifestyles**

Mobile devices and networks of connectivity are key enablers in the emerging mobility of activities. New, more efficient and faster network technologies continue to emerge to support mobile devices. What is interesting about this is not the technologies per se. Current technologies will be outdated and irrelevant in the near future. It is the fact that these technologies are having a strong impact on people's everyday lives. The combination of telecommunications and computing has changed, and is continuing to change the way people interact with each other socially. For instance, the amount, content and timing of messages sent between persons is changing. Or as Norman [35] puts it:

> *"What's interesting is that many times, the messages have almost no content. It's "Where are you now? What are you doing? How are you feeling?" Which is fine, because if you're continually in touch, you don't need to say very much. You're just sort of touching."*

**Information appliances**

Mobile devices enable persons to pursue more activities when physically mobile. Currently there are two very different viewpoints on the design of these devices. On the one hand, the market is flooded with devices that can do "anything, anytime, anywhere," an approach assuming unlimited mobility of activities. This mostly technology driven approach sometimes leads to relevant functions bundled in one device, and sometimes to the most unlikely combinations of functionality. Right now, the computing and communications industry are in a transitional stage where the cost of computing power and the novelty of technological possibilities is encouraging the, sometimes arbitrary, bundling of functions [50]. The advantage of this approach is that users have one very portable device they can use for many different purposes. The disadvantage of this approach is that usually the device is sub-optimal on any one of its individual incorporated functions.

On the other hand, there is the viewpoint of information appliances: smart products created with specific tasks of the user in mind. Simple devices that work together – each one doing what it does best, and relying on natural interaction with other devices for the things it does not need to do [50]. The ideal being that the user of these information appliances focuses on the task that has to be accomplished and not on the tools needed to accomplish it. Much like when you write something, you do not want to be thinking about the pen you are writing with. You want to be focused on the content of the writing. This objective might be accomplished in the mobile computing area by creating unambiguous devices optimized for their tasks, all networked and working together. Leading to a fleet of appliances tailor made to accomplish a multitude of user tasks in an enjoyable and gratifying way.

I will focus on this approach of information appliances. I will focus on devices that have a clear purpose. Devices that consider the subtleness of the mobility of activities. Devices that consider what activities persons actually want to pursue when mobile, that are optimized for these activities and that accomplish more complex tasks by working seamlessly together with other mobile or larger, fixed devices.

A key notion in the design of information appliances is recognition of the fact that the goal is to make the devices simple, but not simplistic. Focusing functionality might increase usability, and appropriateness of the device for the function, but focusing the functionality too much, to a single purpose, can lead to many different appliances that are, rightfully, perceived as being too specific to justify to be carried around at all times. Or, again, as Norman [38] puts it:

*"(…) I'm not in favor of single purpose devices. I'm in favor of single activity devices, things that bring together into one container, one unit, activities or tasks that naturally go together. What I recommend is that we observe what activities people do and what people's needs are, and try to discover the interactions among them. Then we design and build devices where there are heavy interactions, and we use separate devices where there are very few interactions."*

In my project, I have used user studies, interviews and observations of real people in real environments, to get a sense of activities that go together (chapter 4).

## 2.4   Mobile Lifestyle Defined

As has been shown in the previous sections, it is likely that mobile lifestyles of everyday people are not characterized by the vast amount of different places they visit throughout the day; rather they are characterized by a mobility of activities over a limited number of different locations. Another key notion is the realization that these different locations and environments influence the character of a mobile activity.

I now need a workable definition of a mobile lifestyle that captures the essence of the findings and considerations presented in the previous sections. This definition will form a starting point in the exploration of the concept of friction. I define a mobile lifestyle as:

*"The everyday pursuit of multiple activities at multiple locations, where each location is not specifically related to a particular activity"*

An implication of this definition is that some activities are pursued when actually physically mobile. Networked and mobile devices have made this mobile lifestyle possible and can therefore be considered to be a prerequisite for it.

## 2.5   Example Population: Families with Working Parents

To make the previous considerations tangible and real and to test them in real life, I need an example population. HP Labs evaluated a number of possible example populations with the view to selecting a group, which would have a mobile lifestyle, which would potentially be susceptible to many occurrences of friction and which would be likely candidates to employ mobile technology. After several iterations, working parents with dependent children were chosen as an example population of everyday people with a mobile lifestyle that display a high mobility of activities in combination with a high physical mobility.

I use the terminology of example rather than target population to stress the fact that my interest is primarily in identifying relevant usage situations. It is not in targeting demographic populations. The outset is that looking at working parents will expose certain functionality and usage situations very clearly, make them very explicit. These usage situations are likely to have a resonance in other populations. However, they may not be as clearly exposed and easily researchable in those populations. But they will be there and will be relevant. Consequently, certain functionality that is visibly exposed through looking at the lives of working parents is very much relevant to similar usage situations for a broader group of persons with mobile lifestyles.

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# 3

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*Friction: a Metaphorical Approach*

In the previous chapter, I have presented a view on mobility. I have charted different aspects of mobility. Furthermore, I have defined the concept of a mobile lifestyle. Finally, I introduced families with working parents as an example population with mobile lifestyles. These explorations and insights in mobility form the basis for the exploration of the concept of friction. The purpose of this exploration is to highlight interesting aspects of friction. To provide a new way of looking at mobile lives. To serve as a starting point to identify specific occurrences of friction in the lives of the example population through user studies. There are many possible metaphorical interpretations of the concept of friction. Those that are valuable in structuring and interpreting user studies to identify design opportunities are presented here.

## 3.1  Approach

After establishing a clear picture of mobility, it is now possible to take a close look at the concept of friction in the defined mobility area. Although there is a vague notion of what friction in a person's mobile life can entail and include, a deeper and more precise understanding of the concept is needed. To achieve this understanding, I will explore the concept of friction in the fields of physics and mechanical engineering. This exploration is then generalized to and, where possible, even mapped onto people's lives. In effect, friction as defined in physics will be used as a metaphor for friction in people's lives.

Figure 6 depicts the mapping process and approach. In sequence, the definition (sections 3.2 and 3.3) and the effects (section 3.4) are explored and mapped to friction in mobile lifestyles in general and more specifically
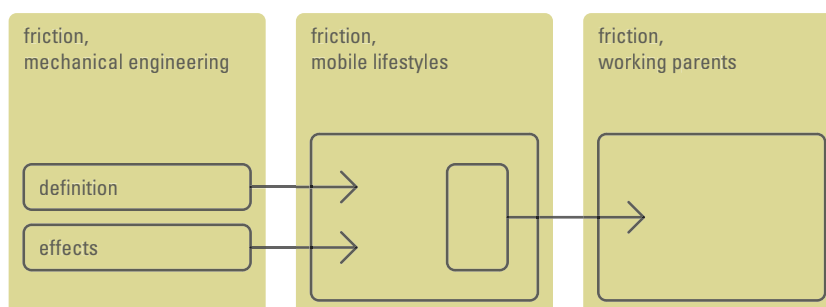


Figure 6 Various aspects of friction in mechanical engineering are mapped to the concept of friction in mobile lifestyles

to the mobile lives of working parents. The sections of this chapter alternate between aspects of friction in the engineering area and the consequent mapping of these aspects to the domain of mobile lifestyles. In this mapping process, the insights gained in mobility in chapter 2 are used. Examples of occurrences of friction in the lives of working parents are provided to clarify each aspect of the abstract metaphor. These examples all originate from a questionnaire and interview study of working parents conducted by HP Labs in the course of this project (chapter 4). Furthermore, they originate from personal observations made during eight interviews with working parents as a part of this study.

## 3.2 Definitions of Mechanical Friction

To fully benefit from the metaphorical span and depth of the concept of friction, friction in mechanical engineering is studied in detail. In mechanical engineering, tribology is the science and technology of interacting surfaces in relative motion [29, 58]. In this field, friction is defined as *"the resistive force acting between bodies that tends to oppose and damp out motion" [23]*, or as *"the resistance encountered when one body moves relative to another body with which it is in contact" [57]*. Figure 7 presents a typical graphic representation of friction. Friction can be either static or kinetic. Static friction is defined as the frictional force opposing placing a body at rest into motion. Kinetic friction is defined as the frictional force tending to slow a body that is already in motion. The force due to kinetic friction is generally proportional to the applied force; the coefficient of kinetic fiction ($\mu$) is defined as the ratio of frictional force to the normal force on the body.

From these definitions, it is clear that there are a number of preconditions for friction to occur in a given situation: there have to be at least two bodies that are in relative motion and they have to be in contact with one another.



$$F_F = \mu \cdot F_N$$

F = exerted force
$F_F$ = frictional force
$F_G$ = gravitational force
$F_N$ = normal force
$\mu$ = friction coefficient
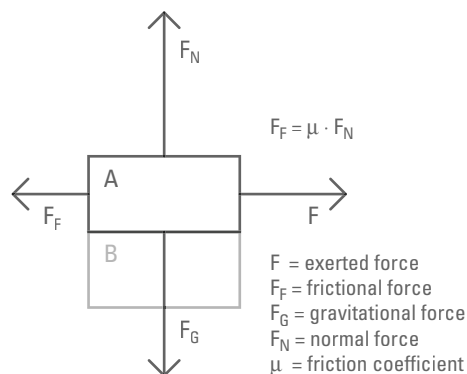
Figure 7 Friction proportional to the normal force occurs when two contacting bodies are in relative motion

**The differences between friction and stress**
When trying to look at metaphorical friction in mobile lifestyles it is very tempting to put the concept of friction on a par with the general occurrence of problems in mobile lifestyles. Friction is then degraded to a mere synonym for problems, or also commonly used, stresses and strains. This should be avoided. The power of the concept of the metaphor of friction lies in its unique defining characteristics. These can help me identify focus points in a vast mobile lifestyle problem space. Identifying the differences between friction and the much more common phenomenon of stress helps in distilling these defining characteristics. It highlights the characteristics that make friction different and special.

So, what are the differences between friction and stress? Taking the mechanical world as a starting point, and looking at the example of moving parts in a machine, we see that loads are often supported on a small surface area of the component. Contact pressures and stresses therefore tend to be high. Friction forces on the other hand are typically relatively small and occur on a large surface area of the components. Furthermore, whereas excessive

contact stress leads to component failure by overload, in which case components yield or fracture from excessive contact loading, friction typically only slowly shows its effects through the occurrence of wear.

Friction therefore differs from stress on at least three dimensions. Firstly, its occurrence is spread out over a relatively large area compared to stress. Secondly, its intensity is relatively small compared to that of stress. And thirdly, its effects typically only become clear after a relatively long period of time as compared to stress.

**Mapping the definition of mechanical friction**
From the high-level definition, it is clear that friction is inherently linked to motion. Without motion, there is no friction. And in most cases when there is motion, there is friction. This notion is very useful, because it sets the required precondition for a smooth integration of the earlier defined concepts of mobility in the friction metaphor.

I have so far identified three unique defining characteristics that make it possible to differentiate friction from the more general notion of problems, stresses and strains. The first characteristic is the non-focused character of friction. This suggests a focus on events that intertwine the entire mobile lifestyle. The second realization is that of the typically relatively small intensity of friction. This suggests a focus on small and in-intrusive events in mobile lifestyles. I will discuss the implications of the third notion, the long-term nature of the effects of friction, in section 3.4.

## 3.3 Interpretations of the Definitions

> *… it is necessary to know the nature of the contact which this weight has with the smooth surface where it produces friction by its movement, because different bodies have different kinds of friction.*
>
> *Leonardo da Vinci [from [5]]*

One approach to explore the metaphor of friction further is to fit the concepts of physical mobility (section 2.1) and mobility of activities (section 2.2) into the definition of mechanical friction. The moving parts in these concepts, persons and activities, are mapped to the moving parts in the definition of mechanical friction (figure 8). In this section, I present several possible interpretations of the definition of friction from this perspective. These interpretations are abstract renderings of what the metaphor of friction can mean. In a sense, they are different situations that can occur in a mobile setting. Situations in which the concept of friction possibly plays a meaningful role. I need these interpretations as a starting point in the set up of user studies in which the metaphor of friction is explored in reality, in the lives of working families (chapter 4). They point to situations that are promising to explore in the example population.

In these situations, a value judgment considering the goals of persons and whether friction helps in reaching these goals, that in a sense would be equivalent to considering the direction of the frictional force in the definitions, is omitted. This value judgment can be very situation specific and is not needed to identify usage situations from the user studies. Possible positive or negative occurrences of friction are touched on in the next section, in the intuitive interpretations of friction in section 6.1 and in several specific usage situations (section 5.5 and 6.3).

**First interpretation: friction between a mobile activity and its environment**
As established in section 2.1 physical mobility has two aspects, the act of being in motion between two places, which I called dynamic mobility, and the act of residing in different places over time, which I called static mobility. From a friction-mapping point of view, only dynamic mobility is relevant, because of the prerequisite constraint of relative motion in the definitions of friction that are used in mechanical engineering (section 3.2). This condition is met in the case of dynamic mobility, but not in the case of static mobility.
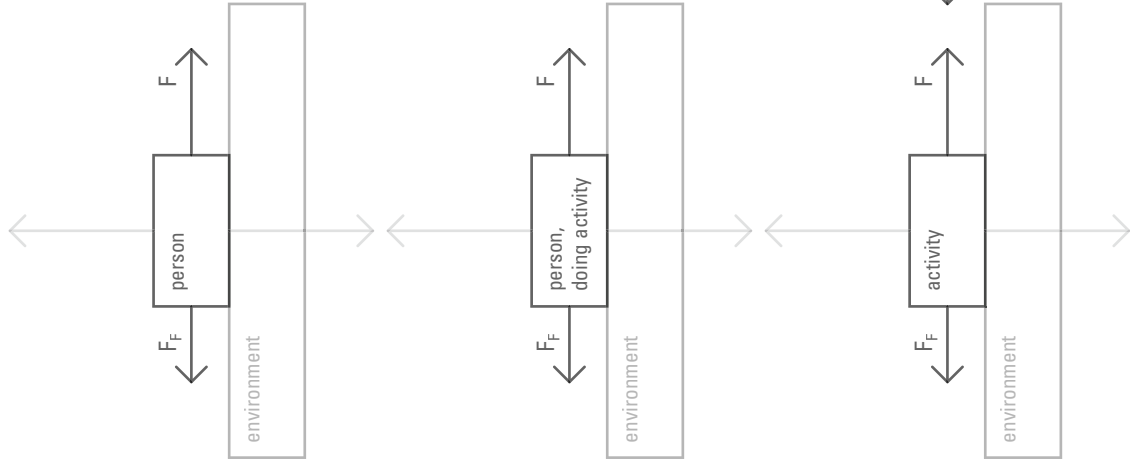
Following page: Figure 8 Overview of the different interpretations of the definition of friction

mechanical friction definition

$F_F = \mu \cdot F_N$

$F$ = exerted force
$F_F$ = frictional force
$F_G$ = gravitational force
$F_N$ = normal force
$\mu$ = friction coefficient

$F_N$

$F_F$

$F_G$

$F$

A

B

mobile lifestyle defintion

person
activity
environment

person

F

$F_F$

environment

person,
doing activity

F

$F_F$

environment

activity

F

$F_F$

environment

person A,
mobile activity A

person B,
mobile activity B

F

$F_F$

activity A,
person A

activity B,
person A

F

$F_F$

activity A,
person A

activity A,
person B

F

$F_F$

activity A,
person A

activity B,
person B

F

$F_F$

1
mobile activity - environment

2
mobile activity - mobile activity,
different persons

3
activity - activity,
different activities,
same person

4
activity - activity,
same activity,
different persons

5
activity - activity,
different activities,
different persons

Literally mapping the definition of physical, dynamic mobility to the definition of friction, results in the situation depicted in figure 8 (1, top). The figure shows that friction occurs between a moving person and their environment. This is still a very mechanical interpretation of the concept of friction. For example, a walking person's shoes gripping the floor fits this mapping.

Considering the fact that the person that is moving might be doing an activity, such as talking to someone on their mobile phone, the picture becomes more interesting (figure 8 (1, middle)). An even clearer view appears when completely focusing on the activity that is executed in relation to the environment (figure 8 (1, bottom)). It is now clear that in a situation where a person is executing an activity while on the move, the activity is in relative motion to its environment. Friction occurs between the activity and its environment.

Extending this notion, it can be observed that friction changes in size with changes in the environment (figure 9). Consider a person walking from a marble floor onto a carpeted floor. In this situation, the friction between the person's shoes and the floor changes. This is caused by the different friction coefficients of marble and carpet. The friction coefficient for shoes on marble is lower than that for shoes on carpet. Mapping this notion to the metaphor, it can be seen that friction between an activity and its environment can change with the environment. Certain activities are more suited for certain environments, analogous to the fact that a carpet floor is more suited for walking on with slippery shoes than a marble one.

An example will help illustrate this. Food shopping can be done both in the grocery store and from the home using the Internet. Interpreting the metaphor, there is one activity ("food shopping") and there are two environments ("home" and "shop"). In this interpretation of the metaphor, the friction between the activity "food shopping" and the environment "home" is bigger than the friction between "food shopping" and the environment "shop". The reason is the better suitability of the shop environment to the activity of shopping. In the shop, foods can actually be touched and smelled and inspiration to buy goods is triggered by browsing around in the shop. These qualities do not exist in a home setting.

This notion of varying friction coefficients in varying environments for a single activity is tightly linked with the earlier realization that environments influence the characteristics of an activity (section 2.2). Strictly speaking, this interpretation of friction therefore contains aspects both from the concepts of physical mobility (section 2.1) and mobility of activities (section 2.2).
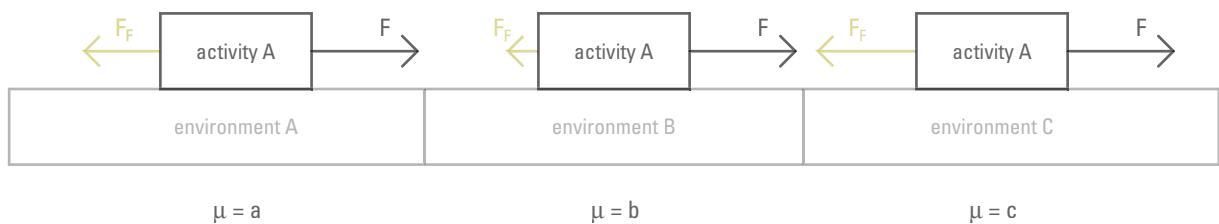


Figure 9 Friction changes in size in different environments

An example of this interpretation of friction in the lives of working parents is the statement of one parent I interviewed (chapter 4) that she did not feel comfortable making home calls at work due to a lack of privacy. In this case, the friction between the activity "making home calls" and the environment "work" is higher than it is for the environment "home":

> "(…) there are things you want to use the phone for, but you don't feel… well, one, I just don't have the privacy to use the phone at work. If it was a real emergency or something like that, that I didn't want to discuss with people around me I could do it, but it's just not that easy to do. I could go outside with the mobile phone, but sometimes that's not really convenient."

**Second interpretation: friction between different mobile activities undertaken by different persons**
There is a second possible interpretation using the concept of physical mobility. In this case, multiple persons are considered that are engaged in mobile activities. Friction can now be seen to occur between them (figure 8 (2)).

This interpretation has a resonance with the earlier mentioned awareness implication from mobility of activities (section 2.2). In a mobile setting, persons have an increased need to be aware of one another.

An example of this interpretation of friction in the lives of working parents is the great need and effort that working parents exhibit to monitor their spouse's and kids' activities whenever those activities influence their own activities. Currently parents do this largely by mobile phones and e-mail. Both devices that are not optimized for this purpose (from the user studies in chapter 4):

> *"(…) we've found the mobile useful to be able to keep tabs on each other, particularly now the children are getting a bit older and want to go out, at least we can stay in contact."*

### Third interpretation: friction between different activities undertaken by the same person

Taking the concept of mobility of activities, as explained in section 2.2, as an aid to map friction to people's lives, leads to the interpretation depicted in figure 8 (3). Friction occurs between different activities that are in relative motion. This abstract concept is best understood by considering the fact that a person in a setting of mobility of activities at some point has to juggle their attention between different activities that require simultaneous attention (section 2.2).

An example of this interpretation of friction comes from the questionnaire in the working parents study. In this questionnaire, working parents perceived and classified interruptions at work as highly stressful. The interviews point in the same direction (from the user studies in chapter 4):

> *"I don't have many home interruptions at work, but when I do, I find it stressful."*

### Fourth interpretation: friction between different persons undertaking the same activity

As opposed to looking at friction that occurs between different activities undertaken by the same person, it is possible to consider the friction that occurs between different people undertaking the same activity (figure 8 (4)). When different people are engaged in the same activity at the same time, but in a physically different place, as is likely to occur in a mobile setting, friction can occur because of this fact. This friction resonates with the well-explored area of distributed collaborative work. Examples of friction can be interpreted as lack of awareness of the other person and lack of progress information of activity completion from the other person.

### Fifth interpretation: friction between different activities undertaken by different persons

Finally, friction also may take place between different activities undertaken by different people (figure 8 (5)). One activity undertaken by one person influences a parallel activity undertaken by a second person. From a person's point of view, activities done by other people influence their own activity as they are engaged in it.

The difficulty working parents report in scheduling the many activities of the family unit is an example of these final two interpretations of friction. This is especially true where there are shared activities or there are many dependencies between activities.

The friction between different people undertaking the same activity (fourth interpretation) occurs when the members of the family unit try to schedule a new event considering all their shared and individual appointments. This can be a very difficult process.

The friction between different activities by different people (fifth interpretation) is apparent in the influence that appointments and activities with various persons in- and outside the family unit have on the scheduling process (from the user studies in chapter 4):

> *"(…) because we have so many different diaries and things I'll put reminders in my (electronic PC) diary, which are essentially for work, but my wife can't see what I've booked and I can't see what she's booked, we will write things down on the calendar at home, but I don't check that daily, so things do get missed (…)"*

When considering these interpretations and schematics of friction it is important to realize that although in each instance only two bodies are pictured in between which friction exists, each body can actually experience friction from a multitude of other bodies, in the abstract model being activities, persons or environments (figure 8 (top

right)). For instance, this occurs in the above example of synchronizing calendars with persons in the family unit, where typically more than two appointment activities with multiple persons are involved.

**Five interpretations of the definition of friction**

In this section, I have presented five interpretations of friction by using the friction definition of mechanical engineering and the concepts of mobility I defined in sections 2.1 and 2.2 (figure 8). These interpretations indicate possible situations in which friction plays a meaningful role. In the interview study, I will look for these situations to see if they actually occur and if the metaphor of friction can lead to new insights or pose valuable accents in those situations. Some of these interpretations will prove to be more relevant than others. That is to be expected since they reflect an abstract process that largely exposes it value only after verifying it in reality.

To make the situations more explicit and precise I will take the analogies one step further. In each of the interpretations, I consider the aspects of static and kinetic friction in the mappings. Table 1 presents these detailed interpretations. The situations resulting from the previous interpretations are clarified and expanded. This table is a useful guide in the formulation of the questions of the interviews described in chapter 4. It is one of the aids to locate friction in mobile lifestyles.

| | Analogies to the bodies in the definition | Analogies to static friction in the definition | Analogies to kinetic friction in the definition |
|---|---|---|---|
| 1 | Mobile activity - environment | - Starting an activity while on the move <br> - Start moving while doing an activity | - Doing an activity while on the move <br> - Stopping an activity while on the move <br> - Stop moving while doing an activity |
| 2 | Mobile activity – mobile activity, different activities, different persons | - Meeting someone engaged in a mobile activity | - Spending time, doing a mobile activity, with someone who is doing a mobile activity |
| 3 | Activity – activity, different activities, same person | - Starting an activity while engaged in another activity | - Changing focus on activities <br> - Stopping an activity |
| 4 | Activity – activity, same activity, different persons | - Other person starting to pursue same activity | - Pursuing an activity together <br> - Stopping the activity while other person continues <br> - Continuing the activity when other person stops |
| 5 | Activity – activity, different activities, different persons | - Other persons starting to use the results of your activity | - Working on different activities |

Table 1 Mappings of the friction definition, including static and kinetic friction, to mobile lives of people, using the earlier defined concepts of mobility

## 3.4   Duality in Desirability of the Effects of Friction

*(…) a ring is worn thin next to the finger with continual rubbing. Dripping water hollows a stone, a curved ploughshare, iron though it is, dwindles imperceptibly in the furrow. We see the cobblestones of the highway worn by the feet of many wayfarers. The bronze statues by the city gates show their right hands worn thin by the touch of all travelers who have greeted them in passing. We see that all these are being diminished since they are worn away. But to perceive what particles drop off at any particular time is a power grudged to us by our ungenerous sense of sight.*

*Lucretius (95 – 55 B.C.), De Rerum Natura, I [from [5]]*

Besides exploring and interpreting the definition of mechanical friction, there are other ways to gain an understanding of what accents the concept of friction can bring in the space of mobile lifestyles. What fruitful interpretations are in people's mobile lives. One way is to explore the effects that mechanical friction typically has. This enriches the metaphor and helps in further coming to grips with the abstract concept of metaphorical friction.

**Desirability of friction**

In many engineering instances, low friction is desirable. The satisfactory operation of joints, for example, whether hinges on doors or human hip joints, demands a low friction force. Work done in overcoming friction in bearings and other mechanical components of machines is dissipated as heat, and its reduction will lead to an

overall increase in efficiency. But low friction is not necessarily beneficial in all cases. In brakes and clutches for example, friction is essential; high friction is similarly desirable between a vehicle tire and the road surface; just as it is between shoe and floor for walking and between nuts and bolts to form a connection [24]. This duality in desirability of friction is an important and core part of the understanding of friction. The occurrence of friction can be both experienced as positive and negative; it can be perceived as desirable or undesirable.

**Effects of friction**
Looking closely at the desirability of friction, it is clear that it is directly related not to the occurrence of friction per se, but to the effects the occurrence of friction has. There are two distinct effects of friction: wear and energy loss.

*Wear*
Whenever surfaces move over one another, wear will occur. In mechanical engineering, wear is defined as *"either mass or volume of material, removed or displaced from a body which is repeatedly stressed in mechanical contact with another body or bodies." [59]* In effect, it is damage that occurs to one or both of the contacting surfaces of bodies that are in relative motion.

The desirability of wear depends on the specific situation in which it takes place. An example of a situation in which undesirable wear occurs is a machine with moving parts during normal operation. This leads to unwanted results such as an increased clearance between the moving components, unwanted freedom of movement, loss of precision, increased mechanical load and vibration. Grinding and polishing are good examples of situations where controlled wear is wanted. In fact, grinding and polishing rely completely on the controlled removal of material. In addition, the "running-in process" of machinery with cogwheels relies on wear to let the parts fit smoothly together. In machinery, where some misalignment may exist it is best to use a material that can adjust or accommodate itself, that breaks in properly [33]. In the friction metaphor, this implies consideration of the fact that an activity, environment or even device can adjust itself to reduce friction.

Furthermore, an important fact to consider in the occurrence of wear, is that the effects usually only become noticeable after long periods of time of normal operation of machinery. In other words, wear is not easily observed when using a short-term perspective. The observation of the inherent long-term nature of wear has the implication of a long-term focus when looking at the effect of friction in mobile lifestyles.

*Energy loss*
The second effect of friction, energy loss, is the loss in kinetic energy that occurs due to the frictional force of the bodies that are in relative motion. In a mechanical situation, this energy is dissipated in the form of heat. Again, depending on the situation this can be either an unwanted or a wanted effect. For example, when hitting the brake in your car, you want it to stop. The car stops through energy loss due to friction between brakes and the wheels of the car. In this situation, energy loss is desirable. Now consider the situation of opening a bottle with a twister cap. The higher the friction between cap and bottle, the higher the energy loss and the more unlikely it is you will be able to open the bottle. In this situation, energy loss is undesirable. These examples clearly express the duality of the effects friction in different situations

**Mapping the effects of friction**
The observation that one of the effects of friction, wear, occurs over long periods of time in normal operation of machinery has two implications. Firstly, as mentioned before, it suggests the importance of a long-term focus in establishing the effects of friction in people's lives. Secondly, the fact that it results from *normal operation*, provides an affirmation within the conceptual friction framework to look at the day-to-day lives of people, as opposed to special events in their lives.
Another general observation that is relevant to the mapping process is the realization that the desirability of effects caused by friction, and thus the occurrence of friction itself, varies with the situation. It is situation specific.

## 3.5 Countering Undesirable Occurrences of Friction

In mechanical engineering, the undesirable effects of friction are countered in several ways. Lubrication, the use of special low friction materials or changes in the machine design are some of the most common. Of these, lubrication has the most potential to explore as a metaphor.

A lubricant is a substance capable of altering the nature of the surface interaction between contacting solids [42]. Most lubricants are introduced into a sliding system with the aim of reducing the amount of interaction between the contacting surfaces. A lubricant functions by introducing between the sliding surfaces a layer of material with a lower shear strength than the surfaces themselves. In effect, lubrication prevents the contacting surfaces from making contact. It lowers the likelihood of direct contact between the surfaces.

**Mapping lubrication**

Friction between surfaces can decrease when they make less contact. Reversing this observation implies that when looking for friction the focus should be on surfaces that do make close contact. Using the concepts of section 3.3 this means looking for activities, persons or environments have a close relationship, a high mutual influence or in general depend on one another.

## 3.6 A Metaphorical Interpretation of Friction

It is very easy and tempting to equate the concept of "friction in people's lives" with "problems in people's lives" or "stresses and strains in people's lives." In the previous sections, I found some unique identifying characteristics to counter this natural inclination and to help benefit from the span and depth of the concept of friction. These characteristics present workable metaphorical interpretations of the concept of friction. They are the source to structure and evaluate the user studies to locate friction in mobile lifestyles (chapter 4). They identify focus points and areas of interest. The characteristics of friction I identified and the focus points they suggest are:

- Friction is inherent to motion; this suggests a focus on mobile lifestyles (section 3.2)
- Friction is typically an everyday process; this suggests a focus on people's everyday lives (section 3.4)
- Friction typically has a non-focused character; this suggests it intertwines the entire mobile lifestyle (section 3.2)
- Friction typically has a small intensity; this suggests a focus on small and in-intrusive events in mobile lifestyles (section 3.2)
- One of the effects of friction, wear, is typically only noticeable after long periods of exposure to friction; this suggests a long term perspective to chart the effects of friction (section 3.4)
- The desirability of the effects of friction is situation specific, meaning that the effects of friction can be perceived as either positive or negative depending on the situation (section 3.4)
- The amount of friction between activities, persons or environments in relative motion increases with the dependability on one another (section 3.5)

Further focus points are provided by the various situations resulting from the different interpretations of the definition of mechanical friction (section 3.3). Reformulating those interpretations, the impression exists that friction is a relevant factor when:

- Doing multiple activities at multiple locations, where each location is not specifically related to a particular activity (first interpretation)
- Doing an activity in an environment that is not particularly suited for this activity (first interpretation)
- Starting and stopping moving throughout the day (first interpretation)
- Being dependent on other persons that are mobile (second interpretation)
- Activities interrupt one another, when doing multiple activities at the same time (third interpretation)
- Starting and stopping activities continuously throughout the day (third interpretation)
- Trying to pursue an activity with multiple persons, especially when not co-located (fourth interpretation)
- Being dependent on the activities of other persons (fifth interpretation)

These are some possible and valuable metaphorical interpretations of friction. These interpretations provide me with direction in setting up and evaluating the user studies in the example population of working parents, as is described in the next chapter.

# 4

*Working Parents: Friction in Mobile Lives*

In the chapters 2 and 3, I presented interpretations of the concepts of mobility, mobile lifestyle and friction. It is now time to use these abstract concepts to identify real occurrences of friction in everyday lives. As an example population of persons that comply with the notion of a mobile lifestyle and are likely to encounter friction, the focus will continue to be on families with working parents.

## 4.1 Working Parents Studies

The link with everyday reality is made through user studies, using the interpretations of friction as an aid to structure the studies and interpret the results. During this project, HP Labs conducted several studies in the mobile lifestyles of families with working parents.

*Questionnaire study (Q)*
64 questionnaires concerning mobility and stresses in the lives of working parents were analyzed, providing valuable insights on mobile device usage and the activities working parents pursue when mobile.

*Interview study 1 (I1)*
In a first interview study, 28 working parents were interviewed, providing rich information on mobility patterns and stresses in the lives of working parents.

Both the questionnaire study and the first interview study were set up and executed in parallel to the exploration of the metaphor of friction as described in chapter 3. The focus of these studies is on mobile lifestyles and problems that occur in these lifestyles. Their power lies in the rich picture they create of the lives of families with working parents. The exploration of the metaphor of friction proved its value in interpreting findings and identifying accents.
To specifically explore the situations in which the concept of friction plays a meaningful role, to fill in the blanks that were left over by these studies, an additional small interview study was set up. The interpretations of friction were used to structure this study.

*Interview study 2 (I2)*
A second small interview study was conducted with a specific focus on friction issues to fill in the gaps left over by the previous interview study and the questionnaire. The five interpretations of friction (section 3.3) were used to locate friction in the lives of working parents. Three working parents were interviewed in semi-structured interviews.

*Observations (O)*
Where possible, the interviews studies were conducted in the homes of the participants. This allows a direct experience of the environment of working parents. It enriches the picture of their lives. I have included personal observations made during four interviews conducted at the home settings of working parents in the study results.

## 4.2   Working Parents: Mobile Lifestyle

Before using the interpretations of friction to identify fruitful areas for product design, I first need a clear picture of the mobile lifestyles of working parents. This picture is presented in this section. It provides the backdrop for the friction interpretations. For the description of the mobile lifestyles of families with working parents I will use the concepts of dynamic mobility, static mobility, physical mobility and mobility of activities as presented in chapter 2.

**Static mobility: working parents typically visit a limited amount of places in a weekday**
A key finding (I1) when looking at mobility patterns of working parents during working weeks is the realization that working parents visit only a very limited number of places in a typical day. The extent of their characteristic physical mobility is highly limited and routine. Table 2 shows the typical waking hours of working parents as consisting of a limited set of basic phases linked to categories of places.

| | |
|---|---|
| *Home AM* | The period of time from getting up to leaving the house |
| *Home-work transition* | The period of time where working parents are mobile getting from home into work. This may include a number of "transitional places" or places where working parents have to stop, mainly to drop off children at school or nursery. |
| *Workplace* | The period of time spent mainly in the work place or at work-related sites engaged mainly in working activities. Some working parents made trips out during the day either to attend to domestic chores, or for work meetings or lunches. |
| *Work-home transition* | The period of time where working parents are mobile getting from work into home. This includes a number of different transitional places before arriving home, including picking up kids from school, nursery, child minders stopping at the shops, and a visit to the gym. |
| *Home PM* | The period of time from first getting home to going to bed. "Getting home" is defined as the phase that begins from first getting home, but many working parents then go out for a number of domestic reasons: shops, dentist, music lessons, walking the dog, going to the gym or eating out. |

Table 2 Places working parents typically visit in a weekday

**Dynamic mobility: the car is the dominant mode of transport**
In the study, the car clearly emerged as the dominant form of transport for almost all working parents. In most cases, this is an active form of mobility (section 2.1). However, it is important to note that this analysis should only be taken in the context of the sample used and the location the experiment took place, Bristol, UK. It is not unlikely that factors such as the specific structure of the city and the availability of public transport have a big influence on modes of transport used. As an example, the public transport in Bristol is renowned for its inefficiency, high costs and unreliability. This possibly influences the use of this mode of transport by the sample.

Many of the journeys taken by the working parents were reported to combine various activities they needed to perform. These multi-purpose journeys frequently combine the activities of commuting, taking children to or from school and domestic chores. For example, interviewees stated that shopping was done in combination with collecting the children from their daytime location and taking children to evening activities.

**Coordination is important when mobile, mobile phone is the most used device**
Again, the predominant way in which working parents are mobile during the day is by driving the car. This is a form of active mobility. This clearly influences the type of activities working parents pursue when mobile.

In the interview study, working parents report doing a range of different activities whilst mobile. These include listening to the car radio for relaxation purposes or catching up on the news and using the mobile phone. Made and received phone calls while physically mobile often had the purpose of letting the partner know what they were up to, providing awareness of key activities. For instance, two female participants let their partners know they

were on their way home from work and one female participant received a call from her husband reporting he had just left work (I1).

The questionnaire study shows that the mobile phone is by far the most popular device for the researched working parents to take with them while commuting between home and work. The diary is the second most carried artifact, with approximately half the number of persons carrying it. It is important to note that although these items are taken with the participants during their commutes, this does not necessarily imply that they are used. It may be that persons simply carry them with them, transporting them between the two situations, only using them if the occasion arises.

The interviewed parents in the second interview study pursued only a few activities when physically, actively mobile, moving an appointment backwards being the most cited one. Calling someone to tell them they will be late for an earlier agreed appointment is the main reason to start an activity while on the move. This is done via the mobile phone. For persons that do not use their mobile phone regularly, this is one of the few instances that they *do* use their mobile phone. These persons are willing to carry their phone every single day only for possible occurrences like this.

**Activities working parents pursue in multiple places**
From the interview studies, several typical activities that working parents pursue at multiple places were identified. Home activities, that are done at work, work activities, that are done at home and scheduling and coordination, that is done at home, at work and when mobile are the most noteworthy of those.

*Home-work crossover*
Especially parents that are "knowledge workers" tend to have a home-work crossover in that they pursue home activities at work and work activities at home. The difference in home and work environments influences the character of home and work activities that are pursued at each location (section 2.2).

*Scheduling and coordination*
From the interviews, it is clear that scheduling and coordination are very much activities working parents do in multiple places. Scheduling for home and work purposes is done both at home and at work. Furthermore, a majority of interviewed persons report that coordinating appointments is one of the few activities they actually pursue when physically mobile.

## 4.3   Working Parents: Friction

After getting a feel for the mobile lifestyles of working parents, it is time to identify areas of interest for product design using the friction metaphor. A valuable help in identifying usage situations in which the concept of friction plays a meaningful role are the interpretations of the friction metaphor as presented in section 3.3. Some of the hypothesized situations proved meaningful in the lives of working parents, some proved less relevant. Following are interpretations of the user studies using the friction metaphor. The goal is not to validate the friction interpretations and unambiguously describe situations. It is to probe the mobile lives of working parents for an area for product design that resonates with the friction metaphor on several levels.

**First interpretation: friction between a mobile activity and its environment**
Friction does not appear to be a relevant factor between a dynamically changing environment and an activity, as hypothesized in this friction interpretation (I2). This is partly due to the kind of activities working parents pursue when mobile, these tend to have a limited dependency on the environment, and the relatively infrequent occurrence of doing activities when mobile (section 4.2).

The crossing of frictional borders when being physically mobile, as hypothesized in section 3.3, does occur, but seems to be too infrequent to be relevant (I2).

From a static mobility and mobility of activities angle, friction that is different in different environments for a single activity does occur and is indeed a relevant factor. Examples include:

- One parent deliberately worked from home one day per week to shield this day from work meetings. This way she used the fact that the friction coefficient between the activity "having work meetings" and the environment "home" is higher than it is for the environment "work" to her advantage (I2).
- The activity of scheduling changes character in different places, suggesting different friction coefficients of various aspects of the activity for various environments: long-term home oriented planning is preferably done at home, short-term planning is done at home and at the office, just-in-time coordination is done when mobile (I2).

**Second interpretation: friction between different mobile activities undertaken by different persons**
The interviewed parents exhibit a great need and effort to monitor their spouse's and children's activities where those activities influence their own activities. Current ways of doing this, via mobile phones and e-mail, are not optimized for this purpose and can require much effort and many communication sessions (I1). Examples of situations in which family members provide awareness of one another are:

- One parent's son always sends an instant message on his instant messenger to let her know he has arrived home safely from school (I1).
- One person uses her mobile phone to call her son every morning, checking if everything is OK and if he has locked the door of the house before leaving for school (I1).
- Several parents always have their mobile phone switched on, mainly to make themselves available for family members (I1).

**Third interpretation: friction between different activities undertaken by the same person**
Multiple activities pursued by the same person can lead to activities interrupting one another (sections 2.2 and 3.3). Subjects classify interruptions as highly stressful, both at work and at home (Q).

Possible occurrences of the pursuit of multiple activities when physically mobile were explored. This did not occur frequently. Hence, friction occurrences here were not obvious (I2).

**Fourth and fifth interpretation: friction between different persons undertaking the same activity and friction between different activities undertaken by different persons**
Friction between the children's activities and parents' activities is common (fifth interpretation) (I1). To deal with this, parents value ways to keep their children occupied in a manner that they do not have to worry about them. Essentially, the activities are separated and the friction between them is reduced. Examples include:

- One parent said she "sticks her daughter in front of TV" in the morning so she can carry on with her own activities (I1).
- One parent said she could not live without the walker to put her youngest in. It allowed her, amongst others, to cook a meal without being disturbed too much (I1).
- One parent would love entertainment in the car to keep the children occupied (I1).
- One parent complained that when she drove her youngest child to the nursery in the morning, the oldest child also had to come because she was not comfortable leaving her home alone (I1).

Scheduling and coordination are particularly rich in occurrences of friction in the fourth and fifth interpretations (I1, I2). This is especially true where there are shared activities or there are many dependencies between activities. The friction between different people undertaking the same activity (fourth interpretation) occurs when the members of the family unit try to schedule a new event considering all their shared and individual appointments. This can be a very difficult process. In addition, meeting people in the right place at the right time, staying synchronized in a changing reality requires effort. Friction is a useful concept in adjusting routines; there is friction in coordinating changes on earlier made appointments.
The friction between different activities by different people (fifth interpretation) is apparent in the influence that appointments and activities with various persons in- and outside the family unit have on the scheduling process. For example, the high workload dad has on Monday night, influences his ability to do football practice with his son the same night.

Finally, I found an occurrence of friction that is directly linked to the concept of mobility of activities, but does not fit neatly in the predefined friction interpretations. Several interviewed parents experience friction in not being able to do an activity in multiple places. They experience friction because there is lack in the mobility of an activity. Examples are:

- One parent sometimes has to stay at work to wait for an important e-mail, because she cannot access work e-mail at home (I1).
- Several parents want to work from home, but do not have the opportunity to do so (I1).
- Several parents experience friction in not having access to the family calendar when at work or physically mobile (I1). One parent deals with this by carrying her wall calendar between work and home (I1).

## 4.4   Identifying a Fruitful Area for Product Design

Looking at the lives of working parents from different angles provides different insights. For example, when looking at families with working parents, IKEA identify organization in their homes as a fruitful area to focus on (figure 10). Using the friction metaphor provides different focus points. In the previous sections, I have looked at the mobile lifestyles of working parents and I have used friction interpretations to probe these lifestyles for interesting areas for product design.
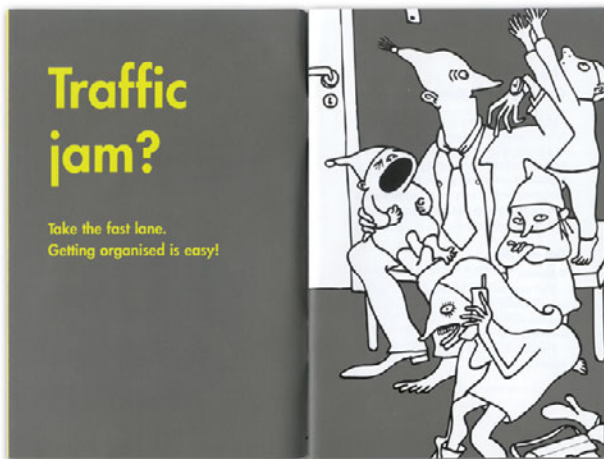


Figure 10 IKEA address the problems of working parents from a furniture angle, focusing on home organization [20]

Interpreting the studies and being immersed in the lives of working parents, one set of activities emerged that clearly resonates with the friction metaphor. These are scheduling and coordination activities. These activities are a core element of the daily routines of families with working parents. The resonance with the concepts of friction combined with the central part these activities play in the lives of working parents make this an especially fruitful area to explore in the example population. Scheduling and coordination are mobile activities in the sense that working parents engage in these activities in various environments. These are activities that seem to be valuable when physically mobile. These are activities that involve multiple persons that depend very much on one another, which make them prone to friction. Finally, these are activities that intertwine the day-to-day lives of families with working parents through many small and in-intrusive events. All these are characteristics defined in the metaphor of friction (section 3.6).

Before I can describe the ways in which the friction metaphor adds value in looking at scheduling and coordination activities, I first have to describe scheduling and coordination activities in detail. I present this description in the next chapter.

<div style="text-align: right; font-size: 4em;">5</div>

# Focus: Scheduling and Coordination

Looking at the activities of scheduling and coordination closely, it is clear that many forms of mobility and important friction characteristics resonate in these activities. Numerous facets of the previously defined friction metaphor (chapter 3) are present and relevant when considered from the perspective of scheduling and coordination activities. In this chapter, I present a detailed description of scheduling and coordination activities and the resonance they have with the friction metaphor.

## 5.1 Scheduling and Coordination from the User Studies

### Coordination in a close group of people

From interviews with working parents that have a partner, it is clear that many activities are coordinated within the family unit. Shared family activities are common and often require much iteration to coordinate. Usually this is between the parents, but when older, the children tend to be more involved in this. Especially the after school activities of the children tend to influence the schedules of their parents heavily, primarily since children usually rely on their parents for transport.

What is a particularly interesting finding from the friction interview study (I2) is the realization that working parents without partner still operate in a close network of people, replacing the family unit. One interviewed working parent relied completely on the help of a small group of mothers, parents of friends of her daughter, to cope with her everyday life (I2):

> "I think I rely very much on the fact that there's two or three mums who I've got to know over the years, who their daughters are friends with my daughter, and so I rely on them to kind of help out."

So, to coordinate the activities of parents and dependent children there always seems to be a close group of few people involved. Within this group, communication with the purpose of scheduling and coordination is frequent. Due to the many shared family activities and due to this intense communication, there is a high common ground, shared information, mutual knowledge and mutual assumptions [see for instance [11, 12, 26]], between the members of the group. This influences the character of communication. Subtle communication is sufficient to convey meaning to insiders. Outsiders that miss the common ground typically find these communications incomprehensible.

For instance, Tolmie et al. [55] relate about a mother and her neighbors that had arrived at a seemingly elaborate, yet beautifully simple and obvious method for notifying one another of their imminent departure to school to pick up their children, so that they could walk there together.

The arrangement worked in this way: whoever was ready first knocked on the door of the other, but did not wait for a reply. Instead, they just slowly started to walk up the road. The other mother whose door had been knocked on similarly opened the door a crack to acknowledge the fact they had heard it, but did not necessarily leave immediately but rather gathered together their bits and pieces to get ready to go to the school. Then they walked out and caught up with their neighbor. The usual understanding of what happens when someone knocks on a door is that they wait for an answer and the person inside opens the door to see who is there. In this case those expectations were thoroughly transcended and for outsiders, at first sight, quite remarkable. Yet for the two mothers this was a thing they did every school day, never paused to comment upon, and that was eminently logical. But it was not a thing that they could engage in at just any time of day or on any day of the week. It was quite specifically unremarkable to them within the context of their "going to school" routine.

A practice related by a parent in the interview studies (I1) is an additional example of common ground used in families. This time, common ground is explicitly present in a coordination and awareness activity. Every day when this parent leaves work, she phones her partners' mobile phone from her own mobile phone, but puts it down after one ring. She does this because her husband can then see that she had called and at what time she called. As it is a daily routine, he automatically knows that this means she has left work and has gone to collect their son from the nursery. A very low-bandwidth message thus conveys a reassuring meaning that is based on mutual assumptions only apparent to the persons involved.

The common ground and mutual trust in such a close group of few people evolves slowly over longer periods of time. This becomes especially evident when a new member is added to the group (I2):

> "(…) whenever you're just starting up something. So I think that's why, with Helena now and her mother who we've only really got to know this last year, I still feel a bit more uneasy when it's my week (to pick up the kids), or what will happen if something happens. Whereas Christine, the other lady who Jenny's been best friends with her daughter for four years now (…), she's rock solid. I trust her more than I trust myself."

From a metaphorical friction perspective, this can be seen to be clearly analogous to the running in process of machines where cogwheels are fitted smoothly and tightly together by consciously using wear in the first operation cycles (section 3.4).

Finally, within the close group of persons involved, sharing calendars and schedules is not considered problematic. As this would be for instance with a bigger group of persons where privacy starts to play a bigger role. For instance, in the interviews (I1), one mother related that her son checked her diary to find out which of her Saturdays were free for him to have a birthday party. In addition, one mother related about checking both her own and her husband's diary.

### Routine and changes in routine
The interviewed working parents operate on a daily routine that remains reasonably constant over longer periods of time, but does change several times per year due to for instance changes in school term activities of the children, holidays and season based activities. This constant routine is subject to small, localized, day-to-day changes because of events such as differences in workload of the parents and irregularities in after school activities. In other words, the routine is the stable basis on which small, localized changes occur.

Two sources of difficulties and confusion in routine planning are changing and non-obvious routines. One divorced parent I interviewed related about the fact that her ex-husband has their daughter is in his custody on a different night each week. Usually they agree on the exact night on Sundays, face-to-face. She finds this erratic event very difficult to deal with. She has similar difficulties with the horse riding her daughter does, a weekly activity. Ever so often, the horse-riding teacher has a day off, and the routine of picking up her daughter from horse riding changes (I2): *"It's not always exactly the same thing."* Another example of non-obvious routines are activities that happen on alternating weeks and are therefore hard to keep track of (I2):

> "So at the moment, with the dancing (…) Christine always used to drop them off and always picked them up, and there was just the two of them. Now Helena (…) she joined their same group. Now actually Helena's mum has

*offered: "Well I'll pick them up every other week." Which is nice, but I find it really hard because it means I have to think: "Is this the week I'm picking them up or not?" And then you get more worried actually that I've got it wrong. So I find that hard to cope with."*

This parent furthermore commented:

*"(I) have not yet worked out an easy way to (remember the weekly alternating schedule)."*

She does not consider writing the schedule in her diary every week an option because sometimes she swaps weeks and that changes the planning. Swapping weeks is generally a last minute thing.
The above examples were all of non-obvious routines. An example of changing routines is the varying working schedule of one parent who does shift work that is influenced by his workload. His wife works nights. When he has to work late, he usually calls his wife from work, landline to landline, to arrange who will look after the children that night. Generally, his wife then talks to his mother who lives nearby and arranges for her to baby-sit that night.

One example of a negative occurrence due to forgetting a routine is the story of a parent whose daughter had forgotten what she was supposed to do that day after school. She was confused with her after school activity for that specific day. She was under the impression that her mother would pick her up directly from school, while in reality she was supposed to go to an after school nursery. Consequently, the child waited outside of school, but there was nobody to pick her up. Eventually, through the lucky event that a former child minder saw her waiting outside the school, the issue was resolved.
The interesting fact here is not the occurrence of this event, but the impact it had on the day-to-day routine of the parent and her daughter. Since this event, every day in the car, the mother now makes sure she has a good understanding of her day to prevent a similar event from happening. This is an act of reaffirmation or confirmation of daily routine. Similarities with checking every day whether everybody has all their things before leaving the house, an event frequently observed in the first interview study, exist.

Another attractive finding from the friction interview study (I2) is the realization that the small, localized changes to the reasonably stable routine schedule are typically coordinated when persons are physically mobile. The most common example of this is delays of earlier agreed upon appointments (section 4.2). Many persons we interviewed often use their mobile phone to make outgoing calls only for this reason; when they are stuck in traffic or their bus is late. Changes that are more far-reaching, such as persons that will not be able to keep an earlier agreed upon appointment, are sometimes coordinated when physically mobile, but typically when static, either at home or at work. These changes tend to generate much communication and require much iteration (I2):

*"There's usually lots of phone rounds when something happens. So either one of the kids is ill or you've got clashes (between appointments)."*

There are more differences in how parents deal with routine planning and localized events. One parent says he keeps his day-to-day home responsibilities and appointments in his head, but has the need to make a note for distant and special events (I2). One parent consults her calendar every week to check if any birthdays are coming up (I1). In addition, in one family the mother checks the wall calendar every day to see if something unusual was happening that day (I1):

*"There will be some days when (the wall calendar is) completely blank and that's just a normal day. But if there's anything different happening, like if one of the children's on a school trip or something, then that will be written in there or if they need anything different. (…) So I check that every morning to check nothing unusual is happening."*

This suggests a need for a calendar focused *not* on day-to-day events, but on odd, localized events. This is supported by another parent who did not use any calendars and did indeed forget the odd, special event of the interview I was doing, taking place (I2). This lead to some surprise, but the routine was quickly adjusted, indicating the flexibility of daily routines and schedules.

Furthermore, one parent says he has a buffer for special events that he feels he has to make a note of (I2). One or two days after finding out about the event, he enters it with any others in his electronic work calendar. He feels he forgets details about the events in his buffer, such as the exact date and time of the event. This suggests a possible need for temporary storage of appointment details, a buffer of events, in a mobile device. Appointments can be entered in the full calendar at home or at work later. Or, of course, a need for full access to your calendar, whenever an event is mentioned for the first time, to make note of it.

### Transitional awareness
An interesting activity directly linked to coordination and being aware of schedules was frequently observed in the interviews (I1). Oftentimes, partners would communicate when they would leave work or be on their way home. This provides the partners with some awareness of what the other person is doing. It is noteworthy that these awareness messages are typically sent when persons cross over in different environments and activities, for instance when going home from work, or arriving at work. The tool used for sending these "transitional awareness" messages tends to be the mobile phone. The messages tend to have little more content than the conveyance of the change of environment or activity. In some arrangements, these awareness activities are highly structured and strict. One son for instance would send a message to his mother every day when he got home from school (I1). Another example is the previously mentioned instance of partners phoning each other, solely leaving their number to indicate they are on their way to collect their child from the nursery.

### The environment influences the character of the activity
From the interviews (I2), it is clear that scheduling and coordination are very much activities that are done in multiple places. Scheduling and coordination for home and work purposes is done both at home and at work. Furthermore, all interviewed persons report that coordinating is one of the few activities they actually pursue when physically mobile (I2).

Scheduling actually changes character in each of these instances: long-term home planning tends to be done more at home with the persons involved present (section 5.3). Changes to the planning are done both at home and at work (I1, I2), and especially small changes are made when physically mobile with the persons involved typically not co-located (I2) (table 3). From a friction metaphor perspective, there is one activity in three manifestations that all have different friction coefficients in the different environments.

| Activity | Preferred environment (friction metaphor: lowest friction coefficient) |
| --- | --- |
| Long-term planning | Home |
| High impact adjustments on earlier agreed appointments | Home and work |
| Low impact adjustments on earlier agreed appointments | Anywhere (home, work and mobile) |

Table 3 Different friction coefficients make environments variously suitable to different aspects of scheduling and coordination

This changing character of scheduling leads to different requirements for products used in each environment. A wall calendar that can be used by multiple persons at once and that is available at a glance would be a good solution to aid in scheduling at home, it would however not be very suitable for coordinating changes when on the move, where a more personal and portable device is needed.

Descriptions of the ideal piece of technology of two of the participants in the interview study (I1) provide examples of the mobility of these activities and illustrate the perceived need for devices to support this mobility:

> "(My ideal piece of technology) would be something like the calendar that I have in my loo, but it would be something that I could carry around with me. But that maybe my family could have one each as well and they could all enter things on it (…)"

> "(My ideal piece of technology) would probably be a calendar that I could hang on the wall that would then miraculously shrink and come with me (…). I have in fact (tried to do something similar) before I got this little personal diary. I used to take the calendar off the wall and carry it with me. But it wasn't really convenient because it was too big."

## 5.2  Artifacts Used for Scheduling and Coordination

From the working parents studies it is clear that numerous artifacts support scheduling and coordination activities. Paper and electronic diaries, wall calendars, pin boards, mobile phones and PDA's are used in varying degree in home, work and mobile settings. In families, these artifacts tend to be prolific. There is for instance an average of 3.2 diaries per household, including paper and electronic ones, for home and work purposes (Q, I1):

> "If there's a family event, theoretically it could hit six different places, which is quite daunting. I had no idea (until filling out the questionnaire) that we had six potential places to mark one event."

> "I have a (…) wall planner, my paper diary, I use (a) calendar, (…) Tim's got a handheld mini thing. Well, I've got one as well, but mine's not in use at the moment (…)"

> "There must be a way of documenting all this. I've tried all sorts. I've tried whiteboards in here and I've tried writing it all down on a big piece of paper. And then I got a sheet of paper that was divided up. So it had Monday to Friday down here, and then Geoff, Jane, Rosie, Ben along the top, and all the times and dates we were doing everything. Because they were doing lots of different activities at school. (…) So I've done all that when they were younger, to try and work in my head what everyone was doing. But I suppose you just get used to it and we all know what we're all doing really, and different routines. But there must be a way to connect all this (all the bits of paper) together."

The wall calendar is the most popular planning device in the home, the electronic diary in the office (Q). In general, the home is for the greater part reflective of paper-based and tangible methods whereas the workplace reflects the use of electronic devices and services.

The majority of working parents (77% of participants in the questionnaire study) prefers flexibility of their devices for both home and work use (Q). Working parents can be observed to input work routines or school events as constraints in home oriented wall calendars (I1):

> "My husband works shifts, so his shifts are always all written on (the wall calendar), exactly what he's doing, so that children know when he's going to be in the house and whether they need their keys to get in the house or whether he's going to be at home when they come home."

> "(The wall calendar is) like (a) bible, it has everything on there, all the school stuff, everything the kids have to do—everything."

> "We have a calendar in the toilet; it's just a handy place. So, whenever anyone goes to the loo they can check the calendar. It's a wipe clean one so if anything ever changes then they wipe it off. And it's got four sections: one for my husband, one for me and one for each of the children, so we all write in what we're going to be doing and where we're going to be on each day."

The mobile phone is by far the most popular device for working parents to take with them while commuting between home and work, with the diary in second place (Q).

Figure 11 presents a more detailed look at the artifacts in the home used for scheduling and coordination activities. The photos of these artifacts were taken as part of four interviews I conducted in the homes of working parents (O).

In pictures 1, 2 and 3, the calendar, to-do list and important phone numbers are all grouped on one wall. Indicating a close association between these areas. Ticked off items on a to-do list stuck to the "notes" board are visible. The chaotic organization of the pin board is especially noteworthy. In picture 4, two appointments for the month are jotted down on the family calendar. This has been done in a consistent format; name and time are entered in the correct date slot. In pictures 5 and 6, there are two scheduling related notes on the fridge: a schedule of a leisurely activity and a confirmation note for a recurring appointment. The third note has important phone numbers for the children in case something happens: phone numbers of their parents and general emergency numbers. Picture 7 shows a rare instance in which a PDA is used for home purposes, in this case for a to-do list with home activities. Finally, picture 8 shows a diary a mother always carries with her, but never uses. It
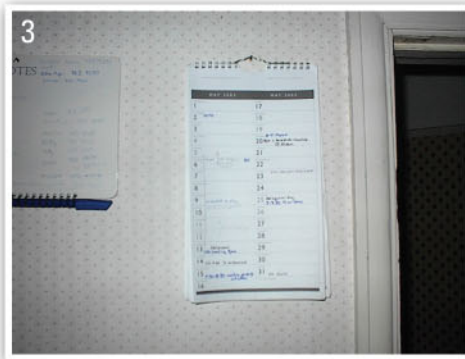
Figure 11 Artifacts in the home used for scheduling and coordination activities

is empty. She uses her mobile phone for reminders. The phone will send her an alert at the specified date and time with the activity to be done.

From the questionnaire study and these observations, the artifacts used for scheduling and coordination activities in the home can now be identified as the wall calendar, the pin board, the diary and the mobile phone. These artifacts and devices used each have their own specific purpose:

- Families with working parents use the wall or kitchen calendar for shared and personal schedules where these influence other family members, with a focus on long-term planning and special events such as birthdays.
- The pin board and the fridge are used to display bits and pieces of appointments and partial schedules such as dentist appointment cards and invitations. These bits and pieces are all paper based.
- The paper diary is used for personal schedules.
- Finally, the mobile phone is the device that is used for coordination when physically mobile. It is not mainly used as a communication device, for chitchat, but as a way of monitoring and coordinating the activities of the family unit, especially when on the move. It helps to maintain awareness of where partner and children are and what they are doing. In addition, it makes one "available" to the family.

## 5.3  Scheduling and Coordination in the Literature

The impression of scheduling activities in families with working parents as presented in the previous sections is largely based on the friction interview study (I2) with a small sample. Comparison of results with other research studies is useful to establish an impression of the validity of the results and to enrich the image of scheduling activities. Before discussing these results, it is important to realize, as Sawhney [46] and Bachen [4] both note, that few studies on scheduling and coordination in the domestic domain, or, more broadly, mobile domestic communication patterns in families, exist. The studies that do exist, that are publicly available and relevant are discussed below.

In their research, Sawhney and Gomez [46] want to gain an understanding of communication patterns in distributed domestic relationships. In their preliminary results based on the analysis of four interviews with two families, they found that husbands and wives keep in touch throughout the day for routine home-related tasks. Furthermore, they report the two families, who do not owned mobile phones, claim they felt these would be beneficial for use within the family. They mention two key reasons: coordination with spouse and children while on the move and minimization of their concern for their whereabouts and safety when they are out late.

Tollmar et al. [54] are interested in a basic understanding of how communications between family members takes place and how new forms of communication technology can improve social contacts between family members. One finding from rapid ethnographic studies covering eight families is that the use of the telephone usually changes when families have children. Before, they could spend hours on the phone, but after it had become a device for interchanging practical information.

Darrah, English-Lueck, and Freeman [13, 14, 19] have been studying the use of technology in households in the Silicon Valley, US area with special attention to the home-work crossover. They have investigated this area in several ways, involving statistical surveys, interviews and ethnographic studies of a multitude of families over the past seven years. Their observations are based a broad diversity of studies, including 450 detailed interviews in a study in cooperation with the National Science Foundation, and ethnographic fieldwork that was conducted with fourteen families between 1998 and 2000.

Darrah et al. found that pagers, mobile phones, answering machines, and PDA's are the tools by which complex household schedules are coordinated and responsibilities are divided. They furthermore found that the complexity of household schedules is partly due to the seemingly endless array of work, school, recreational, and domestic activities that all demand transportation, sequencing and division of labor.

As family members struggled to complete many activities, prioritization and negotiation in planning were often observed. In fact, they often became important activities that defined the family. Scheduling can therefore be a complex undertaking:

> *"We watched for example, while a couple ticked off the future weekends trying to reschedule a child's birthday party; business commitments, previous social commitments and the commitments of potential guests pushed it until months later."*

Planning often began in the families with face-to-face discussions, accompanied by formal record keeping via PDA's, daily planners, charts, lists and Post-It notes.

The families Darrah et al. studied, varied in their relative emphasis on plans and improvisations. Families used a mix of planning and improvisational strategies under specific conditions. Plans seldom unfolded exactly as anticipated, and being in contact allowed adaptation to changing realities. Fears of things that might go wrong in the planning, such as retrieving a sick child from school or forgetting a child somewhere, were ubiquitous. Even if plans did unfold as desired, family members feared that something might go wrong, and maintained contact just to be safe.

Improvisation, when plans are either not made or do not unfold correctly, involved responding to each logistical demand as it arises. Families who used this practice typically depended heavily on being in contact via landline and mobile phones, and e-mail. However, it is interesting to note that families that relied on improvisation did so using predictable building blocks. They implicitly knew who could do what when, and their days were far more predictable than improvisation connotes.

It is important to realize that families did not just use individual devices but ecosystems of technology at the home. Pagers, mobile phones, telephone and answering systems were used together to serve the goals of individuals and families. Most of these ecosystems of technology provided redundant messaging. Family members often e-mailed, paged and called, on one of several phones, in order to be sure the message got through. The need for redundancy reflected both the flakiness of some devices, due to dead batteries for example, and, more interestingly, the unpredictability of others' schedules.

Moreover, Darrah et al. observe that the perceived safety net of technology allowed planning to become ever more "just-in-time." Communication devices allowed plans to be created, shifted and coordinated in the space of a single afternoon. They also note the careful management of non-use of devices, by turning off the phone, avoiding using mobile phones in the car or checking e-mail only at certain hours, to take control of interruptions.

Finally, the researchers found that the family is not a natural unit that simply exists, but one defined by action, activities pursued together. The devices that facilitate this, phones, networked computers, pagers, answering machines, accordingly take on a serious purpose in the family unit.

## 5.4 Characterization of Scheduling and Coordination Activities

From the user studies (section 5.1) and supported by the literature (section 5.3), a number of defining characteristics of the activities of scheduling and coordination in families with working parents have emerged.

### Family schedules are complex

Scheduling in families is a complex undertaking. The complexity is partly due to the sheer number of activities that family members are typically engaged in. It is also due to the impact that each family member's schedule has on the others' schedules, considering individual activities, shared family activities and activities with persons outside the family. Prioritization of activities, planning and negotiation consequently is important behavior that, in part, defines the family.

**Families share a large common ground**

Many activities are coordinated within a close group of a few people. There is a high common ground in this close group of people. This implies that subtle communication is enough to convey meaning to insiders, especially with routine communications. However, in special, infrequent or more far-reaching cases, more bandwidth is needed.

Within the close group of people, communication with the purpose of scheduling and coordination is frequent. Communication of a logistical nature is undertaken both to adapt routines to the changing reality and sometimes to reaffirm routines. Messages concerning transitional awareness are frequent. Oftentimes, keeping the opportunity to communicate changes open is reassuring in itself.

**Family lives are based on routines**

Long-term routine, in the range of several months, is the stable basis on which small, localized changes occur. The routine is reasonably stable and family members tend to know each other's routines. Families vary in their emphasis on plans and improvisations. However, even in families that focus on improvisation, routines are still present and important. Sources of difficulties and confusion in routine planning are non-obvious routines, such as bi-weekly appointments, changing routines, such as varying work hours, and distant and special events, such as birthdays.

| *Long-term planning and scheduling* | *High impact adjustments on earlier agreed appointments* | *Low impact adjustments on earlier agreed appointments* | *Transitional awareness* |
|---|---|---|---|
| - Planning of the week ahead | - Canceling an appointment<br>- Moving an appointment to a non adjacent timeslot<br>- Moving an appointment in situations with adjacent appointments | - Moving an earlier agreed upon appointment back in time | - Being aware of changes in environment and location |
| Interaction with co-located family members | Interaction with non co-located family members | Interaction with non co-located family members | Interaction with non co-located family members |
| Weekly | Daily | Daily | Daily |
| Home | Home and work | Anywhere (home, work and mobile) | Anywhere (home, work and mobile) |
| Complexity:<br>- Vast number of activities<br>- Influence of family member's schedules on one another | Iteration | | Reassurance |
| Difficulties and confusion:<br>- Non-obvious routines<br>- Changing routines<br>- Distant events<br>- Special events | | | |
| Prioritization<br>Negotiation | | | |
| | Common ground: high bandwidth communication to convey meaning | Common ground: subtle communication to convey meaning | Common ground: schedules of other family members are coarsely known |

Table 4 Categorization of different aspects of planning, scheduling and coordination

**Scheduling and coordination changes character in different environments**

Small, localized changes to relatively stable routine schedules are typically coordinated when persons are physically mobile. The most common example of this is delays of earlier agreed upon appointments. Changes that are more far-reaching, such as canceling an appointment, moving an appointment to a non adjacent timeslot or changes that occur in situations with adjacent appointments, are sometimes coordinated when physically mobile, but typically when static, either at home or at work. These changes tend to generate much communication and require much iteration. Long-term home planning tends to be done at home in a face-to-face situation. It is important to realize that families do not use single devices to support these different characteristics of planning, scheduling and coordination. Rather, they use ecosystems of technology.

Table 4 represents the changing character of the activities of scheduling and coordination over different environments.

Finally, it is important to realize there are differences in how families deal with scheduling and coordination, routines and improvisation. Some families have all their planning in their heads, some write everything on calendars; some like to improvise, some adhere to their routines; some communicate throughout the day, some could care less. It is impossible to provide the exact blueprint of scheduling and coordination activities for all families with working parents. This is also not necessary. I will focus on the characteristics as described above. Sometimes these apply in a variable scale for different families. That does not have to be a problem, since charting the current situation has its main value in providing a *starting point* for product design. It provides valuable information on what families do that is interesting and useful from a product design perspective. It provides clues on what families might do if the products were there to enable them. Products influence the way people do things. An obvious and extreme example is the widespread use of the mobile phone that has changed communication patterns. Designing products for scheduling and coordination activities will influence the way these activities are done. As the graphic designer Paul Rand formulated it, the research data themselves are not creativity; they are possible clues for conceptualization [43].

## 5.5   *Friction in Scheduling and Coordination*

In the previous sections, I have presented a detailed impression and characterization of scheduling and coordination activities in families with working parents. In my description of these activities, I have used several concepts of mobility as explained in chapter 2. I will now describe the resonance with the friction metaphor as explained in chapter 3. I will explain what new ways of looking at these activities the friction metaphor provides, what focus points the friction metaphor provides in these activities. In other words, how the friction metaphor adds value when looking at scheduling and coordination.

**Resonance with the friction metaphor**
*Scheduling and coordination are part of mobile lifestyles*
Scheduling activities cross the environments of home and work. In this sense, scheduling and coordination are mobile activities. Furthermore, coordination is an activity that is valuable when physically mobile. Therefore, using the definition as proposed in section 2.4, scheduling and coordination activities are part of a mobile lifestyle.

*Scheduling and coordination intertwine everyday lives through small and in-intrusive events*
Consistent with the friction metaphor, scheduling and coordination intertwine the day-to-day lives of families with working parents through many small and in intrusive events, these activities are very much part of day-to-day life for families with working parents.

*The effects of scheduling and coordination can be perceived as positive or negative depending on the situation*
From the studies, the impression exists that working parents usually do not perceive scheduling and coordination as particularly enjoyable. The friction metaphor attracts attention to a duality in these activities. Although scheduling and coordination activities are perceived as being a nuisance, these same scheduling and coordination activities keep families aware of their routines, making the family a tighter unit.

*Friction in scheduling and coordination increases with the dependability of activities and persons on one another*
Scheduling and coordination are particularly complex in families due to the busy schedules of these families and the dependability family members and their schedules have on one another. For example, children often rely on their parents for transport. One participant's description of her ideal calendar illustrates this point (I1):

> *"I could see a screen that's split into four. Each person has their own bit, and they log in what they're going to do (…). So there are specific things we all do. You could put those in. There are problems where we're overlapping with the car."*

This makes families with working parents an extremely suitable example population to explore scheduling and coordination activities. The fact that these activities involve multiple persons that depend very much on one another makes them prone to friction.

*Friction plays a meaningful role in the activity of scheduling a new event*
As established in section 4.3, friction is particularly obvious in the activity of scheduling a new event. In this situation, a process of prioritization and negotiation is likely to occur (section 5.3). This is especially true where there are shared activities or there are many dependencies between activities. Consider the analogy with a machine with many moving parts. All these parts have to fit smoothly together for the machine to operate efficiently. Friction occurs between these parts. Less friction when the parts fit tightly together, more when not. The same is true for appointments family members have. Consider the appointments to be the moving parts in the machine. These appointments influence one another. Normally these appointments fit tightly together. Fitting in a new appointment in this tight network of old routines consequently can be difficult. The appointments are likely to fit less closely together and friction is likely to increase.
Taking the analogy one step further, in machinery, moving parts in a new machine adjust through wear to fit closely together. Analogous, in a scheduling activity, the existing routines sometimes have to be adjusted to fit in the new appointments. On some levels, adjusting routines and schedules is analogous to adjusting materials in machinery to reduce friction through wear.

*Friction plays a meaningful role in coordination in a changing reality*
Meeting people in the right place at the right time, staying synchronized in a changing reality requires effort. Friction occurs when family members try to synchronize through coordination. Oftentimes, reality changes the previously established appointments and routines. Friction is a useful concept when making small changes to previously established routines. There is friction in coordinating changes on earlier made appointments. In certain instances, these changes can generate much communication and require much iteration.

## Focus points identified by the friction metaphor
From the previous descriptions, it is clear how the friction metaphor resonates in the activities of scheduling and coordination. In this resonance, the friction metaphor has identified several focus points that form starting points for product and interaction design. These focus points are exactly the added value of the friction metaphor. They provide a new way of looking at the area of scheduling and coordination. These focus points are:

- Emphasis on the realization that scheduling and coordination activities change character in different environments
- Emphasis on dependability between appointments of family members
- Emphasis on two usage situations:
    o scheduling a new event
    o coordination in a changing reality

Against the backdrop of the detailed characteristics of scheduling and coordination in families with working parents, I will mold these focus points into a tangible design in the next chapter.

# 6

*Design*

In the previous chapter, I have presented a detailed description of scheduling and coordination activities in families with working parents. I have identified these areas in the larger domain of mobile lifestyles through interpretations suggested by the friction metaphor. Additionally, the metaphor has provided focus points and new ways of looking at scheduling and coordination. Detailed understanding of scheduling and coordination activities in combination with the identified focus points now form the outset for product and interaction design. This chapter presents the process of molding this understanding and these focus points into a tangible design. It presents the incremental and iterative steps in the design process, the goals and choices as well as the resulting design.

## 6.1  Design Explorations

**Idea exploration: making the friction metaphor tangible through design**
So far, I have used the friction metaphor to identify the area of scheduling and coordination as fruitful for product design. I have also used the metaphor to identify focus points in this area (section 5.5). These are the starting points for product and interaction design.

The aim is to make the identified focus points tangible and real, to make them explicit through product design. To meet this goal, I have explored the metaphor of friction through creativity sessions modeled on Synectics [44]. The creativity sessions were based on seventeen stimulating statements of friction (figure 12). These statements were "force-fitted" back on the scheduling and coordination activities of working parents, generating new product design ideas based on friction in the scheduling domain. Figures 13 and 14 show an impression of this process. These design ideas are creative and intuitive interpretations of the reasoning on friction in scheduling and coordination activities presented in chapter 5. These ideas suggest new angles, themes and implementations of previously defined concepts.

1. *The "running-in process" of machinery with cogwheels relies on wear to let the parts fit smoothly together.*
When is there running-in in the activity of scheduling and coordinating?
2. *In machinery, there is the notion of constrained and non-constrained motion.*
What do these concepts mean in the activity of scheduling and coordinating?
3. *In material engineering, at very high speeds, friction decreases significantly, due to melting of material.*
What does this mean, mapped to the activity of scheduling and coordinating? When are parents, scheduling and coordinating activities or schedules mobile with high velocities?
4. *Friction stops passive motion, in other words: a continuous effort is needed to keep moving.*
What does this mean, mapped to the activity of scheduling and coordinating? When are parents, scheduling and coordinating activities or schedules in passive motion?
5. *In turbulence, negative friction occurs.*
What does this mean, mapped to the activity of scheduling and coordinating? When does negative friction occur in the activity of scheduling and coordinating? In turbulent situations?
6. *Friction is essential to start motion.*
What does this mean, mapped to the activity of scheduling and coordinating? When do parents, scheduling and coordinating activities or schedules start motion?
7. *The harder we pull on the chord with a properly designed knot, the higher the friction in the knot and the more it resists slipping.*
What does this mean, mapped to the activity of scheduling and coordinating?
8. *Friction is essential to power motion.*
What does this mean, mapped to the activity of scheduling and coordinating? When are parents, scheduling and coordinating activities or schedules in powered motion?
9. *The removal of regular friction (e.g. normal interruptions) can have positive effects: flow (Csikszentmihalyi).*
What are other positive effects? What other friction removal also has positive effects?
10. *Friction is essential to steer motion (both due to frictional force occurring in turns, but also due to the operation of the steering wheel).*
What does this mean, mapped to the activity of scheduling and coordinating? When are parents steering their lives or activities? When are they being steered?
11. *Friction between yarns in woven fabrics keeps fabric together.*
What does this mean, mapped to the activity of scheduling and coordinating?
12. *Grinding and polishing processes rely on friction.*
What processes in the activity of scheduling and coordinating rely on friction?
13. *Friction is essential to have a grip on your surroundings (e.g. shoes, car tires, nail in the wall, nut and bolt connection).*
What does this mean, mapped to the activity of scheduling and coordinating? When do parents scheduling and coordinating activities or schedules need a grip on their surroundings?
14. *Friction is essential in brakes, to stop motion.*
What does this mean, mapped to the activity of scheduling and coordinating? When do parents, scheduling and coordinating activities or schedules need to stop motion?
15. *When the friction between environment and object is smaller than internal friction (as in the wheels of a car), the object (car) starts to slip.*
What does this mean, mapped to the activity of scheduling and coordinating?
16. *The removal of regular friction (e.g. normal interruptions) can have negative effects: RSI (Repetitive Strain Injury).*
What are other negative effects? What other friction removal also has negative effects?
17. *In cases of non-linear friction, the faster you go the more friction you incur.*
What are occurrences of this in the activity of scheduling and coordinating?

Figure 12 Statements of friction used to explore the metaphor of friction in product design
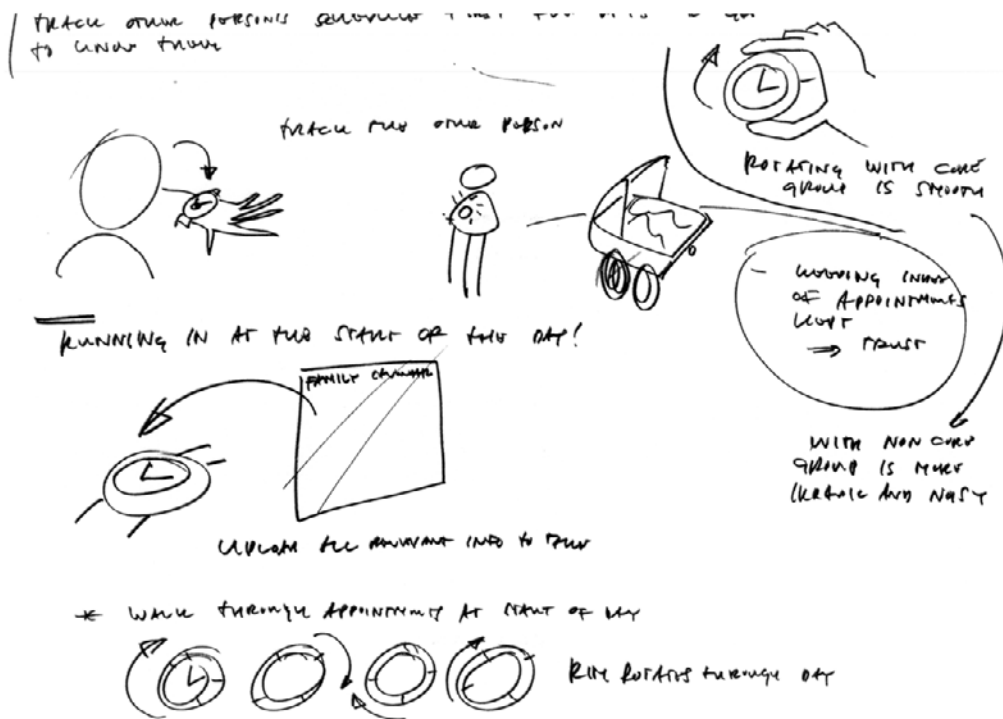
Exploration of statement 1 (fragment): the "running-in process" of machinery with cogwheels relies on wear to let the parts fit smoothly together
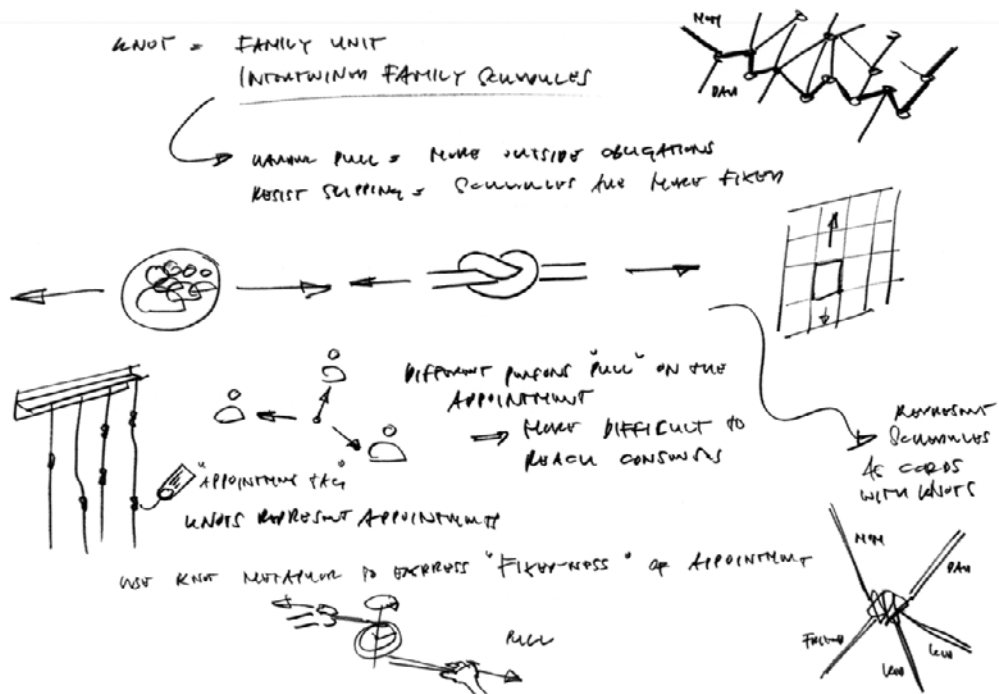


Exploration of statement 7 (fragment): the harder we pull on the chord with a properly designed knot, the higher the friction in the knot and the more it resists slipping

Figure 13 Examples of explorations of friction statements in product design

Exploration of statement 13 (fragment): friction is essential to have a grip on your surroundings (e.g. shoes, car tires, nail in the wall, nut and bolt connection)



Exploration of statement 14 (fragment): friction is essential in brakes, to stop motion

Figure 14 Examples of explorations of friction statements in product design

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**Iterating on the idea exploration**
The creativity sessions lead to an abundance of partial design ideas, interesting thoughts and design angles. Iterations on these ideas, parallel explorations and clustering lead to several promising product design directions capturing and summarizing the best of the idea explorations. These design directions are the "long-term planner", "kitchen awareness clocks" and the "coordination watch". Figures 15 to 18 present these design directions. In addition, figure 19 presents several un-clustered general design considerations.

The synergy between long-term planner and coordination watch is the basis for further design development. These are devices that cater for two distinct usage situations and interact both virtually and physically to accomplish a goal. Through their design, they express that scheduling and coordination activities change character in different environments. The long-term planner offers very tactile and expressive interaction in scheduling a new appointment. The coordination watch offers a very low-impact and gestural meaningful interaction of adapting to a changing reality. These are all focus points identified in section 5.5. Both are promising, and already show glimpses of a clear expression of the concept of friction through their product and interaction design.

→ coordination watch

The *coordination watch* is an interpretation of the clock governed and deadline oriented lives of working parents and is based on the realization that communication when mobile typically has a coordination character. Added to that, it uses the well-developed common ground in families and the consequent low bandwidth messages that can be sent to coordinate changes in appointments.

This design starts from the action of a person looking on their watch to check the time and realizing they will be late for an appointment. With their *coordination watch*, they rotate the appointment that is displayed on the dial to a point further in time.

The rims of the watches of the other persons involved in the appointment now start to rotate. This opens up expressive interaction possibilities to counter-rotate in the negotiating process of setting a new time. In addition, it opens a tactile channel to express feelings about a person's tardiness.

The user coordinates changes in their appointments through these interactions:
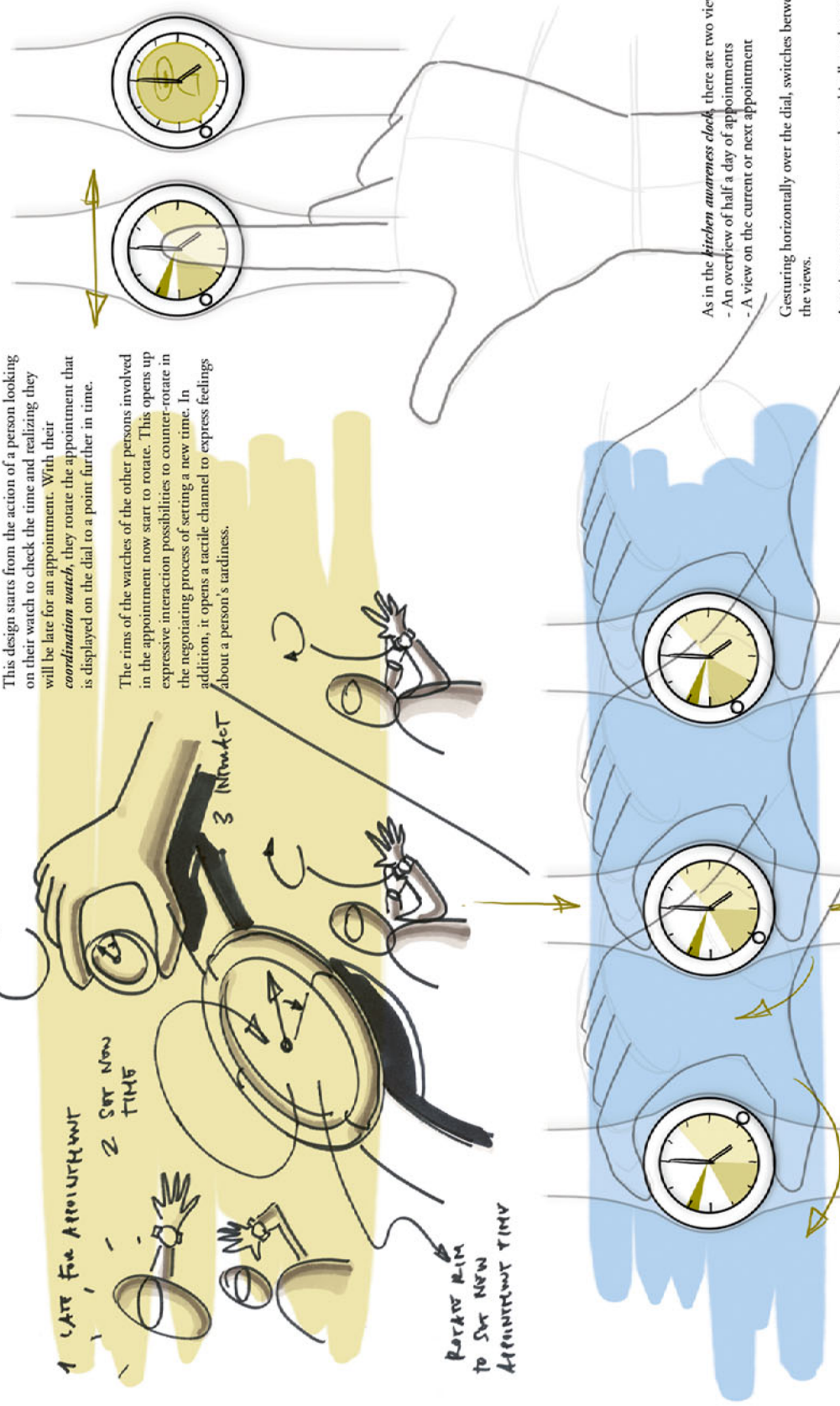
1) *Rotate to select the appointment*
The user rotates the rim to select the appointment they want to reschedule by aligning the rim indicator with the appropriate appointment displayed on the dial.

2) and 3) *Press and rotate to set new time*
The user now presses and simultaneously rotates the rim to the new appointment time. The pressing and rotating actions are again interpretations of the concept of friction in the interaction: a continuous effort is needed to overcome the friction that resists motion of appointments. Additionally, appointments that are more important require more force to rotate than less important ones. Friction is thus also used to express the importance of appointments.

As in the *kitchen awareness clock*, there are two views:
- An overview of half a day of appointments
- A view on the current or next appointment

Gesturing horizontally over the dial, switches between the views.

Appointments are represented graphically and textually to express time, place, persons and aim of the appointment.

Figure 15 Design direction: coordination watch

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→ coordination watch (continued)
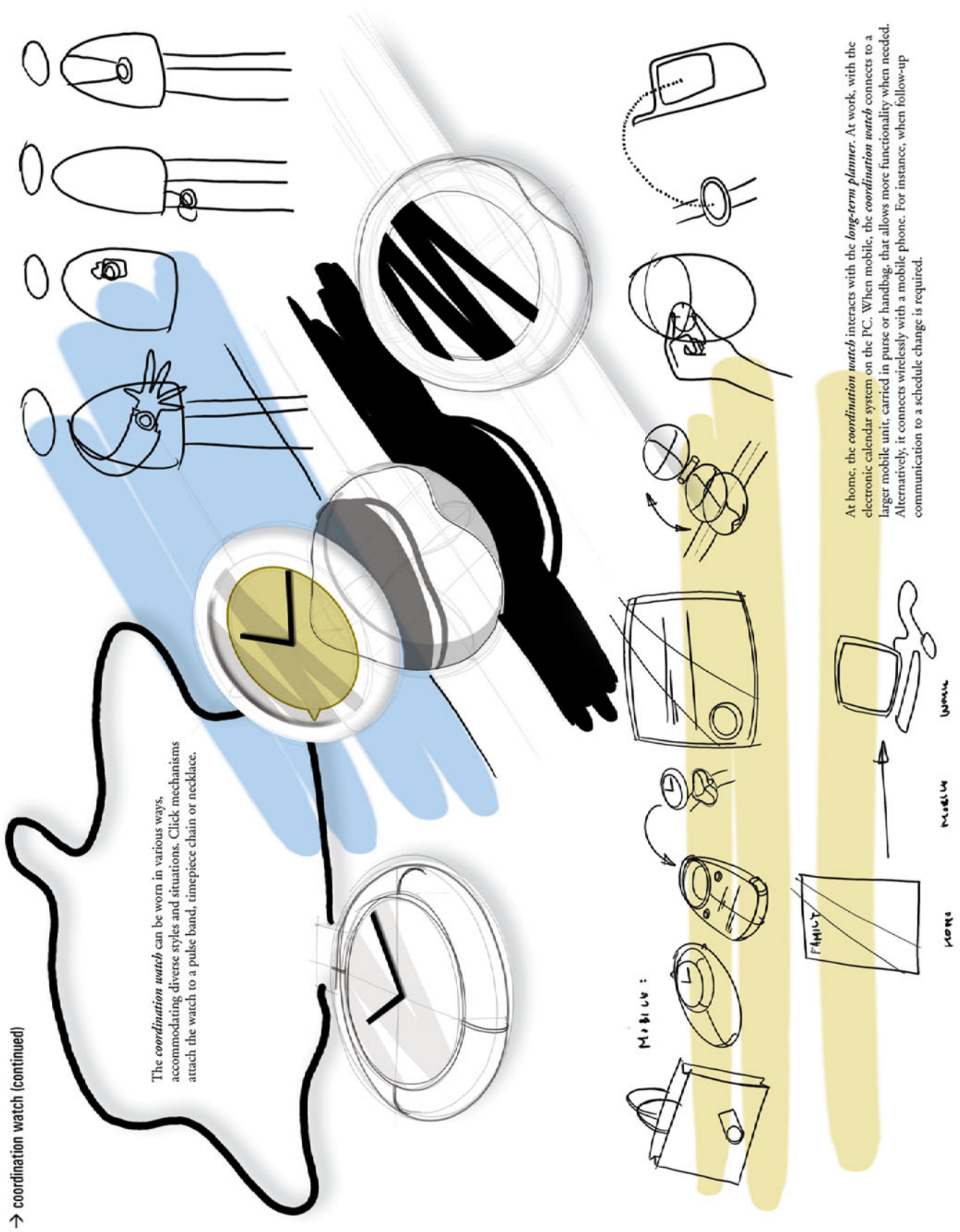
The *coordination watch* can be worn in various ways, accommodating diverse styles and situations. Click mechanisms attach the watch to a pulse band, timepiece chain or necklace.

At home, the *coordination watch* interacts with the *long-term planner*. At work, with the electronic calendar system on the PC. When mobile, the *coordination watch* connects to a larger mobile unit, carried in purse or handbag, that allows more functionality when needed. Alternatively, it connects wirelessly with a mobile phone. For instance, when follow-up communication to a schedule change is required.

Figure 16 Design direction: coordination watch (continued)

The *long-term planner* is inspired by the difficulties of balancing conflicting schedules when making long-term planning. The analogy with a strategic game as chess is made in the exploration of this process.

The detachable parts of the *coordination watches* form the "personal pawns" on a flat dynamic calendar surface. The devices communicate wirelessly over either 8012.11 or Bluetooth.
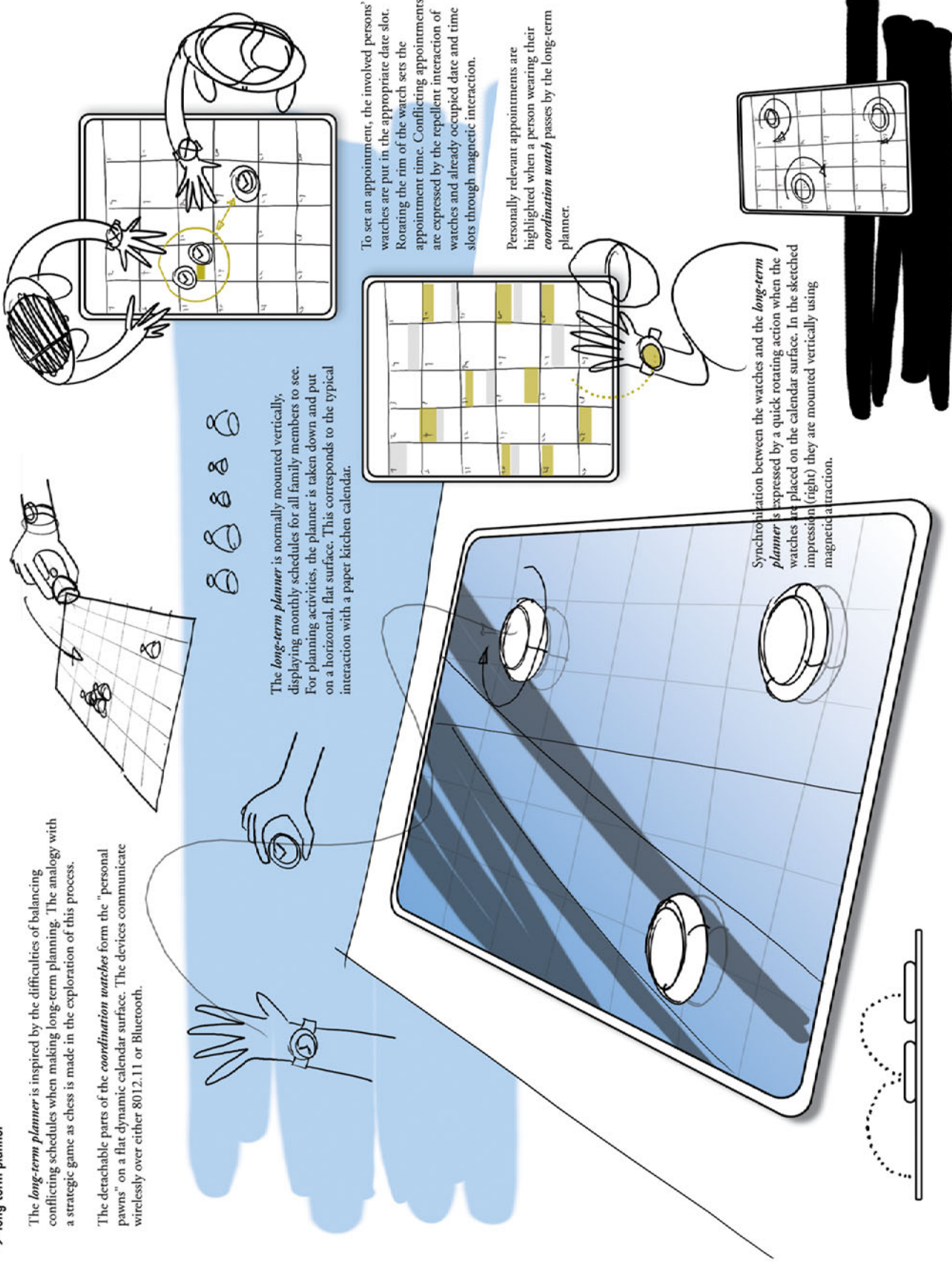
The *long-term planner* is normally mounted vertically, displaying monthly schedules for all family members to see. For planning activities, the planner is taken down and put on a horizontal, flat surface. This corresponds to the typical interaction with a paper kitchen calendar.

To set an appointment, the involved persons' watches are put in the appropriate date slot. Rotating the rim of the watch sets the appointment time. Conflicting appointments are expressed by the repellent interaction of watches and already occupied date and time slots through magnetic interaction.

Personally relevant appointments are highlighted when a person wearing their *coordination watch* passes by the long-term planner.

Synchronization between the watches and the *long-term planner* is expressed by a quick rotating action when the watches are placed on the calendar surface. In the sketched impression (right) they are mounted vertically using magnetic attraction.

Figure 17 Design direction: long-term planner

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→ awareness kitchen clocks

Changes in appointments are articulated by the rotating clock rim and an animated dial update. This corresponds to the action taken on the *coordination watch.*

Kitchen clocks for each family member display their schedule and appointments.

Appointments are represented graphically. In the sketched situation, mom is picking up her daughter from school, as is articulated in the corresponding appointments on their clocks. Dad's clock shows his schedule for the second half of the day using the twelve hours on the clock dial. Their son has soccer practice in ten minutes.

The *awareness kitchen clock* consists of traditional, analogue time hands superimposed on a TFT display dial that is dynamically updated.

There are two views:
- An overview of half a day of appointments
- A view on the current or next appointment

Pulling the cord attached at the bottom of the clock, switches between the views.

Figure 18 Design direction: awareness kitchen clocks

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Appointment pebbles are physical reminders of important appointments that a person can carry with them. The pebble shape refers to wear that is a result from friction.

The tangible aspects of friction are materialized in this calendar where setting appointments involves pushing down "person pawns" in the appropriate timeslot nubbin on the calendar surface.

An interpretation of the concept of constrained and non-constrained motion is used to make the rigidity of appointments tangible. Appointments can be moved within certain limits. For example: a scheduled time to go shopping can only be moved within the opening hours of the shops. Other constraints include the number of persons involved and their schedules.

Pinned down or padlocked appointments cannot be rescheduled at all.

This sweater with calendar is an attempt at removing friction from the activity of scheduling. Wearing your schedule on your sweater allows persons instant access to your availability and gives them the ability to see how you are keeping your schedule.
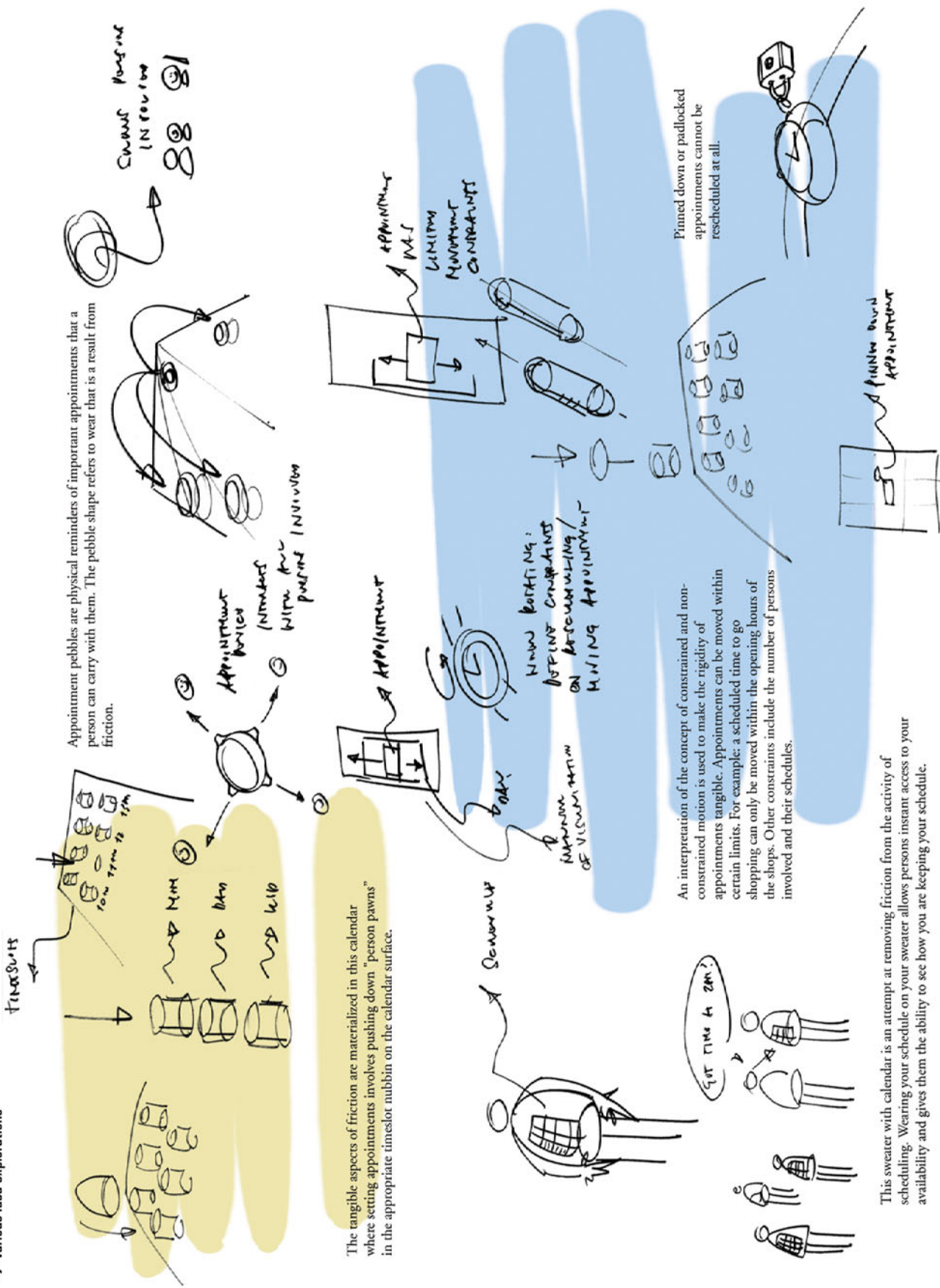
Figure 19 Various un-clustered design directions

**Refining the design**
Now that I have established a focus on the design directions presented by the long-term planner and the coordination watch, it is time to explore the interaction between these devices and their tailored functionality further. In these detailed investigations, the threads in the design continue to be the rich picture of scheduling and coordination activities from the user studies (summarized in section 5.4), the focus points provided by friction metaphor (section 5.5) and the goal to express and make explicit these insights through design.

*Scheduling a new appointment: appointment expression*
Figure 17 already proposed one way to express the friction that occurs in the process of scheduling a new event on the long-term planner. To chart alternate meaningful interactions in this process, I first need to look into the building blocks of schedules: appointments. I need to look into different visualizations and expression of appointments. I need to explore new ways of visualizing and expressing shared events. Only then, it is possible to start exploring ways of interacting with these appointments, adjusting them and scheduling new ones.

In this process, the focus is on the unique defining characteristics of appointments in the context of families with working parents. Firstly, I want to express the entangled nature of schedules of family members, through shared appointments on the one hand and clashes, problems and conflicts in schedules on the other (section 5.5). In addition, I want to express the routine building blocks that form the basis of schedules of families with working parents, with special consideration for non-obvious routines, changing routines and distant and special events (section 5.4). These issues provide guidance in the process of investigating appointment expression as described in figures 20 to 23.

*Scheduling a new appointment: interaction design*
Taking the visualizations of appointments from figures 20 to 23 as a starting point, figures 24 to 27 present three different interaction designs in the usage situation of scheduling a new event. In these interaction designs, the goal is to express the friction in this process, the prioritization and negotiation that occurs when adjusting routines and when fitting in a new appointment (section 5.5).

To guide these interaction designs, I introduce scenarios with a fictional family in various situations. The family Lundegaard is a family with working parents consisting of mom and dad Lundegaard, their son Pip and their daughter Stella. Different usage situations of this family based on the user studies (chapter 4), form concrete starting points for design. The scenarios of scheduling various kinds of appointments lead to the different designs proposed in figures 24 to 27.

Evaluating these designs on the previously established focus points, the first interaction design (figures 24 and 25) expresses the difficulties of fitting a new appointment in old routines through individual haptics. Haptic experiences express the rigidity of appointments and accordingly augment the negotiation process. Furthermore, this design provides expressive interaction in connecting personal pawns to set an appointment between persons. In addition, literally feeling holes in a shared calendar is a good example of haptically expressing the interaction of schedules in a scenario where two people want to schedule time together and the time of this appointment is variable. However, the design does not express richly and fully the interaction of schedules of the individual family members in all scenarios.
The second design (figure 26) does express this interaction of schedules. In this design, persons move pawns towards one another to bridge clashes, problems and conflicts in schedules. Distances of motion give an indication of the size of conflicts. However, the abstract nature of this visualization presents the danger of making schedules hard to interpret.
This problem is solved in the third design (figure 27) in which the interaction of schedules is visualized in a personal and insightful way. Its basis is in the very mundane events that make up family routines, such as picking up and dropping off children.

Weighing these factors, the haptic expression of friction in the first design and the visualization of interaction of schedules in the third design provide the basis for the final refinement of the detailed visual and interaction design. Figures 28 to 31 present this refinement. Section 6.2 presents the full interaction design. This design expresses the interaction of schedules through visually shared appointments between family members, combined

### Pip

| Monday 9/12 | Tuesday 10/12 | Wednesday 11/12 | Thursday 12/12 | Friday 13/12 | Saturday 14/12 | Sunday 15/12 |
|---|---|---|---|---|---|---|
| 7-8 home<br>8.30-15.30 school<br>15.30-18 after school club<br>18.30-20 football | 7-8 home<br>8.30-15.30 school<br>15.30-18 after school club | 7-8 home<br>8.30-15.30 school<br>15.30-18 after school club<br>18.30-20 football | 7-8.30 home<br>9-x dentist<br>x-15.30 school<br>15.30-18 after school club | 7-8 home<br>8.30-15.30 school<br>15.30-18 after school club<br>19-20 guitar lesson | | 14-17 football |

### Stella

| Monday 9/12 | Tuesday 10/12 | Wednesday 11/12 | Thursday 12/1 | Friday 13/12 | Saturday 14/12 | Sunday 15/12 |
|---|---|---|---|---|---|---|
| 7-8 home<br>8.15-15.30 school<br>15.30-17.30 after school club | 7-8 home<br>8.15-15.30 school<br>15.30-17.30 after school club | 7-8 home<br>8.15-15.30 school<br>15.30 -17.30 after school club | 7-8 home<br>8.15-15.30 school<br>15.30-17.30 after school club<br>18.30-20 piano lesson | 7-8 home<br>8.15-15.30 school<br>15.30-17.30 after school club | 9-10 no swimming this week, teacher has a day off | |

### Dad

| Monday 9/12 | Tuesday 10/12 | Wednesday 11/12 | Thursday 12/1 | Friday 13/12 | Saturday 14/12 | Sunday 15/12 |
|---|---|---|---|---|---|---|
| 7-8 home<br>8.30 neighbors drop off Pip at school today<br>9-17.30 work<br>18 pick up Pip from after school club<br>18.30-20 Pip football | 7-8 home<br>8.30 drop off Pip at school via neighbors<br>9-17.30 work<br>18 pick up Pip from after school club | 7-8 home<br>8.30 neighbors drop off Pip at school today<br>9-18 work<br>18.30-19.30 gym<br>20 pick up Pip and friends from football (parents of friends bring today) | 7-8.30 home<br>9-x with Pip to dentist<br>x drop off Pip at school<br>x-17 work<br>17.30 pick up Stella from after school club<br>18.30-20 Stella piano | 7-8 home<br>8.30 drop off Pip at school via neighbors<br>9-17 work<br>17.30 pick up Stella from after school club<br>18.30-19.30 gym | | 14-17 Pip football |

### Mom

| Monday 9/12 | Tuesday 10/12 | Wednesday 11/12 | Thursday 12/1 | Friday 13/12 | Saturday 14/12 | Sunday 15/12 |
|---|---|---|---|---|---|---|
| 7-8 home<br>8.15 drop off Stella at school<br>8.30-18 work<br>17.30 friends pick up Stella from after school club today<br>19-20.30 yoga (bi-weekly) | 7-8 home<br>8.15 drop off Stella at school<br>8.30-17 work<br>17.30 pick up Stella from after school club | 7-8 home<br>8.15 drop off Stella at school<br>8.30-17 work<br>17.30 pick up Stella from after school club<br>19-20.30 yoga | 7-8 home<br>8.15 drop off Stella at school<br>8.30-17.30 work<br>18 pick up Pip from after school club | 7-8 home<br>8.15 drop off Stella at school<br>8.30-17 work<br>18 pick up Pip from after school club<br>19-20 Pip guitar lesson | 9-10 no swimming with Stella this week, teacher has a day off | |

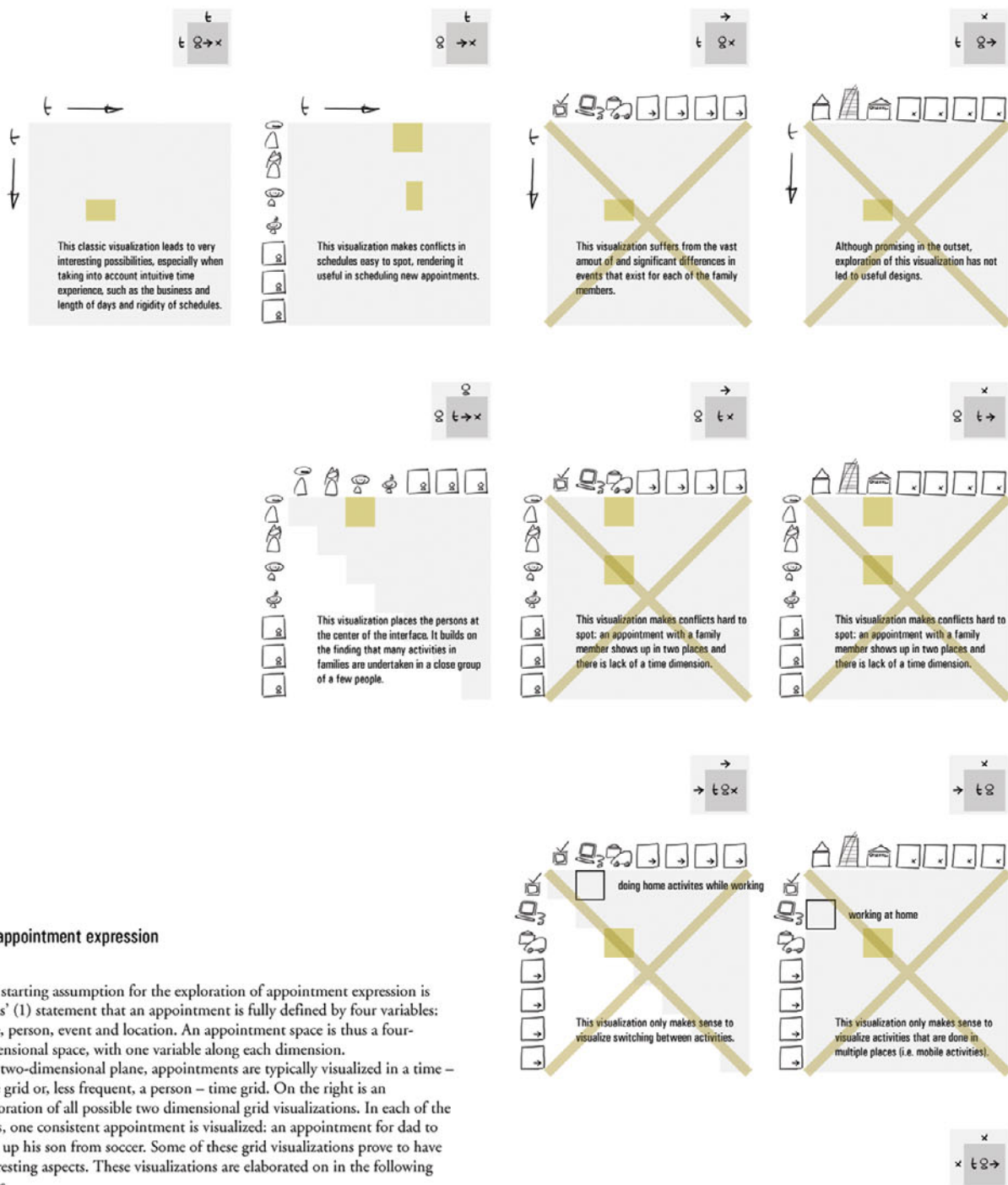Table 5 Weekly schedules of the fictional family Lundegaard

with clear expressions of shared transport, an important activity in families with working parents. It expresses routines through visualizing appointments as routine building blocks that recur throughout the week.

A shared family schedule of the fictional family Lundegaard constructed from data on 28 days from 28 working parents gathered in the first interview study (section 4.1), forms the basis in the refinement process of appointment expression. Table 5 presents this family schedule. This schedule captures the characteristics of family schedules identified in the user studies and literature review (chapter 5). It incorporates changing routines in the varying work hours of the parents, special events in the dentist appointment of Pip on Thursday, important events such as Stella's piano lesson, and many occurrences of shared transport, both within the family and with the aid of friends and neighbors. Furthermore, the schedules overall have a large number of activities. Finally, the children's schedules influence their parents' schedules heavily.

*Scheduling a new appointment: use study*
The final schedule visualizations used in the long-term planner are unconventional (figures 28 to 31). A small use study gives clues to their understandability and expressiveness and suggests directions for further refinement. It is important to note that the below results from this study are preliminary and testing with a larger sample is recommended to get a better feel for their relevance.

The study leads to believe that the schedule representations are comprehensive. However, people do have to get used to the representations, they learn to interpret the schedules by using them. Furthermore, subjects are able to interpret the routine building blocks that make up the schedules of the family. They interpret the lines between the building blocks as providing order information on their occurrence and would like to see more order information in this, arrowheads were suggested by more than one subject. Subjects are able to interpret the interaction of schedules. They can see who is involved in each appointment through the colors or the text. The same is true for shared transport, although the expression of shared transport through the varying width of lines is not clear to any of the subjects without explanation. Even without the pawns indicating family members (as explained in figure 38) the visualizations provide the right information to schedule new events. Finally, the design is more sequential in nature than expected. Faded routines are used less than expected. Subjects tend to use the design by sequentially browsing through the days.

This classic visualization leads to very interesting possibilities, especially when taking into account intuitive time experience, such as the business and length of days and rigidity of schedules.

This visualization makes conflicts in schedules easy to spot, rendering it useful in scheduling new appointments.

This visualization suffers from the vast amout of and significant differences in events that exist for each of the family members.

Although promising in the outset, exploration of this visualization has not led to useful designs.

This visualization places the persons at the center of the interface. It builds on the finding that many activities in families are undertaken in a close group of a few people.

This visualization makes conflicts hard to spot: an appointment with a family member shows up in two places and there is lack of a time dimension.

This visualization makes conflicts hard to spot: an appointment with a family member shows up in two places and there is lack of a time dimension.

doing home activites while working

This visualization only makes sense to visualize switching between activities.

working at home

This visualization only makes sense to visualize activities that are done in multiple places (i.e. mobile activities).

This visualization provides very interesting and new opportunities, especially in scheduling appointments.

## → appointment expression

The starting assumption for the exploration of appointment expression is Frens' (1) statement that an appointment is fully defined by four variables: time, person, event and location. An appointment space is thus a four-dimensional space, with one variable along each dimension.
In a two-dimensional plane, appointments are typically visualized in a time – time grid or, less frequent, a person – time grid. On the right is an exploration of all possible two dimensional grid visualizations. In each of the grids, one consistent appointment is visualized: an appointment for dad to pick up his son from soccer. Some of these grid visualizations prove to have interesting aspects. These visualizations are elaborated on in the following pages.

1 Frens, J.W. (1999). The design of a portable appointment manager which considers content and emotional value of appointments. Master's Thesis, Delft University of Technology, the Netherlands.

ŧ – time
Ȣ – person
→ – event
× – location
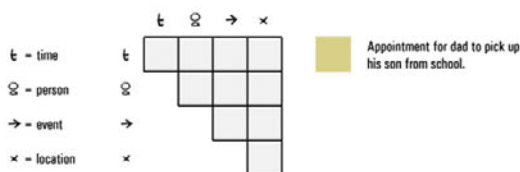
Appointment for dad to pick up his son from school.

Figure 20 Exploration of appointment expression

→ **appointment expression**

This time expression is based on "routine building blocks", i.e. a small set of recurring activities (e.g. "work", "pick up son"). The emphasis in this visualization is on the activities. The rigid framework of time is de-emphasized. Family members can change their routine building blocks locally, adapting to changing realities. This corresponds to behavior observed in the interview study.

The visual layers in the week view represent routines (in this instance blue) and special events (yellow).

Dark areas of compressed time represent nights. Nights identify the beginning and ending of days. Nights provide an indication for the length of the day. This is an important intuitive measure to indicate how tiring the day is. Working parents often mentioned making long days and feeling tired.

Weekends are separated from working weeks, indicating the subjective perceived difference between the two.

Input of home and work hours is done through transitional awareness.

Weekends are less busy with appointments, separating them visually form the working week. Extended representations of the nights indicate the fact that the family tends to sleep in on the weekends.

The size and saturation of days in the year view represent their business.
Yellow areas represent infrequent and special events, such as weddings and birthdays.

Visually layered schedules of family members provide a way to spot conflicts in schedules.

zoomed out in time

zoomed in in time

By gesturing left to right the user zooms out and in on time. Zooming changes the character of the time expression. When zooming in, the focus is on routines. When zooming out the focus shifts to distant and special events.

Using a different color scheme emphasizes special events like this one. Rigidity of the appointment (due to uncertainties, constraints and dependencies) is expressed by fading out the appointment in time. In this instance, the plumber might come at 8 and leave at noon or he arrives at 9 and leaves at 11.

Panning in time is continuous and smooth, like moving a large sheet of paper under a passe-partout.
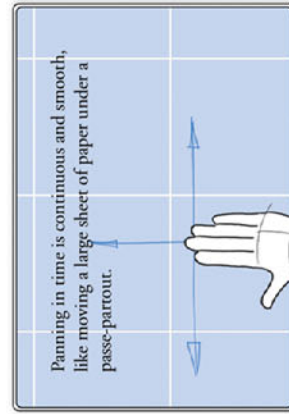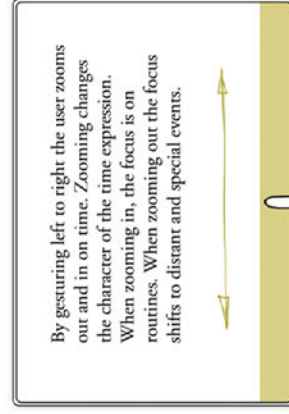
Times and descriptions of appointments are visually included in the appointments. There is no backdrop of time. The combined appointments make up time. This de-emphasizes the rigid framework of time.
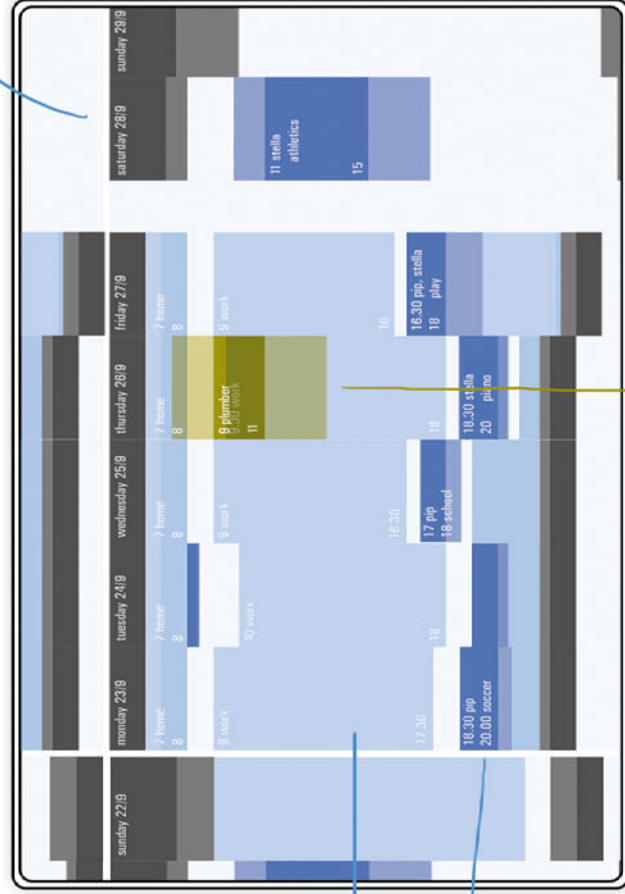
Appointments that family members perceive as being more important, such as this soccer appointment between dad and Pip, are represented by more saturated shades.

This soccer appointment has a fixed and rigid starting time: Pip cannot be late for the start of soccer practice. The ending is less rigid, represented by fading in time: dad and Pip always hang around for a while after the soccer practice has ended.

Figure 21 Exploration of appointment expression

→ **appointment expression**  This visualization is based on time streams of the members of the family. Visualizing personal schedules along a shared time axis makes conflicts in schedules easy to spot when doing scheduling activities.
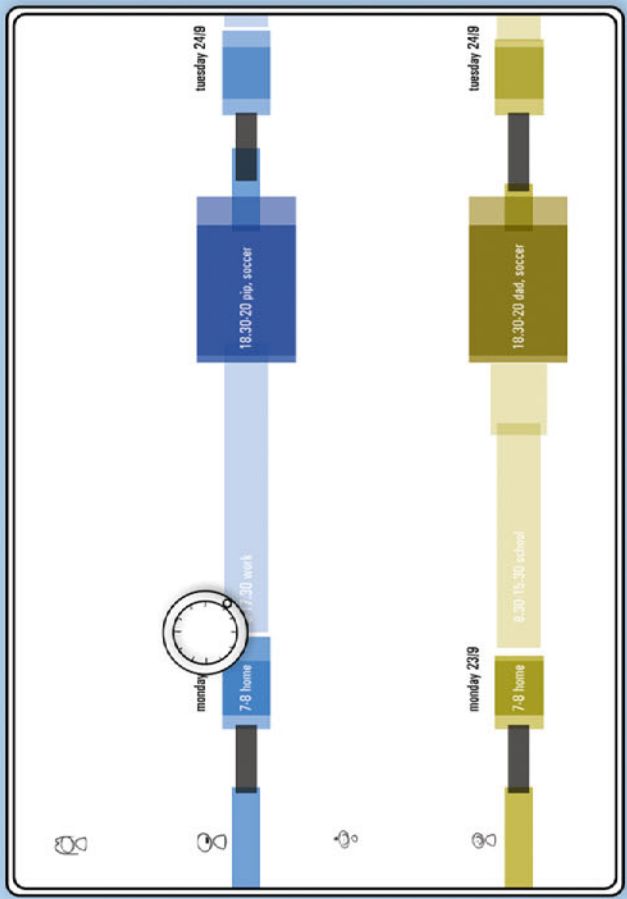
*Size (height) and color of appointments allows users to differentiate between appointments. In individual perceived importance for instance. A dad might want to let the soccer practice of his son stand out.*
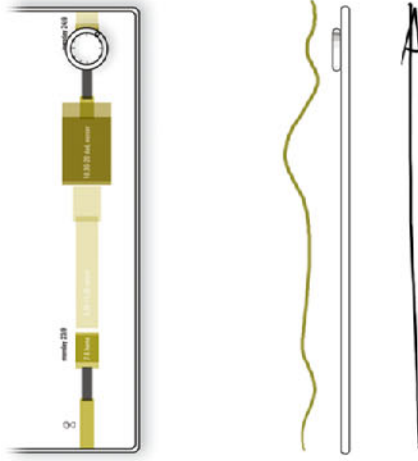
Moving the personal pawn over a time stream allows users to feel their appointments. Force feedback through magnets provides tangible information on the business of periods. The pawn is slightly detained at busy times, resulting in the feeling of a lag.

This mechanism is especially suitable for tactile time navigation: the user feels the business of periods.
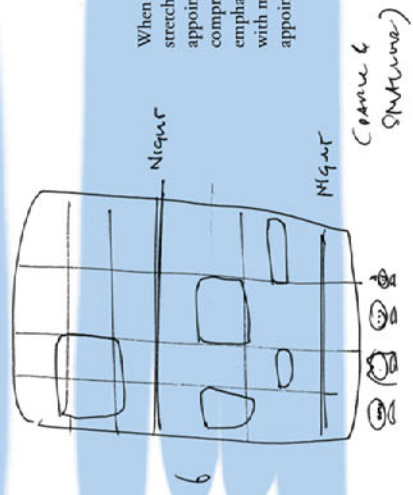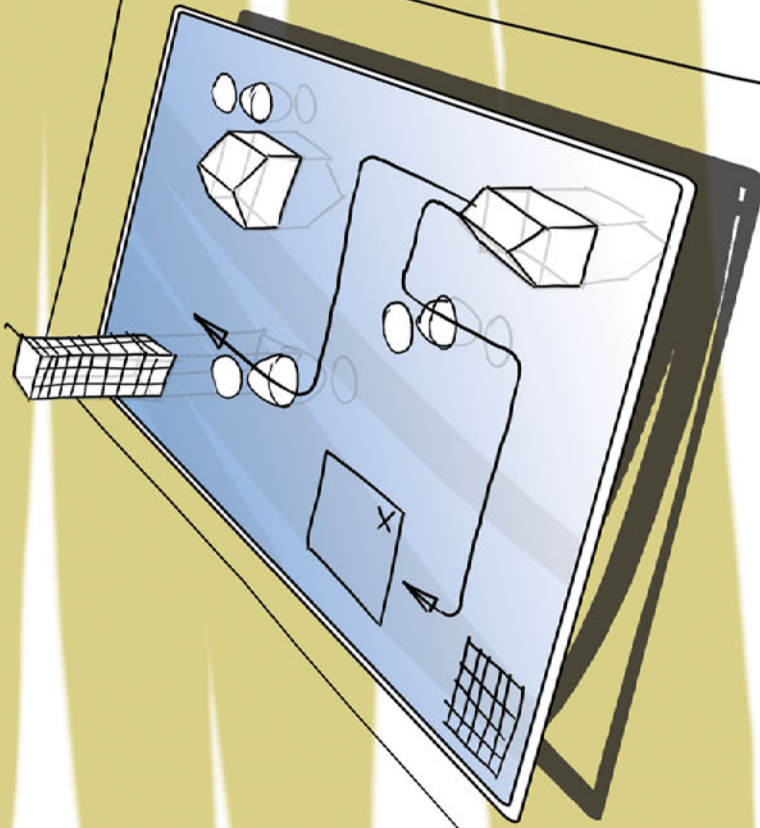
When *inspecting* daily schedules, stretches of time with low appointment density, like nights, are compressed. When *scheduling*, the emphasis flips: low-density areas, with many opportunities for new appointments, are expanded.

Figure 22 Exploration of appointment expression

This expression of appointments starts from the finding that working parents typically visit a limited number of places during the day. Therefore, these locations can be represented by a limited set of images or even tangible objects on the surface of the long-term planner.

In this design, physical elements on the surface of the long-term planner represent often-frequented places. Places that members of the family visit only once or very infrequently are represented graphically. Personal pawns represent family members. Cycling through time will move the personal pawns from place to place. In effect, this is a visualization of daily cycles.

Movement of the physical objects is achieved through electromagnetism.

The surface of the long-term planner changes throughout the day. Pawns will move in real time from location to location.
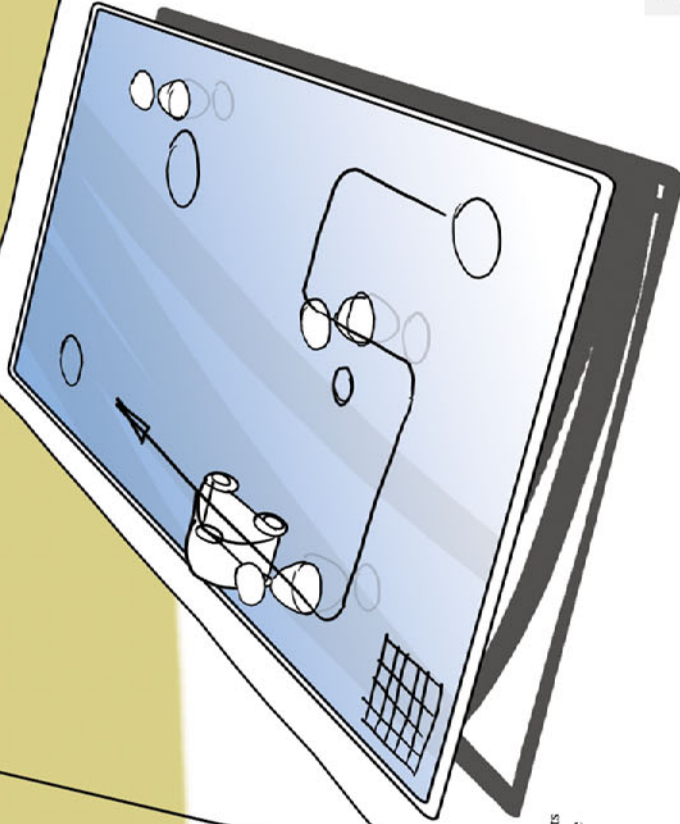
In this set up (right), the location of the car during the day is added to the visualization. This builds on the finding that many family appointments revolve around transporting children from place to place. It helps in clearly making explicit the availability of the car. Typically a crucial resource in scheduling activities.

The tangible character of this representation invites the user to manipulate items. To schedule appointments by moving objects. It encourages shared interaction. Specific scheduling activities with this visualization are explored further on.

Figure 23 Exploration of appointment expression

64

Scheduling new appointments and activities within the family is a shared activity with co-located family members present. Interviewed families typically do long-term family scheduling in a home setting and on a weekly basis. In the sketched scenario, it is Sunday early in the afternoon. After lunch, mom and dad Lundegaard sit down in the kitchen to schedule the new ballet class their daughter Stella will be taking this term. Stella and Pip are playing in the lounge. Mom and dad take down the long-term planner from the wall and put it on the kitchen table.

**1**

The family starts scheduling the new ballet class by putting their coordination watches on the surface of the long-term planner. The watches represent the individual family members. Placing the watches specifies the start of a scheduling activity. The coordination watches are synchronized with the long-term planner. A quick rotation of the watches when making contact with its surface visualizes this continuous synchronization and link between the devices. The long-term planner displays the schedules of every person that has placed their watch on its surface.

**2**
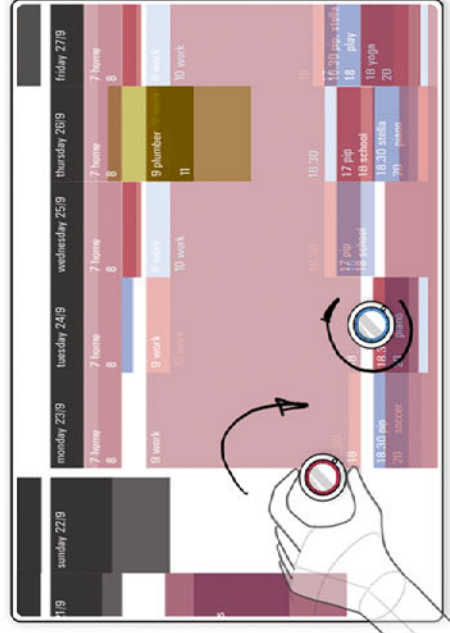
Adding a pawn changes the landscape of schedules. The display updates dynamically with each watch placed.

Moving the pawns to the time slot for the ballet class, several conflicts show up. Stella's Dad will play soccer with Pip that day. Also, mom will be working during part of Stella's ballet class. In the busy lives of these working parents, there is some friction of fitting the new activity into the old routines.

**3**
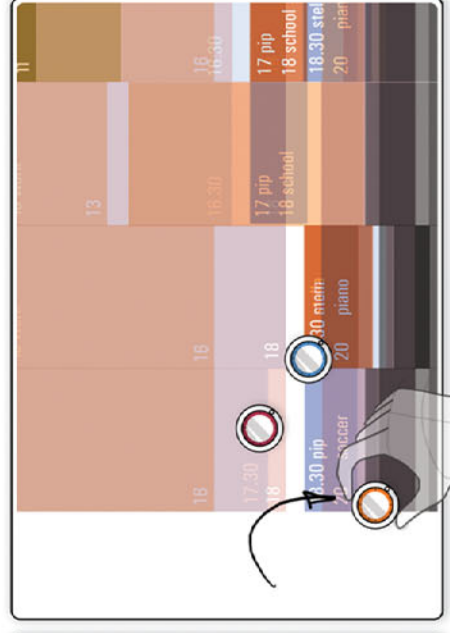
Dad feels his appointment with Pip is more important and rigid that mom's working hours. Haptic feedback in his pawn expresses this. After discussion and negotiation, the family decides that mom will adjust her working hours to accommodate Stella's new ballet classes.

Dad removes his watch from the surface. His schedule is no longer displayed. Stella sets the appointment by connecting her watch with her mom's watch. This is a gestural expression signifying the fact that they will do an activity together. Through these interactions, the persons and the time of the appointment are set.
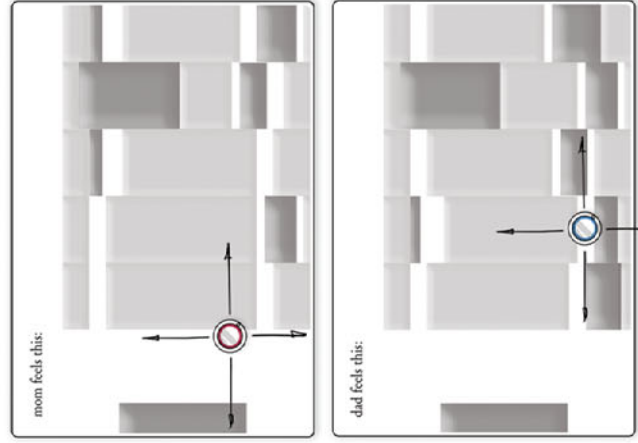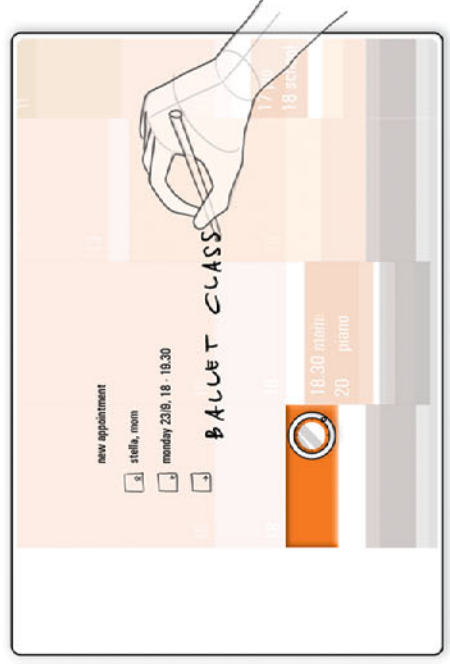
**4**
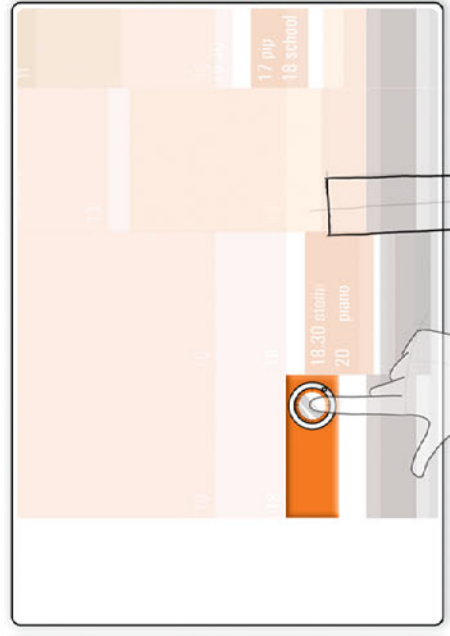
In the final step, mom enters further details by writing on the planner's surface.

The appointment is now fully set in the long-term planner. It is also part of Stella's and mom's watches. Stella and mom take away their watches and can make small adjustments to this appointment through their mobile coordination watch. When the ballet class runs late for example.
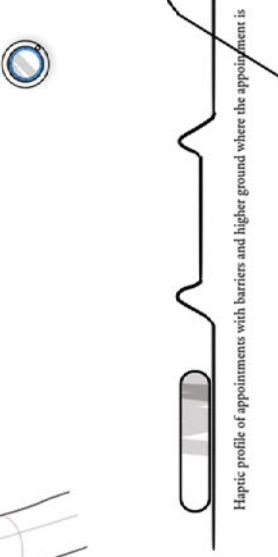
new appointment
stella, mom
monday 23/9, 18 - 19.30
BALLET CLASS

The friction in fitting a new activity in old routines is ideally made tangible by a detailed haptic experience. The analogy with friction in machinery provides the basis for this experience. In machinery, material adjusts or accommodates itself to reduce friction where some misalignment between parts exists.
In this interaction model, this means that adjusting schedules to fit in a new appointment requires force. This adjustment of routines is expressed by haptic feedback. The user moves their pawn through a haptic barrier to set a new appointment in an already occupied spot.

Haptic profile of appointments with barriers and higher ground where the appointment is

Each individual watch, or pawn, "feels" their appointments on the surface of the long-term planner. This is achieved through haptic feedback similar to a haptic computer mouse or game controller.

The shared visual space thus coexists with an individual and simultaneous haptic space. The visual space provides an overview in time, the haptic space orders this space for each individual. Furthermore, it expresses difficulties in the process of scheduling and provides a very direct experience of interaction. The visual and haptic space complement one another.
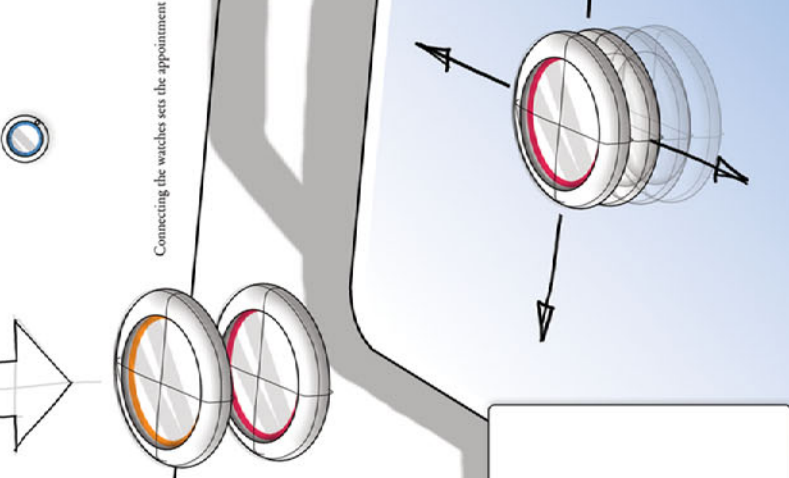
Hills represent occupied spots in schedules. These vary in perceived height to represent individual importance and rigidity of appointments.

mom feels this:

dad feels this:

Connecting the watches sets the appointment

In a different scenario, mom and dad plan to schedule some time together. This is a different kind of appointment than before. In this appointment the people involved are the crucial and defining factor. Mom and dad connect their watches to signify that they want to schedule an activity together. They move the combined watch over the calendar surface to find holes in their shared planning, time slots that they are both available. Haptic feedback provides them with the ability to feel these holes; the visual display provides an overview in time.

Combining watches of other persons, such as mom and Stella, changes the haptic landscape to continue to show the holes in the shared planning of these persons.

After finding the hole in the shared planning, the interactions for setting a new appointment are the same as the interactions described above.

mom and dad feel this:

sunday 22/9   monday 23/9   tuesday 24/9   wednesday 25/9   thursday 26/9   friday 27/9
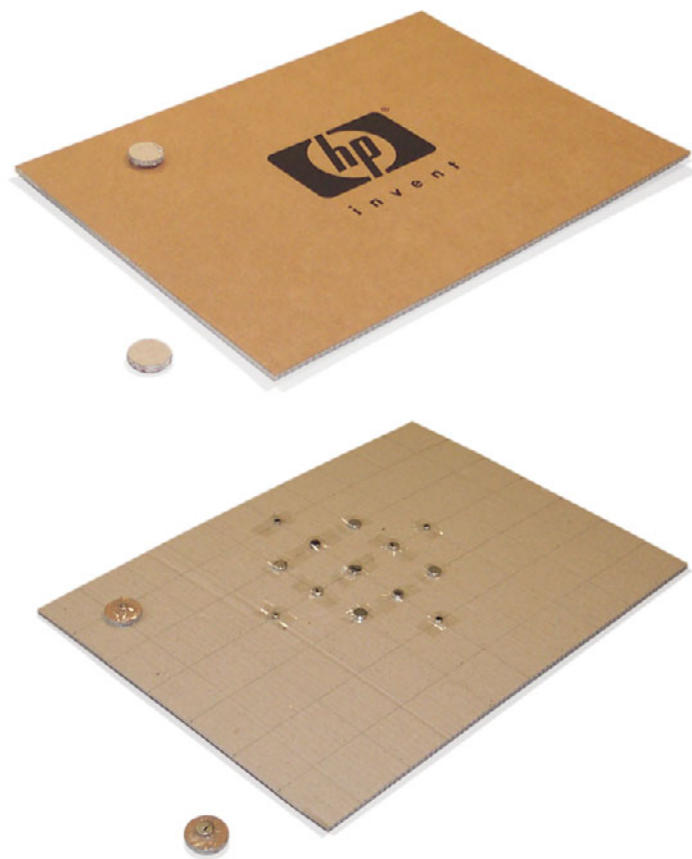
Figure 24 Exploration of interaction design when scheduling a new event

Figure 25 Tangible exploration of interaction design when scheduling a new event

This design presents a different expression and interaction in the scenario of scheduling a new ballet class for Stella. It uses a multi-dimensional scaling method to express the clashes, conflicts and problems in the interactions of the schedules of the individual family members. It also uses the expressive tactile interactions of placing pawns together and moving them towards one another to resolve conflicts.
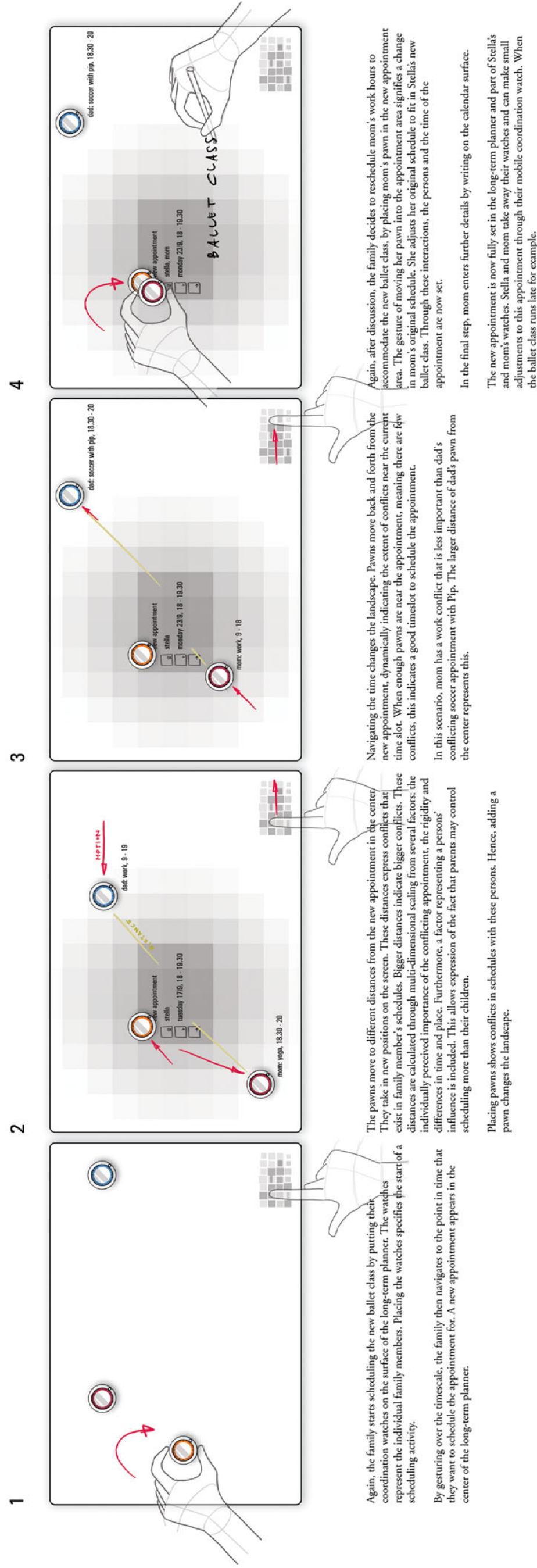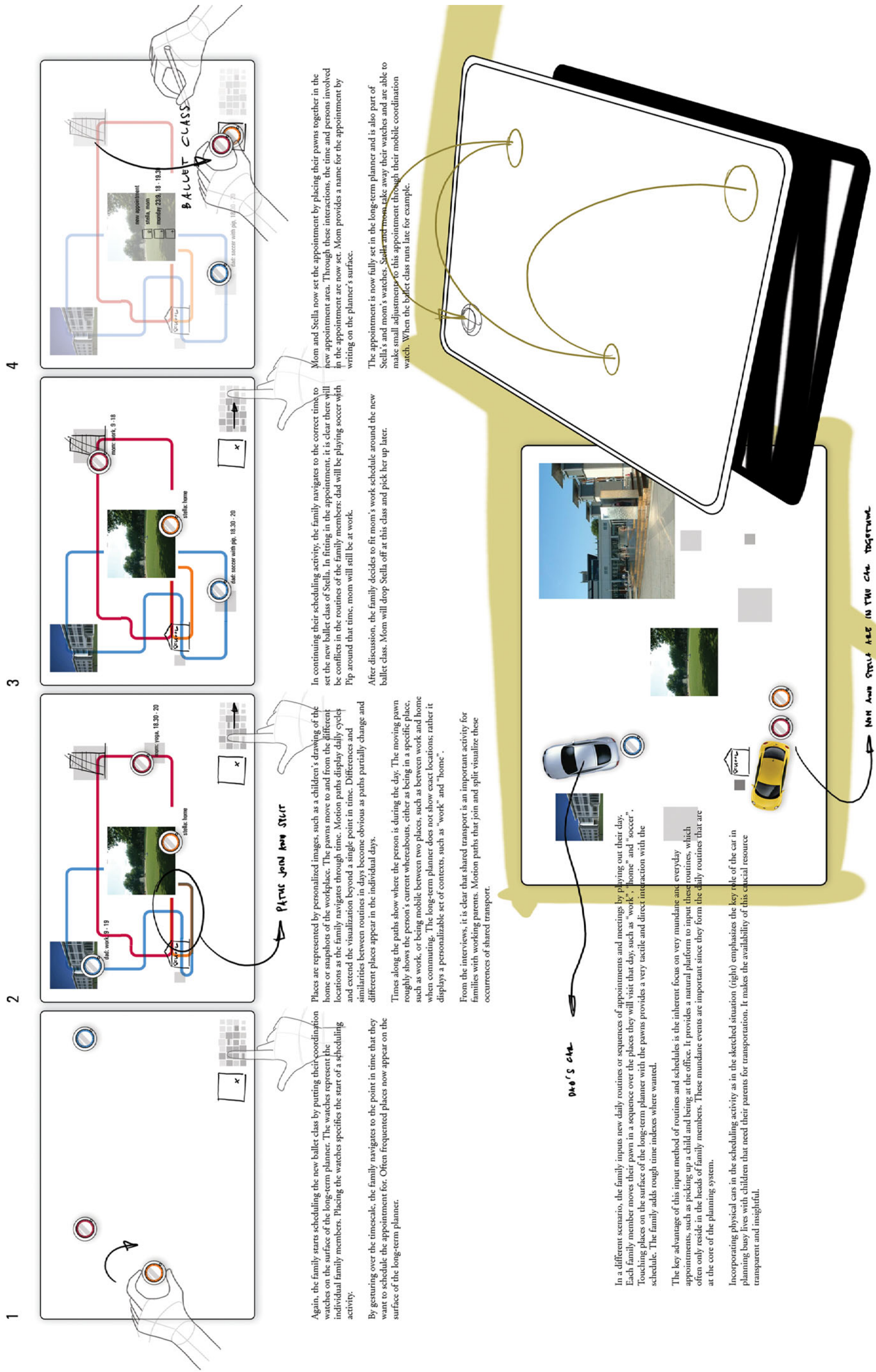
**1**

Again, the family starts scheduling the new ballet class by putting their coordination watches on the surface of the long-term planner. The watches represent the individual family members. Placing the watches specifies the start of a scheduling activity.

By gesturing over the timescale, the family then navigates to the point in time that they want to schedule the appointment for. A new appointment appears in the center of the long-term planner.

**2**

The pawns move to different distances from the new appointment in the center. They take in new positions on the screen. These distances express conflicts that exist in family member's schedules. Bigger distances indicate bigger conflicts. These distances are calculated through multi-dimensional scaling from several factors: the individually perceived importance of the conflicting appointment, the rigidity and differences in time and place. Furthermore, a factor representing a persons' influence is included. This allows expression of the fact that parents may control scheduling more than their children.

Placing pawns shows conflicts in schedules with these persons. Hence, adding a pawn changes the landscape.

**3**

Navigating the time changes the landscape. Pawns move back and forth from the new appointment, dynamically indicating the extent of conflicts near the current time slot. When enough pawns are near the appointment, meaning there are few conflicts, this indicates a good timeslot to schedule the appointment.

In this scenario, mom has a work conflict that is less important than dad's conflicting soccer appointment with Pip. The larger distance of dad's pawn from the center represents this.

**4**

Again, after discussion, the family decides to reschedule mom's work hours to accommodate the new ballet class, by placing mom's pawn in the new appointment area. The gesture of moving her pawn into the appointment area signifies a change in mom's original schedule. She adjusts her original schedule to fit in Stella's new ballet class. Through these interactions, the persons and the time of the appointment are now set.

In the final step, mom enters further details by writing on the calendar surface.

The new appointment is now fully set in the long-term planner and part of Stella's and mom's watches. Stella and mom take away their watches and can make small adjustments to this appointment through their mobile coordination watch. When the ballet class runs late for example.

Figure 26 Exploration of interaction design when scheduling a new event

**1   2   3   4**

Again, the family starts scheduling the new ballet class by putting their pawns together in the watches on the surface of the long-term planner. The watches represent the individual family members. Placing the watches specifies the start of a scheduling activity.

By gesturing over the timescale, the family navigates to the point in time that they want to schedule the appointment for. Often frequented places now appear on the surface of the long-term planner.

Places are represented by personalized images, such as a children's drawing of the home or snapshots of the workplace. The pawns move to and from the different locations as the family navigates through time. Motion paths display daily cycles and extend the visualization beyond a single point in time. Differences and similarities between routines in days become obvious as paths partially change and different places appear in the individual days.

Times along the paths show where the person is during the day. The moving pawn roughly shows the person's current whereabouts, either as being in a specific place, such as work, or being mobile between two places, such as between work and home when commuting. The long-term planner does not show exact locations; rather it displays a personalized set of contexts, such as "work" and "home".

From the interviews, it is clear that shared transport is an important activity for families with working parents. Motion paths that join and split visualize these occurrences of shared transport.

In continuing their scheduling activity, the family navigates to the correct time to set the new ballet class of Stella. In fitting in the appointment, it is clear there will be conflicts in the routines of the family members: dad will be playing soccer with Pip around that time, mom will still be at work.

After discussion, the family decides to fit mom's work schedule around the new ballet class. Mom will drop Stella off at this class and pick her up later.

Mom and Stella now set the appointment by placing their pawns together in the new appointment area. Through these interactions, the time and persons involved in the appointment are now set. Mom provides a name for the appointment by writing on the planner's surface.

The appointment is now fully set in the long-term planner and is also part of Stella's and mom's watches. Stella and mom take away their watches and are able to make small adjustments to this appointment through their mobile coordination watch. When the ballet class runs late for example.

In a different scenario, the family inputs new daily routines or sequences of appointments and meetings by playing out their day. Each family member moves their pawn in a sequence over the places they will visit that day, such as "work", "home" and "soccer". Touching places on the surface of the long-term planner with the pawns provides a very tactile and direct interaction with the schedule. The family adds rough time indexes where wanted.

The key advantage of this input method of routines and schedules is the inherent focus on very mundane and everyday appointments, such as picking up a child and being at the office. It provides a natural platform to input these routines, which often only reside in the heads of family members. These mundane events are important since they form the daily routines that are at the core of the planning system.

Incorporating physical cars in the scheduling activity as in the sketched situation (right) emphasizes the key role of the car in planning busy lives with children that need their parents for transportation. It makes the availability of this crucial resource transparent and insightful.

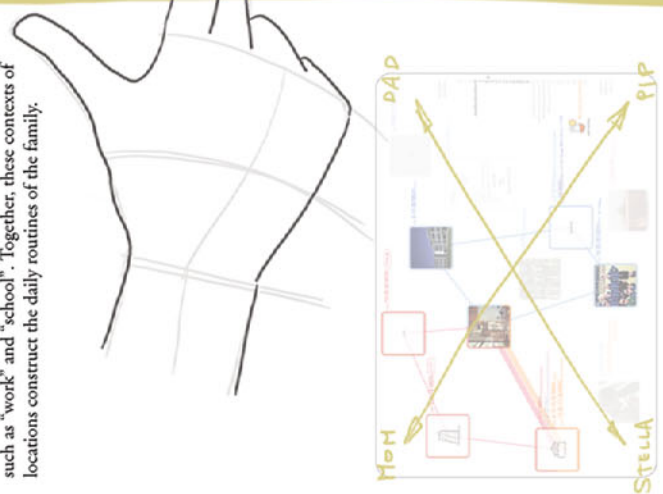Figure 27 Exploration of interaction design when scheduling a new event

These are detailed visualizations of the schedules of family members when scheduling a new event with the long-term planner.

The displayed schedules are constructed from 28 "day maps" of working parents that were collected in the first interview study. These day maps provide detailed hour-to-hour activity reports for 28 days of 28 working parents. The accumulated day maps were used as input for the schedules that are displayed, providing a plausible picture of schedules and showing that real schedules can comfortably be displayed on the long-term planner.

The constructed schedules cover one week for one family. In the displayed situation, the long-term planner shows the week with a focus on Monday. The following pages show the planner with its focus on Tuesday to Friday.

*Time navigation area*

The time navigation area extends the overview in time to months. It displays special events such as birthdays that are relevant on this timescale. Distant and special events can oftentimes set boundary conditions when scheduling. In addition, they sometimes affect and change routines. The time navigation shows global items, vacations, teacher workdays, and other items that impact a schedule in a major way. This area is used as a reference while working in the scheduling area.

In the displayed situation, Jane's birthday is next Thursday. This event is most relevant to Stella, expressed by the orange color of the event. Orange is Stella's color in the long-term planner.

This dentist appointment is also a special event. Since it occurs in the span of the current week, it is displayed in the scheduling area. It has a different size and shape than the normal routine building blocks, emphasizing its special nature.

By touching and gesturing over the time navigation, it dynamically expands and collapses. Smoothly switching from months to weeks to days to hours, allowing the user to navigate to the correct time for scheduling a new event.

In this situation, the family has navigated to Monday. They can move forward and backward by either navigating to the following or previous days or following or previous months.

The superimposed details of each appointment express the recurring of appointments. Darker text areas recur frequently. Recurring appointments form routines. Slight differences exist in these routines. These differences are visualized in the slight changes in text layers.

Where appointments have been input using handwriting, these written descriptions are displayed in the final appointment. This provides a rich platform for personal differentiation and emotional expression.

*Scheduling area*

The most prominent area on the surface of the long-term planner is the location based scheduling area. It shows contexts of locations that the family members frequent, such as "work" and "school". Together, these contexts of locations construct the daily routines of the family.
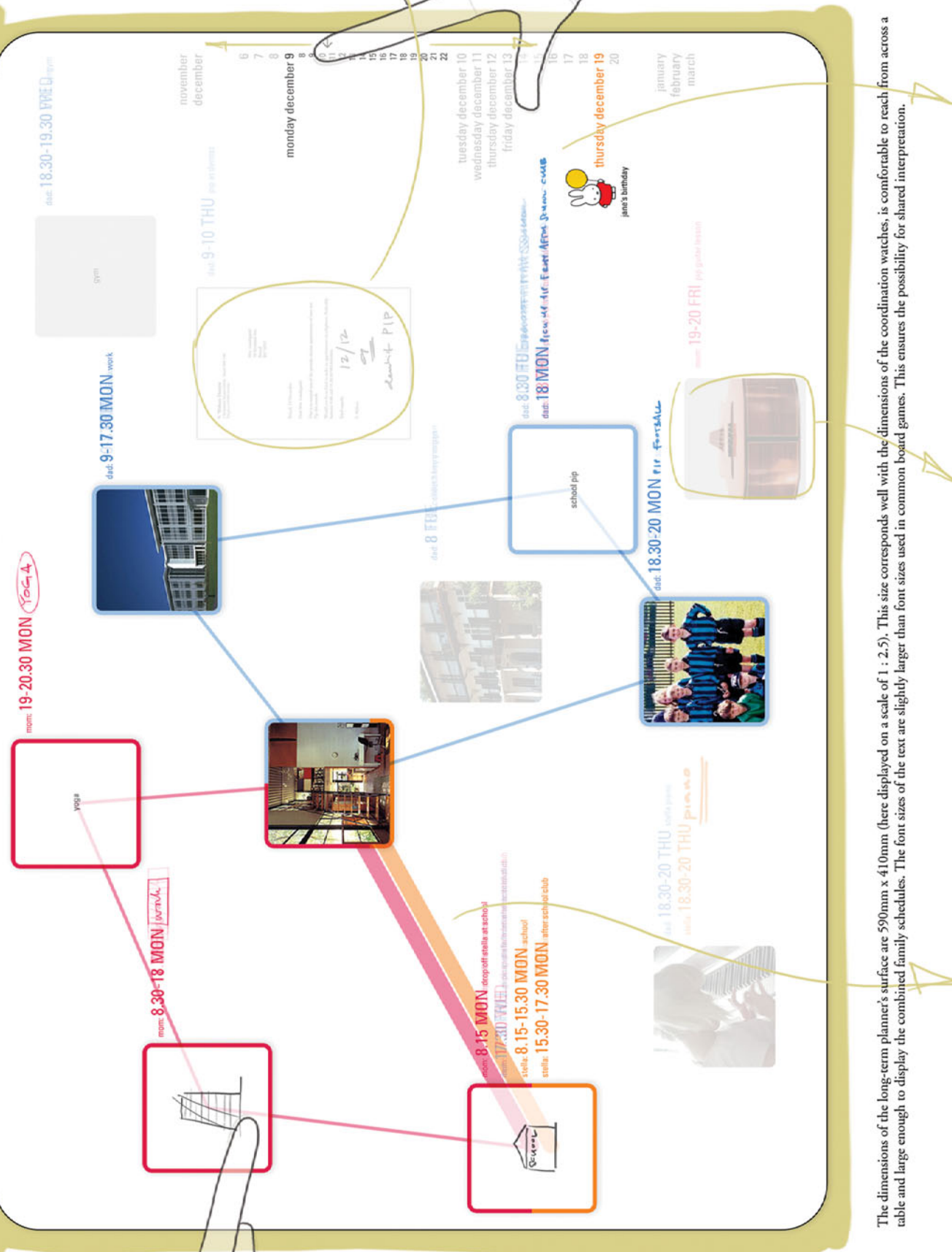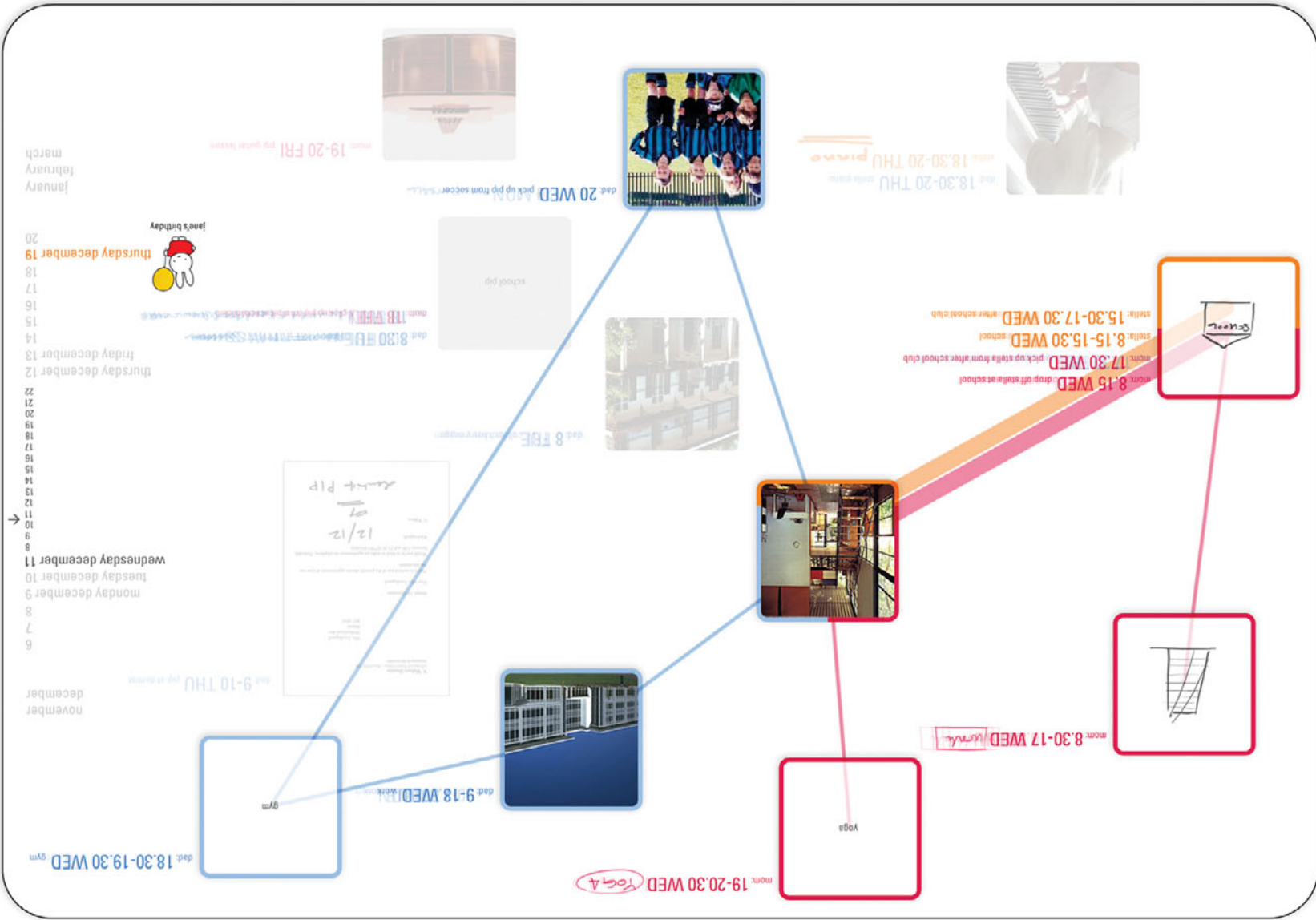
The appointments are loosely grouped in areas. Different colors represent different family members. Stella is represented by orange, dad by blue and mom by red. These correspond to the color schemes on the individual coordination watches. The appointments are loosely grouped in an area for each family member. These areas define a section of prime interest for each person participating in the scheduling activity. This setup invites the family to sit around the planner. Furthermore, the articulation of specific opposite areas visually expresses the negotiation that occurs during scheduling a new event, the "give and take", the compromises that sometimes need to be made; it expresses the process of finding a middle ground.

The appointment locations are not necessarily ordered geographically. They are not direct mappings of geographic locations. Rather, they are contexts of locations.

The families can structure their view of their schedules by touching and dragging these locations.

Grouped personal areas on the long-term planner

The dimensions of the long-term planner's surface are 590mm x 410mm (here displayed on a scale of 1 : 2.5). This size corresponds well with the dimensions of the coordination watches, is comfortable to reach from across a table and large enough to display the combined family schedules. The font sizes of the text are slightly larger than font sizes used in common board games. This ensures the possibility for shared interpretation.

Paths between the displayed locations have several functions. Firstly, they visually link a person's events for that day. Secondly, they provide order information for these routines; following the path is like walking through a person's day. Finally, the paths provide a way to emphasize the shared transport that occurs frequently in families. Using paths that are more prominent where schedules interact emphasizes the tight intertwined nature of the schedules of family members.

The paths do not represent exact geographic paths that the family members travel in the real world. Hence, persons do not necessarily meet when paths cross. The visualization of the paths as direct, straight lines that connect appointments expresses their conceptual character.

Experiments with different visualizations to express the ambiguous character of the paths are shown further on.

Faded out routines give clues to events on adjourning days. The current day view shows faded routines of days to come. Such as this guitar lesson that Pip has on Friday. Routines of adjourning days provide useful information when scheduling a new event. Additionally, touching the faded our routines provides for a very intuitive method of time navigation. Touching on a faded event brings up the next day when this event occurs.

Figure 28 Refinement of schedule visualization and interaction design when scheduling a new event

Weekly routines with a focus on Tuesday (shown on a scale of 1 : 2.5)

Figure 29 Refinement of schedule visualization and interaction design when scheduling a new event

Weekly routines with a focus on Thursday (shown on a scale of 1 : 2.5)

Weekly routines with a focus on Friday (shown on a scale of 1 : 2.5)

Figure 30 Refinement of schedule visualization and interaction design when scheduling a new event

# → scheduling visualization experiments

The visualization of routines and daily cycles can lead to ambiguous interpretations in a location oriented scheduling display. Below are experiments with different visualizations of daily cycles in which this ambiguity becomes clear and is resolved.



In this first design, colored frames represent the people involved in the displayed appointments in the visualization of a daily cycle. Times indicate the order of the appointments.
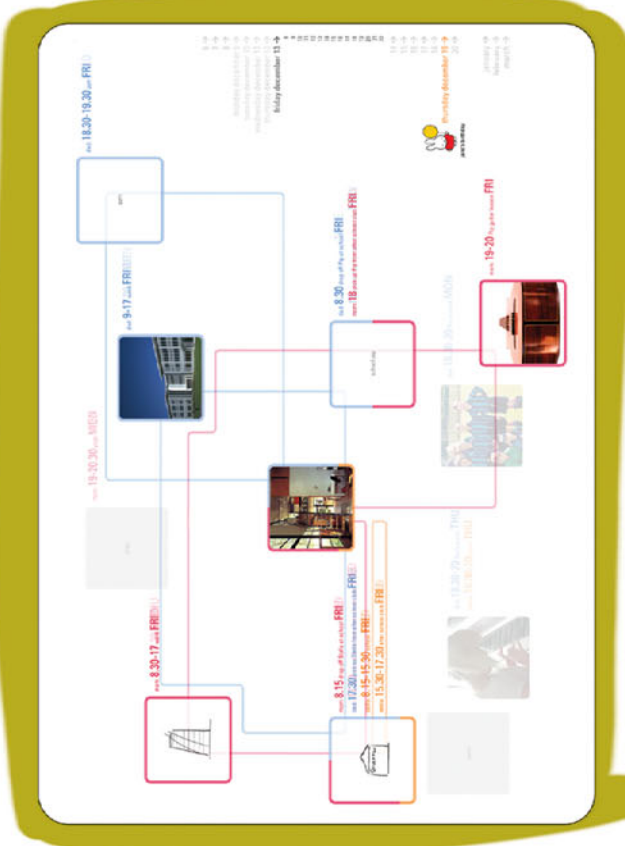
Introducing geometric lines between the appointments makes their relationships clearer and provides an improved expression of their sequential nature. However, visual similarities to paths traveled in the real world make the meaning of the paths ambiguous. Crossing lines can mistakenly be interpreted as meeting points of persons.
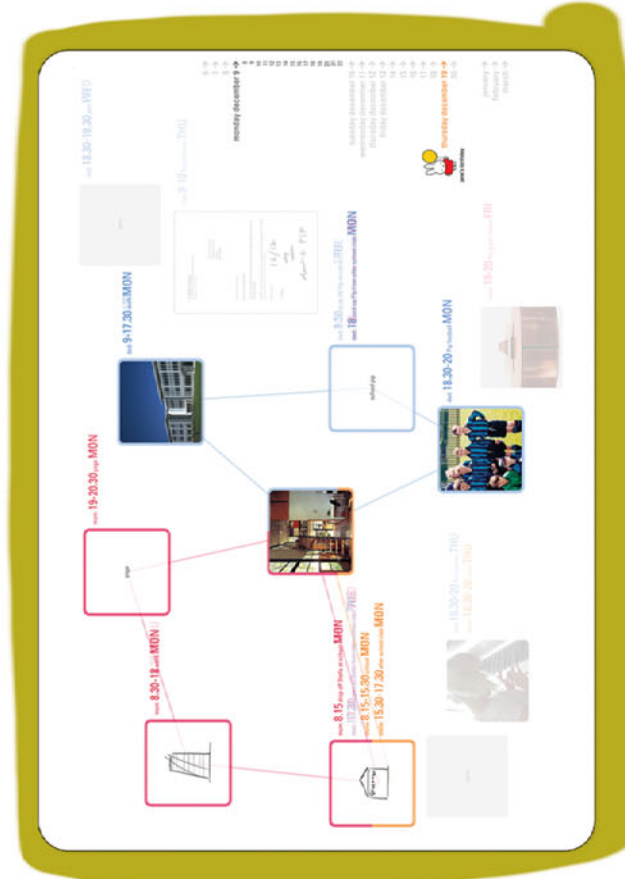
Replacing the geometric lines with these direct, straight lines maintains the positive relationship properties of the previous visualization while making the meaning of the paths less ambiguous. Visual similarities with paths traveled are far less explicit.
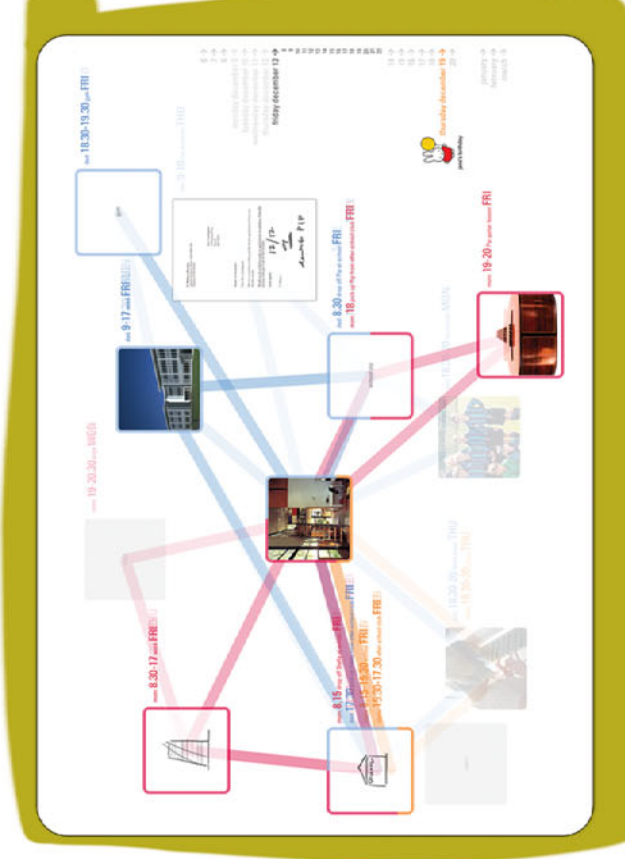
Building on the previous representation and visualizing not only the appointments of the whole week but also their relationships, provides an interesting image. However, the presence of many lines makes this image harder to read and interpret.
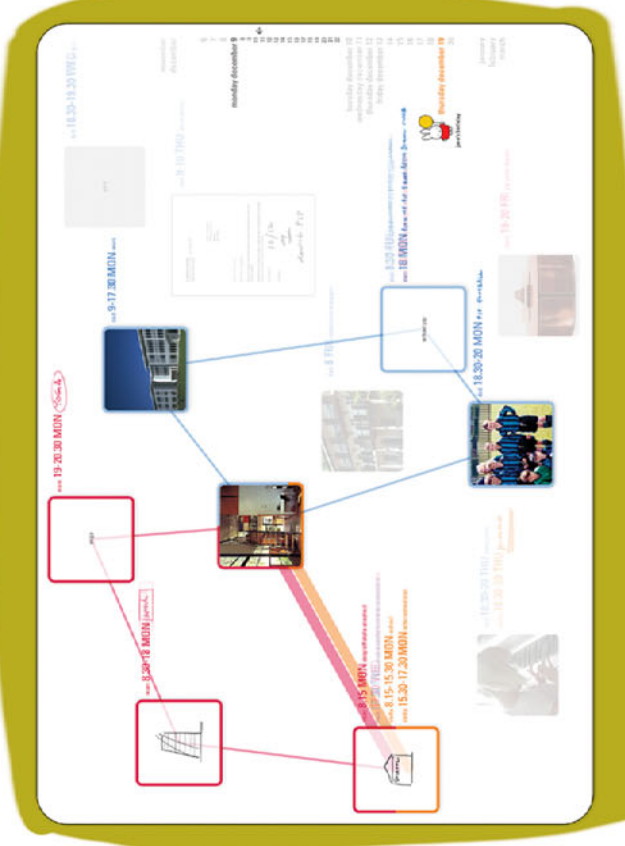
Extending the meaning of the paths to include shared transport, the final visualization uses direct lines with varying thickness between the appointments. Thicker paths are used when shared transport occurs. This emphasizes the entangled nature of the schedules of family members.

Figure 31 Refinement of schedule visualization and interaction design when scheduling a new event

*Staying synchronized in a changing reality*
The coordination watch interacts physically with the long-term planner when scheduling new events (figures 24 to 27 and section 6.2). In this interaction, it is a personal element to bring into the activity of shared planning. It physically and metaphorically represents the user and the things that they think are important in a process of negotiation and prioritization.

When mobile, the coordination watch represents the link with one's family. It caters for the usage situation of coordinating changes in a changing reality. Typically, these are low impact adjustments on previously established routines (section 5.4). Furthermore, it deals with the closely related concept of transitional awareness (section 5.1). These are both important issues when parents are physically mobile. These are the focus points when iterating on the design of the coordination watch as presented in figures 32 to 34.

One way of dealing with the concept of transitional awareness is to provide automatic location sensing. For instance, to provide parents with the exact location of their children. I will not pursue this reasoning. I will keep the family members in charge. They decide to make their schedules available to others in the family and to coordinate important changes. They are responsible for their communications.
Figure 32 presents a second way to approach transitional awareness. Although this solution deals exactly with the current behavior of families with working parents concerning transitional awareness, it provides limited opportunities for expressive interaction regarding changes to previously established routines.
The final design, presented in figures 33 and 34, explores this issue. Section 6.2 presents the full interaction design. In this design, family members have access to their own calendar and those of their family members, providing them with awareness on what the other family members are up to. More importantly, family members are aware of changes in these routines. A key characteristic of the coordination watch is the implementation of a low-bandwidth haptic interaction channel. Users haptically make small changes in existing schedules through simultaneous interaction with a shared appointment. The haptic channel opens up expressive interactions concerning changes in routines. It provides a way to express one's feelings of a change in routines. These interactions make use of the large shared common ground of persons; they use the realization that subtle communications can convey a rich meaning to insiders in a group (section 5.1). This low-bandwidth communication is specifically meant for low-impact changes to schedules (table 4, section 5.4). High-impact changes are dealt with through a cooperation between the coordination watch and the mobile phone as explained in section 6.2.

The coordination watch is a time-based watch device, integrating activities that naturally go together in a single appliance (section 2.3): checking the time, realizing one has an appointment and possibly changing this appointment. Furthermore, the time-based nature of the device is an interpretation of the deadline oriented and clock governed lives of working parents. Additionally, since changes in appointments are typically small, moving an appointment five or ten minutes, a time-based representation of appointments makes sense. Finally, the time-based nature of the device opens up the opportunity to use the meaningful gestural interaction of literally moving an appointment in time, by rotating the rim of the device.

*Staying synchronized in a changing reality: use study*
As in the long-term planner, the schedule visualization used in the coordination watch is unconventional. The same use study that tested the visualizations of the long-term planner gives clues on the comprehensiveness of the schedule representation used in the coordination watch. Again, the results from this study are preliminary and testing with a larger sample is recommended to get a better feel for their relevance.

The results from the study indicate that correspondence of the hour hand with the schedules is obvious for all subjects. Furthermore, the subjects are able to associate times with the appointments better than expected. Finally, none of the subjects have problems in making the link between the visualizations used in the long-term planner and the coordination watch, the subjects can correctly identify corresponding appointments. However, there were comments on the readability of the appointment descriptions displayed on the coordination watch.

This concept focuses on providing reassurance and deals with "schedules in the head". It is an image-based interpretation of the concept of transitional awareness. Transitional awareness concerns frequently observed communications conveying a person's change in environment or activity. For example, a message saying that a person is leaving work or has just arrived home. These messages tend to be short and to the point.



Mom: "Arrived at work."   Pip: "Arrived home."   Mom: "Leaving work."   Dad: "Leaving work."
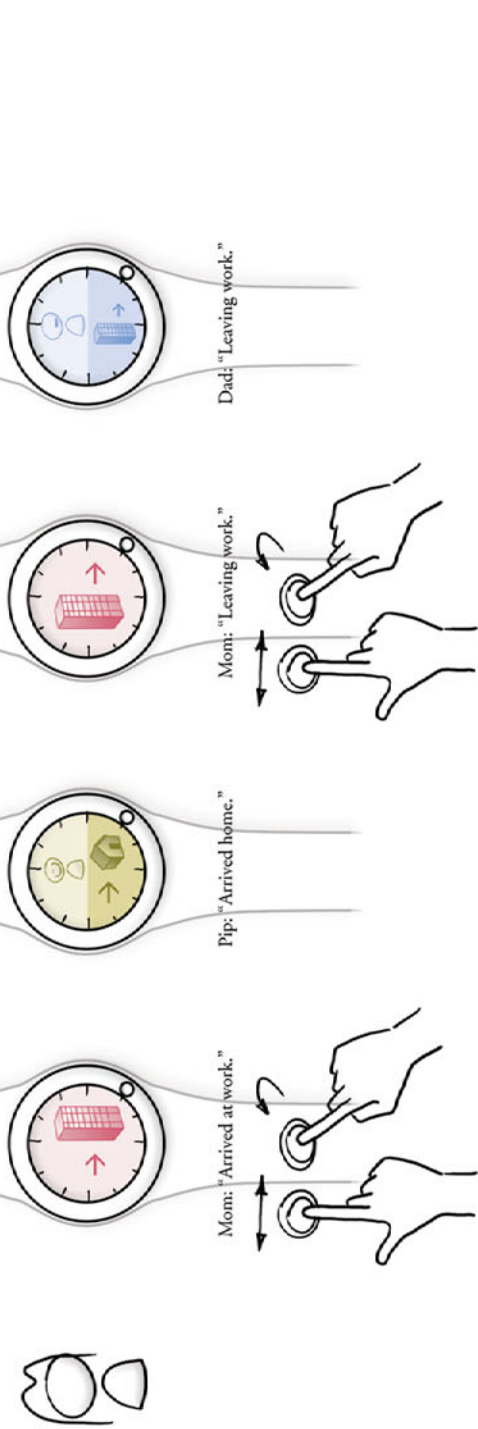
A person sends out their change in environment through sending an image-based message to their core family. This is a very limited set ("leaving work", "arrived home", ...) making visual representation a viable option. This provides a system of coarse awareness based on typical mobility patterns of working parents. Images are provided for the changes parents typically tend to convey and the places they typically visit during the day.
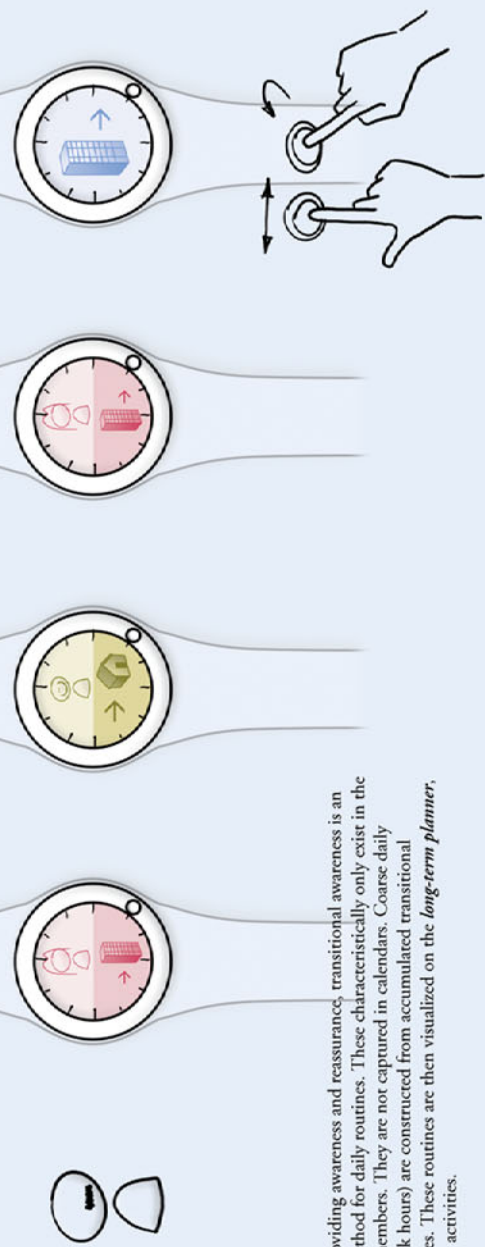
In addition to providing awareness and reassurance, transitional awareness is an implicit input method for daily routines. These characteristically only exist in the heads of family members. They are not captured in calendars. Coarse daily routines (e.g. work hours) are constructed from accumulated transitional awareness messages. These routines are then visualized on the *long-term planner*, aiding scheduling activities.

Figure 32 Exploration of the concept of transitional awareness

1    2    3    4
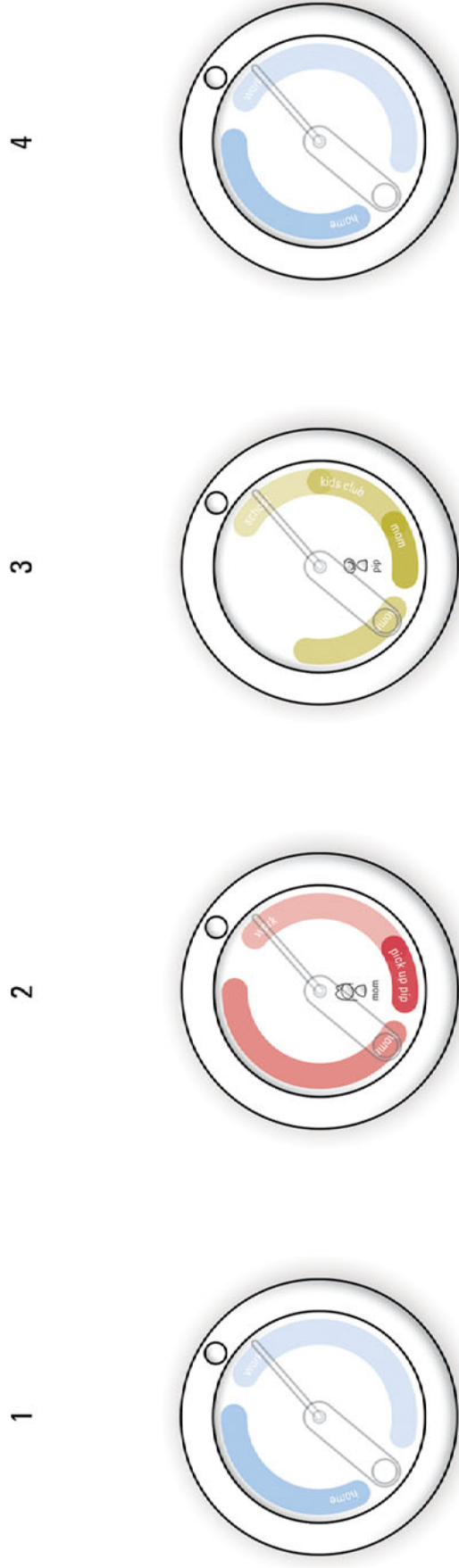
From the interviews, it is clear that family members have a need to be aware of what other family members are up to. Furthermore, they exhibit the need to express their activities to other family members, typically through transitional awareness messages. One approach to deal with these needs is to make personal schedules available for other family members to see. A person has access to other family members' schedules through their personal mobile coordination watch. They can see what the other family members are doing, or what they are supposed to be doing.

There are two important considerations when making schedules available to other family members. The first consideration is that these schedules potentially do not convey a lot of meaning, since personal schedules can largely reside in one's head as opposed to being formalized. However, as seen in the user studies, there are families that do input all their routines. In addition, there have been observed instances where children were able to make sense of their parents' diaries to figure out their availability. In this design, an incentive to input routines is provided by the realization that other persons can see your schedule. The synergy between long-term planner and personal coordination watch will ensure that even more of these routines will be formalized and thus useful for others to see.

Secondly, there is the concern that the shared routines might not be up to date. This design deals with this challenge in making it very easy to adjust to reality. Providing a very easy interaction to make changes to routines. This is explained on the next page.



Tapping in the center of the dial switches between the schedules of the family members, providing awareness of their activities.

Transparent hands indicate the time and ensure visibility of the dynamic dial display. The hands take design cues from the hands used in Joe Colombo's 'Optic' Alarm Clock. The big hour hand clearly corresponds with the schedules, while ensuring easy time interpretation.
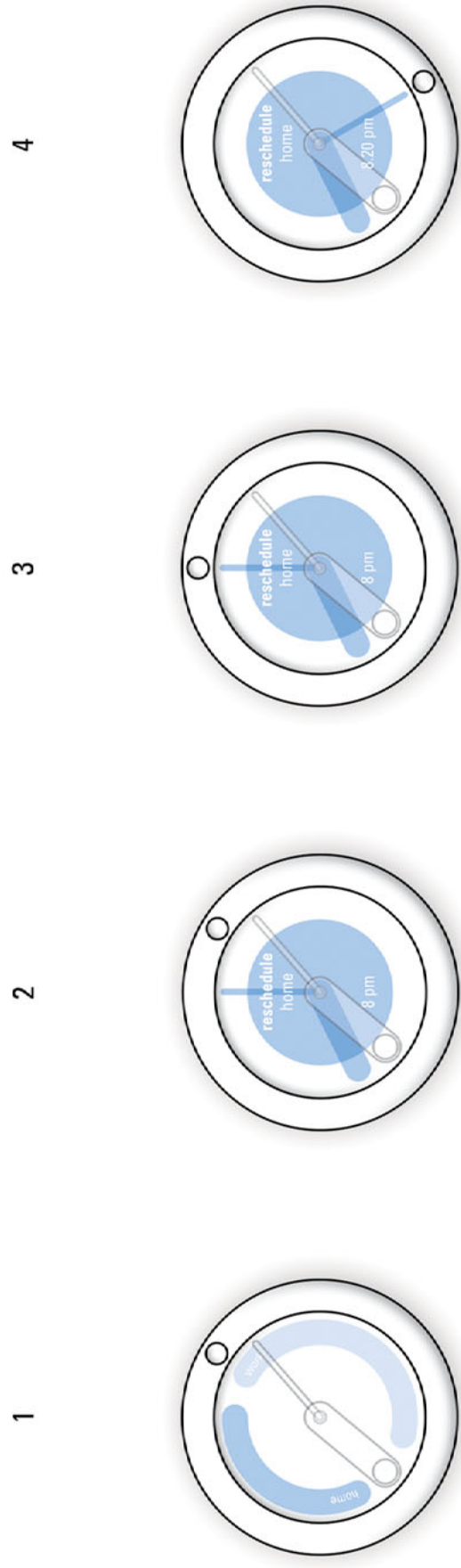
'Optic' Alarm Clock, designed by Joe Colombo, first produced by Italora in 1970, reissued by Alessi in 1988

Figure 33 Exploration of the concept of transitional awareness and adjusting routines

1      2      3      4



Routines change with reality. An important concern of families with working parents throughout the day is "Are the previously established routines still valid?" Plans seldom unfold exactly as anticipated. Being in contact allows adaptation to changing realities. Changing shared appointments "as and when" through the coordination watch provides a way for families to adapt to these changing realities.

Rotating the rim on the coordination watch is the interaction mechanism through which persons make changes to already established routines. This is a very low bandwidth interaction. It is a very tactile and intuitive interaction. It is an interaction with gestural significance. Using the high shared common ground between family members, providing an easy and intuitive way to stay aware of changes in routines and to make changes in routines oneself is at the core of the coordination watch.
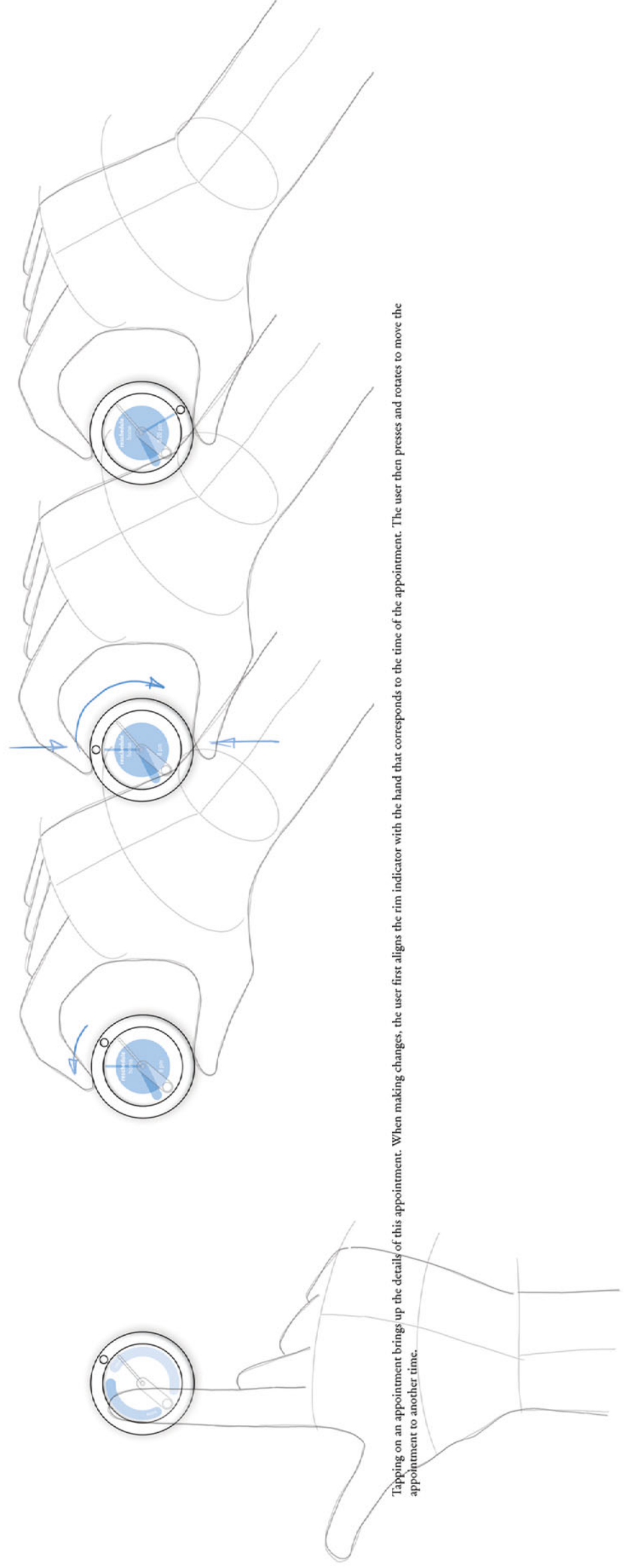
Tapping on an appointment brings up the details of this appointment. When making changes, the user first aligns the rim indicator with the hand that corresponds to the time of the appointment. The user then presses and rotates to move the appointment to another time.

## 6.2  Final Design

The design explorations and refinements described in section 6.1 culminate in the final design. The main goal of this design is to make the insights and focus points provided by the friction metaphor (section 5.5) tangible and real, to make them explicit through its product and interaction design.

**Overview of the design**

The long-term planner (figure 35) is a large (approximately 590mm x 410mm) dynamic surface used when scheduling new events. It displays the schedules of the family members with a focus on their entangled nature and the routine building blocks that form the family's routines. Details on these visualizations have been discussed previously in figures 28 to 31 and section 6.1. The display of the long-term planner interacts with the coordination watches, creating a shared tangible interaction platform, as explained in the usage situation depicted in figure 38.

The coordination watches (approximately 44mm in diameter) are mobile devices used to stay aware of changes in family members' routines and to coordinate changes oneself, as explained in the usage situation depicted in figure 39.

On the one hand, the goal in the product design of these devices is to create objects that transcend the category of technology product in their look and feel, using a familiarity of shapes to make complex technology seem familiar and memorable. On the other, the product design of these devices supports the focus points in their interaction design. The long-term planners' large surface allows easy shared interpretation. Its tangible interaction design allows easy shared manipulation. The corresponding concave and convex shapes of the coordination watches express their physical cooperation and wireless connectivity. The transparent hands on the coordination watch allow simultaneous visibility of time and schedule. The necklace attached to the coordination watch is an example of its wearability, expressing the mobile character of the coordination watch; other possibilities include clipping it in a wristband or simply carrying it as an object in your pocket or purse (figure 16).

**Scheduling and coordination change character in different environments**

Long-term planner and coordination watch cooperate in the complex whole of family scheduling activities They interact physically and remotely to cater for the changing character of scheduling activities in different environments (figure 36).

Figure 36 (left) shows an interaction situation with the long-term planner in a situation with co-located family members. This is a typical situation for scheduling new events (table 4, section 5.4). In this situation, the family members place the planner on a horizontal surface such as the kitchen table. Family members involved sit around the planner. The planner's product and interaction design is optimized for shared activities with multiple persons. When scheduling new events, the coordination watches interact physically with the long-term planner. They are the personal elements that the family members bring into the activity of shared planning. Each family member has their own coordination watch that represents them. Furthermore, the coordination watches are elements one takes away from the planning activity. They represent a link to one's family. They make a group of family members, or friends, tangible through a dedicated device.

When mobile, family members are distributed and interact remotely through their coordination watches. This is an entirely different situation (figure 36 (right)). The coordination watch allows family members to stay aware of changes in one another's routines. When coordinating changes, the coordination watch opens up a two-way haptic interaction channel, allowing distributed interaction with a shared appointment. In other words, when routines are unfolding as planned, the coordination watch provides visual awareness; when there are changes, it provides haptic interaction. When changes are far-reaching and too difficult to coordinate through a haptic-only channel, the coordination watch allows family members to interact via their mobile phone through pre-dialing their mobile to call the remote person. The coordination watch interacts wirelessly with the mobile phone via a short-range network.

Figure 35 Overview of the devices

**Long-term planner and coordination watch are part of an ecosystem of technology**
Families tend to use ecosystems of technology (section 5.4). They use a multitude of devices that in the ideal situation would all interact to accomplish the tasks they have in mind (section 2.3). Or as Sharpe [51] formulates it:

*"The goal of appliance design should always be products that are individually great, and together even better."*

The physical interaction of coordination watches and long-term planner when scheduling a new event is one example of devices that cooperate to complete a task. The coordination watch using a short-range connection with the mobile phone to establish long-range connection with other devices is another. However, there are more interactions. The coordination watches and long-term planner are part of an ecosystem of technology extending from the home to the workplace. They interact with electronic diaries on personal computers commonly used in the workplace, mobile phones, PDA's and any devices having relevance in scheduling and coordination activities (figure 37).
This cooperation allows users of the coordination watch to send changes in schedules to others who do not have a watch device, for instance by converting the haptic interaction to a text message format. Furthermore, it ensures that schedule information can find its way to the system through many different channels, ensuring optimal relevance of the system. Appointments and schedules are obtained from many different sources. Work routines can be constructed from the work calendar, converting tabular data into visually integrated schedules. School holidays and children's club activities can be downloaded from the internet, as is currently possible in for example Apple's iCal [2]. All kinds of appointments can be set through explicit interaction with the long-term planner, for instance by playing out routines as mentioned previously in figure 27. In short, fitting the long-term planner and the coordination watch in this network of devices ensures synchronization not only over persons, as is inherent in their design, but also over all the devices these persons use.

Finally, from a more technical viewpoint, the long-term is connected to a home PC, using its processing power, connection to the internet and storage capabilities.

**Usage situation: scheduling a new appointment**
Figure 38 presents the detailed interaction with the long-term planner when scheduling a new event. Consider the situation in which the fictional family Lundegaard has to schedule a new ballet class their daughter Stella will be taking this term from six to seven on Monday nights. Either mom or dad has to bring her there and pick her up. This is a common question families with working parents deal with (section 5.1). The Lundegaards deal with this issue supported by the long-term planner.

*1)*
It is Sunday early in the afternoon. After lunch, mom, dad and their daughter Stella Lundegaard sit down in the kitchen to schedule their daughter's new ballet class. They place the planner on the table and sit around it.

*2)*
The family starts scheduling the new activity by putting their coordination watches on the surface of the long-term planner. This interaction specifies the start of a scheduling activity. Before placing their coordination watches the planner's display shows the time navigation area on the current day and time.

*3) and 4)*
Mom places her watch and navigates to Thursday morning using the time navigation area on the right hand side of the planner. The planner shows mom's schedule for Thursday. Note that mom's watch does not display her schedule when located on the long-term planner, as it does when it is separated from the long-term planner. Rather, its display solely makes clear that this is mom's watch, representing her.

*5) and 6)*
Stella places her watch on the surface. The dynamic display of the long-term planner now updates. It shows both mom's and Stella's schedules. The display emphasizes the intertwined nature of their schedules by the appointments they visually share in their schedules, in this case "home" and "school Stella" and by an emphasis on
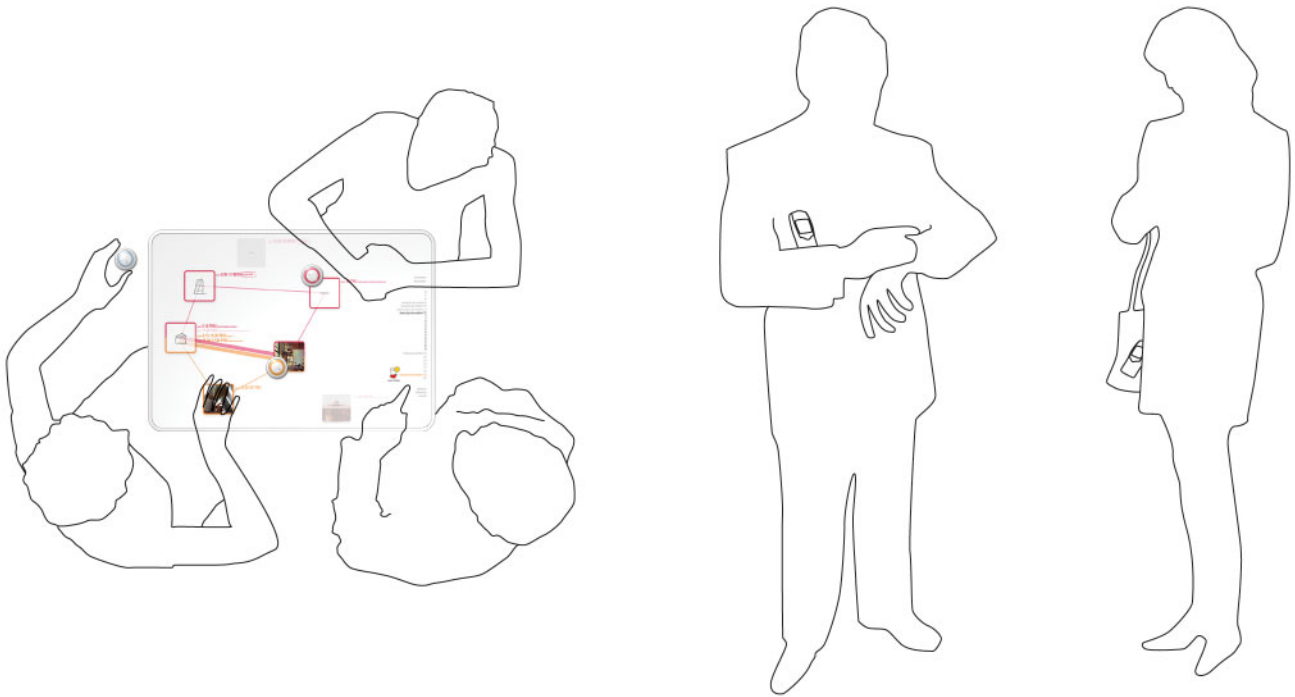
Figure 36 Product and interaction design express the changing character of scheduling and coordination activities in different environments
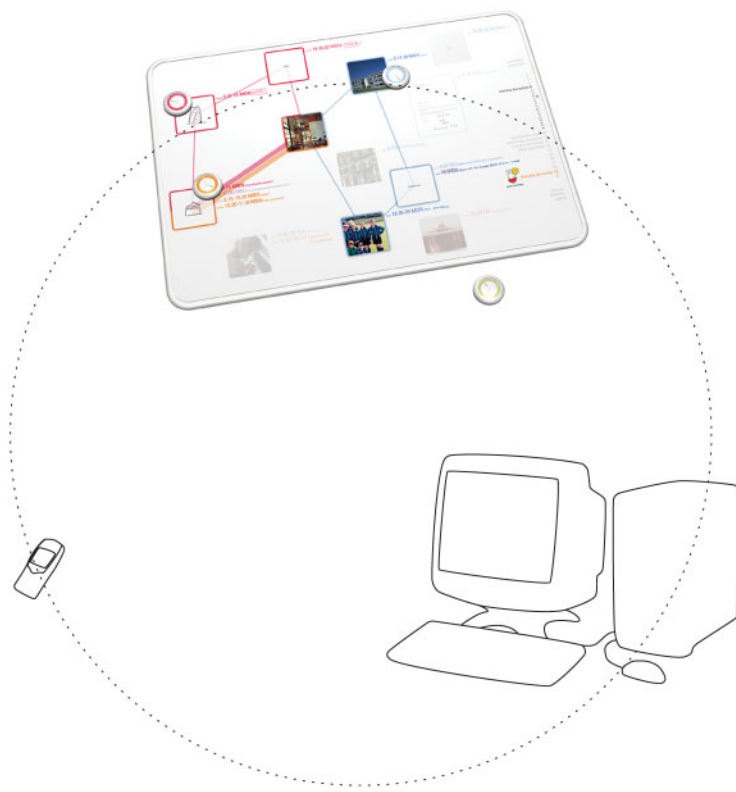
Figure 37 Long-term planner and coordination watch operate seamlessly in an ecosystem of technology

shared transport, in this case when mom brings Stella to school in the morning. Mom's and Stella's watches move over the surface of the long-term planner to the appointment they are engaged in on the specific time that is set in the navigation area[2]. Motion is achieved through electromagnetism as explained at the end of this section.

Also, since Stella placed her pawn, the time navigation area changes, the birthday of her friend Jane is now shown on December 19th. In general, this area displays long-term items that impact schedules in a major way.

*7) and 8)*
Dad adds his watch to the planner. The dynamic landscape of schedules adjusts to incorporate dad's schedule on Thursday. The three schedules are clearly intertwined. On this day, Dad picks up Stella from her after school club and accompanies her to piano lesson. Together with mom, he takes care of transporting their son Pip to and from school. Again, the watches move to take their position as set in the time navigation area. Through their positions, it is clear that while mom is dropping of Stella at school, dad is on his way out to bring Pip to school.

Since Pip is not involved in this scheduling action, he does not place his watch on the long-term planner. The long-term planner displays the schedules of the personal watches that are placed on its surface. Its display changes with the family members involved. This ensures that the shared schedule representations is always tailored to the persons involved and makes it possible to schedule events with a dynamic group of people. For instance, the family members involved in transporting Pip to football might be different from the ones involved when scheduling a family holiday.

*9) and 10)*
To illustrate the time navigation interaction incorporated in the design, the family now navigates to Tuesday by touching on the time navigation area. The schedules on the long-term planner adjust to show those of Tuesday. Again, the watches move to indicate the appointments they are involved in at the specified time in the time navigation area.

*11) and 12)*
Touching on faded routines that are displayed more in the background of the long-term planner is another mechanism of time navigation. In this case, the family wants to know when Pip's next guitar lesson is. They touch on the guitar lesson appointment, shifting the long-term planner's focus to Friday, the first day when Pip's next guitar lesson is. The pawns again move to indicate that while mom is with Pip at the guitar lesson, dad is at the gym and Stella is at home. Note that the dentist appointment that dad and Pip have on Thursday is no longer displayed, since this appointment has passed in time.

*13) and 14)*
Touching on Pip's football practice displays the next day when this takes place. The personal watches again indicate the family situation at that moment.

*14) and 15)*
Since Stella's ballet class is on Monday, the family now navigates to Monday and to the exact time of the ballet class using the time navigation area. Again, the pawns move to indicate the appointments the family members are involved in on Monday at 6 PM.

Now, it is clear that there will be a problem to transport Stella to and from her ballet class. Although Stella is at home at the time of the class, indicating her availability, both mom and dad are engaged in other activities. Mom is about to leave work on her way to yoga and dad has just picked up Pip to go to his football training. The routines need to be adjusted to fit in the new appointment. A process prone to friction (section 5.5).

A process of discussion and negotiation now begins. The family members have to find a middle ground and make sacrifices. This process is supported by an indication of the importance of the appointments mom and dad are engaged in. The same electromagnetic mechanisms that enable the watches to move over the planner's surface, give tactile feedback on the importance of the appointments, the rigidity of the existing schedules. Making tangible the difficulty to adjust routines. When trying to move their watches, and consequently their appointments, mom and dad can feel a lag, indicating the importance of this particular event. In this case, dad's appointment is highly rigid; dad highly values the moments he has together with his son during football practice. Mom's appointment feels less rigid; she is in principle not unwilling to give up her yoga class on Mondays. After
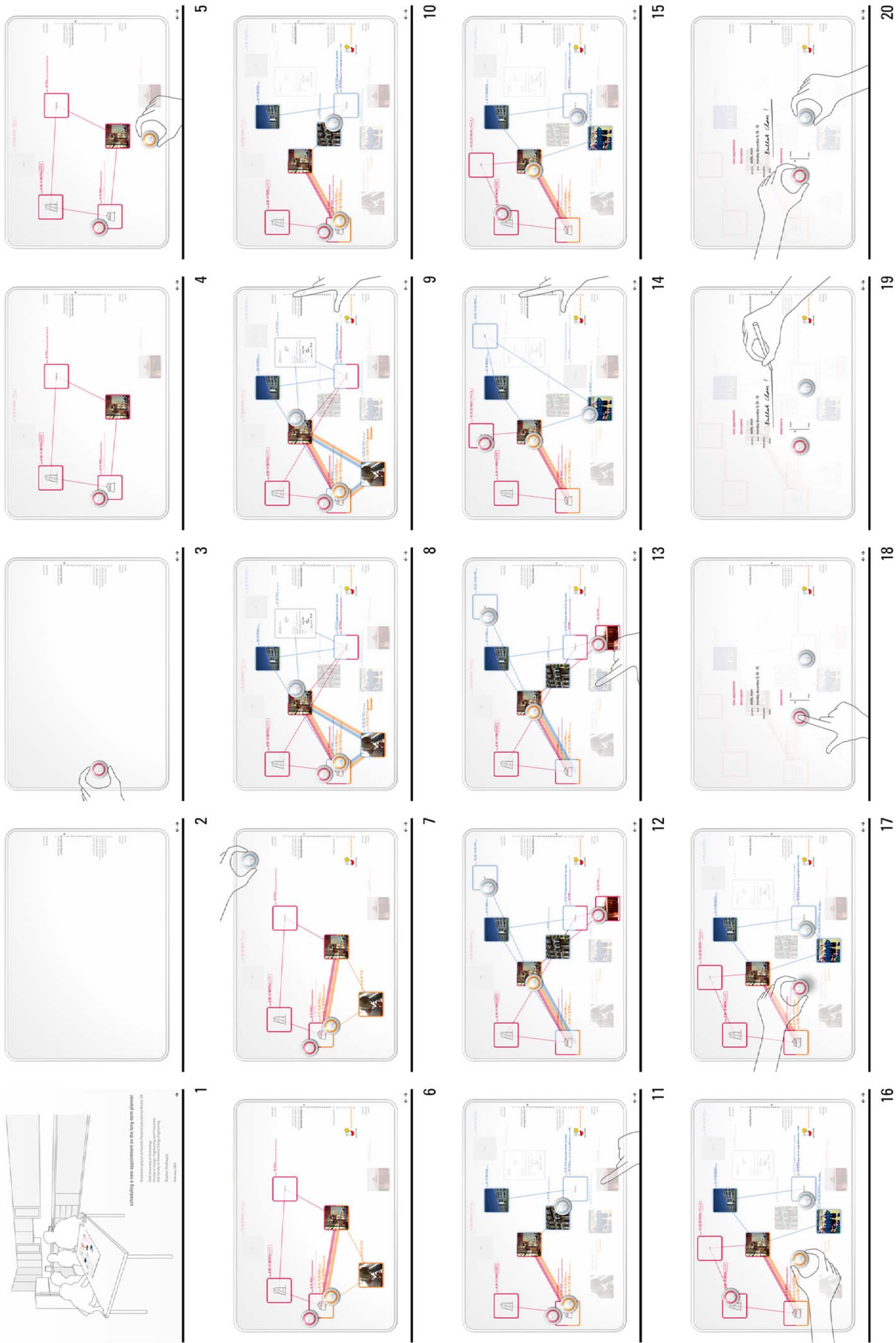
Figure 38 Detailed interaction with the long-term planner when scheduling a new event
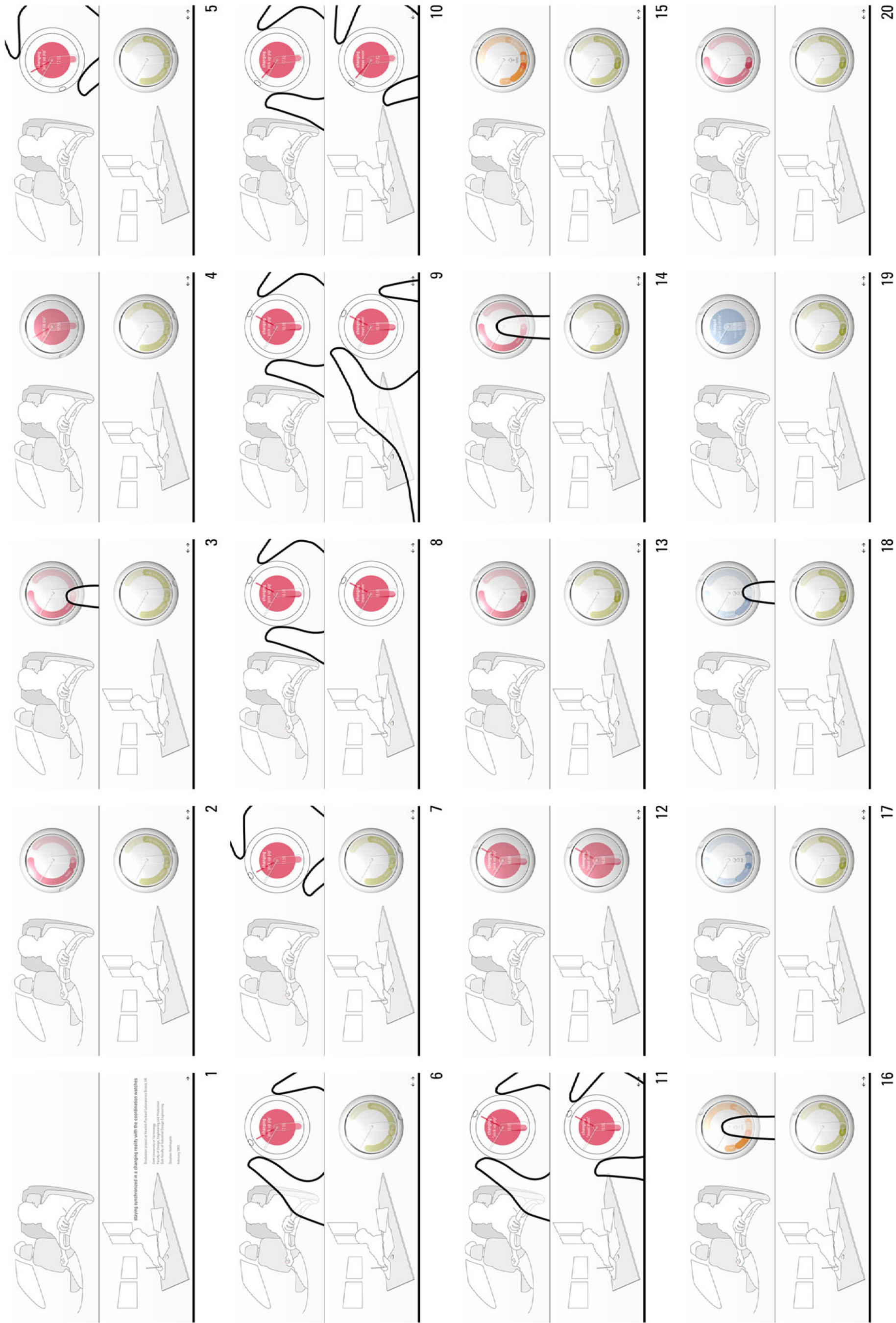
Figure 39 Detailed interaction with the coordination watches when making adjustments to routines

discussion and negotiation, the family decides that mom will adjust her work hours to handle Stella's new ballet classes.

*16), 17), 19) and 19)*
To set the new appointment, Stella moves her watch to a blank area on the surface of the long-term planner. Mom places her watch on Stella's. The corresponding concave and convex shapes of the watches express that they are meant to be placed together. Connecting the watches is a very intuitive representation of the fact that persons will be doing an activity together. Pressing down on the combined watches, mom sets the importance of this event. Through these interactions, the time, persons involved and the importance of the appointment are now set. Further details, such as an appointment description or an image to represent the appointment are added through interaction that is more conventional through touching and writing on the planner's surface.

*20)*
The appointment is now fully set in the long-term planner and in mom's and Stella's coordination watches. Stella and mom take away their watches and can make small adjustments to this appointment through their coordination watches. When the ballet class runs late for example. When making these adjustments, haptic interaction again expresses the rigidity of this appointment, it expresses the difficulty of making changes.

In this usage situation, Stella's ballet class is a specific example of a kind of appointment that is frequent in the lives of working parents. A rigid event in the schedules of the children influences either mom's or dad's or both parent's schedules. To a certain extent, the event is fixed and the persons are variable: either mom or dad can be involved with the appointment. Another kind of appointment is the one previously described in figure 24. Here the persons are fixed and the event is variable. Setting an appointment of this kind using the current schedule representations implies cycling through time and scheduling the event when personal pawns of the persons involved move towards one another.

This usage situation is an example of a scheduling activity with co-located persons. Considering synchronous or a-synchronous scheduling with distributed persons makes sense especially when scheduling events with persons outside the immediate family, for instance neighbors that lift-share. Due to time considerations, this usage situation is not explored here.

**Usage situation: staying synchronized in a changing reality**
Another situation the family Lundegaard is likely to find themselves in is making adjustments to routines, fine-tuning appointments (figure 39). Consider the situation in which family members make small adjustments to their routines due to changing realities, such as varying traffic. They want to keep their family members informed and coordinate these changes. Again, this is common behavior observed in the user studies (section 5.1). The Lundegaards use their coordination watches to deal with these situations.

*1)*
Mom is on her way to pick up her son Pip from after school club. It is Thursday afternoon, ten to six. Mom picks up Pip every Thursday and Friday and knows that traffic can vary a great deal, meaning she can be ten minutes early to pick up Pip, or sometimes ten minutes late. Today she realizes she will be ten minutes late and wants to let Pip know. She deals with this through a low bandwidth interaction with her coordination watch.

*2) and 3)*
Both mom's and Pip's coordination watches display their schedule for the day. Mom wants to let Pip know she will be ten minutes later today. To do this she taps on her appointment with Pip that is displayed on her watch.

*4)*
Mom's coordination watch now displays the details of her appointment with Pip. She is supposed to pick him up at five to six.

*5) and 6)*
Mom rotates the rim indicator to the minute hand that displays the time of her appointment. If she wanted to make larger changes, she would have aligned the rim indicator with the hour hand, making adjustments faster, but coarser.

*7)*
By pressing and rotating the rim simultaneously, mom now moves the appointment ten minutes back in time. Haptic feedback through the rim indicates the rigidity of the appointment.
In this case, mom feels rotating the appointment is fairly smooth, since she frequently fine-tunes it. Had this been an unconventional adjustment, rotating would feel less smooth. The nature of appointment determines how easy it is to rotate. This is very relevant information when making changes to an appointment. Smoothness is determined from the input of importance when scheduling the event in the long-term planner, from simultaneous rotation by the people involved, as explained in the next image, and from the rigidity of adjacent appointments.

*8)*
Through the rotating rim on his coordination watch, Pip notices that mom is rotating their appointment further in time. At the same time, the rotating rim presents Pip with a notification of the change and with a possibility to interact with this change. Had Pip not noticed the rim rotating, he would see the changed appointment later, when inspecting the display of his coordination watch. This is a very low impact notification mechanism. It corresponds with the small changes that are made with the coordination watch. When bigger or more important changes are made, interaction with other devices, such as a mobile phone come into play (figure 37).

*9) and 10)*
Pip is not happy that mom once more is late to pick him up. To express his disgruntlement over these developments he counter-rotates mom's rotation to set the appointment even before the original time of five to six.
The coordination watch provides a platform to express feelings over a change in schedule.

*10), 11) and 12)*
Both mom and Pip are now rotating the rims of their coordination watches. They feel each other's interactions. They are simultaneously but remotely interacting with their shared appointment. They are taking control of each other's device. This is similar to when someone calls you on your mobile and in essence takes control of your device, by making it ring. However, in this situation the interaction is more expressive and provides the illusion of accomplishing something together. Through Pip's and mom's shared interaction the appointment is now set for five minutes past six. Pip now knows he has to wait an extra ten minutes and mom will make an extra effort to be as soon as possible at the after school club to pick up Pip.

*13)*
The watches again display their individual schedules. The newly changed appointment has a richer shade, indicating that it has changed.
The color saturation in the main view of the coordination watches indicates whether appointments have changed. This is information family members typically want to be aware of. Also, past appointments are shown faded in the display.

*14) to 20)*
After changing her appointment with Pip, mom wonders if dad has already picked up their daughter Stella. She taps in the middle of the dial of her coordination watch. Stella's schedule is now displayed. After tapping once more, dad's schedule is displayed. In these schedules, she sees that Stella and dad are now on their way to piano class. Through the rich saturation, she notices that Stella's appointment for dad to pick her up from after school club was changed. Dad's and Stella's shared schedules allow mom to be aware of changes in their routine and provide reassurance on their activities. She taps on the changed appointment to get more information on the details of the change. She sees that dad was 10 minutes late to pick up Stella. If Stella had changed the appointment, the appointment would be displayed in an orange shade. Knowing that dad is often a bit late to pick up Stella for the same reason that she is to pick up Pip, she is reassured.

After tapping again on the dial of the coordination watch, the display switches back to her schedule and mom is on her way to pick up Pip.

## Related work in interaction design used in the final design

The final design is heavily based on knowledge generated in several fields of interaction design. It deals with awareness, expressive communication, tangible interfaces and haptic interaction. Sometimes it uses knowledge from these fields in previously unrealized ways. This subsection briefly describes projects in these fields that have a resonance with my design. Furthermore, it describes the insights that are used in my design and why they are used in my design. Finally, it describes how my project differs from these projects.

*Awareness and haptic interpersonal communication*

Previous work in haptic communication includes ComTouch [10], in which a mobile phone is augmented with a vibrotactile interaction channel. Its goal is to enrich interpersonal communication. inTouch [6] allows abstract communication through the shared but distributed manipulation of wooden rollers. In other words, it creates the illusion that two people, separated by distance, are interacting with a shared physical object. VibroBod [16] uses vibration and temperature as visceral modes to aid intuitive social perception in networked interaction and specifically in interpersonal communication. It explores how warmth and vibration may be used to create an emotional response. The Bed [17] links separated beds through multiple modalities, creating an environment providing a sensation of abstracted presence for intimate, non-verbal inter-personal communication. For example, the Bed uses moving curtains to create a sense of the remote partner breathing. HandJive [21] is a handheld object that allows remote play through haptic input and output. Finally, Feather, Scent and Shaker [52] maps shaking of an object to vibration of an object of a distributed user.

Observational reports in a number of these papers suggest that touch enhances a user's sense of interaction and presence. Users enjoy the experience of communicating through touch in a variety of situations and feel confident interacting with one another through this modality.

Previous work focusing on providing distributed persons with awareness of one another includes LumiTouch [9], in which linked glowing picture frames allow geographically separated couples to exchange and share their sentimental feelings. When one user touches the picture frame, the other frame lights up. The Frame [54] is also a picture frame expressing a person's presence. Orange's Engaged Ring [53] is a ring that changes color to show the emotional state of a remote partner. IDEO's Kiss Communicator [37] maps a kiss that is blown in one device to a light pattern in a similar device held by a distributed lover. Contact Me [36] is an exploration in representing a person's presence using bio-communication and wearable technology.

From these papers, it is clear that touch is especially a modality suited for reassurance. Touch is not, like audition and vision, a "distance sense". In the natural world, one must be very close to an object in order to be able to touch it. Durlach and Slater [18] reason that interacting haptically, the ability to feel objects or other users, can create a strong sense of presence. This is supported by Ho et al. [27] who describe how a sense of "togetherness" is increased with the addition of haptics to a shared task.

The haptic interaction as implemented in the coordination watch combines expressiveness with reassurance. These two inherent qualities of touch make it a very good modality for family members to interact with one another when coordinating changes to their routines. Additionally, it allows for conveying the concepts of friction in a direct manner (section 6.3).

Many of the above-described projects deal with issues involved in emotional communication. These projects aim at using expressive interactions to augment highly personal interactions, such as interactions with a remote lover. My project differs in that I use the richness that these interactions provide to augment and support communications that have a very different nature. Communications that are routine and practical: day-to-day communication in families with working parents.

*Tangible interaction with multiple co-located persons*
Some previous work in the field of shared tangible interaction includes a tangible interface for organizing information using a grid by Jacob at al. [31]. Illuminating Light [56] is a tangible interface for optical design and layout on the PsyBench [7] platform that supports tangible interaction with remote users. Tangible Geospace is an application on the metaDESK [30] platform that uses physical models of landmarks to allow the user to manipulate 2D and 3D graphical maps of geographic locations.

From these papers, it is clear that tangible interfaces support multi-user interactions well. The long-term planner uses this realization to support shared interaction with multiple co-located users when scheduling a new appointment.

My project differs from the above projects in that it uses a tangible interface to interact with shared schedules. An application that has not been studied before. Furthermore, it uses magnetic interaction not only to move objects as many of the above-mentioned projects do, but also to provide tactile feedback. Magnetic feedback is used to express the rigidity of appointments when trying to move the tangible object corresponding with them.

## Technical implementation
Some elements in the final design are rather unconventional. Synchronized rotating rims and autonomously moving pawns on a surface are not common technologies at this point in time. It is important however, that these elements, or rather the concepts they embody, can be realized in principle. To ensure this is the case, to make realization of the design plausible and believable, I will point out the technologies the design incorporates, its boundaries, inherent limitations and best uses. This section does not present a detailed technical implementation of the design, rather it presents principles that may be used to implement the concepts the design intends to express.

*Coordination watch*
Existing watches with calendar functionality such as the Casio PC Unite [8] (dimensions: 50.1 x 36.8 x 13.8 mm), onHand PC [39] and Fossil's Wrist PDA-PC [22] (dimensions: 45 mm x 60 mm x 17 mm) show that schedule synchronization can be achieved in the small dimensions of a watch. The coordination watch has similar dimensions to these devices.

One interaction mechanism in the coordination watch is that of tapping on the dial of the watch. Implementation of this interaction is feasible using principles of Tissot's T-Touch wristwatch [3] and Fossil's Wrist PDA [22].

Another interaction mechanism is that of the synchronized rotating rims. One research project in which synchronized, distributed motion has been successfully implemented is inTouch [7]. In this project, motion initiated by dispersed users is successfully extended over arbitrary distance using the internet. inTouch uses optical position encoders to monitor the physical states of synchronized objects and high performance DC motors to synchronize those states. Furthermore, it uses tailored algorithms to ensure a realistic experience. Finally, it uses a CPU to process the algorithms and a connection to a network to communicate with the synchronized objects.
An important consideration in applying a similar mechanism in the coordination watch is the tight size and power requirements of the DC motors. This component has to be small enough to ensure high wearability of the watch. At the same time, the motor needs to offer enough power to provide meaningful perceived shared interaction. Technical detailing and prototyping can determine if these constraints can be met.
If not mechanically feasible, shared motion may be simulated by using visual and audio channels based on principles similar to those used in a simulated haptic experience for the desktop PC, the Active Cursor [34]. The Active Cursor successfully simulates a haptic experience by cleverly using the domination of the visual over the haptic domain.

*Long–term planner*
When using the long-term planner, pawns on its surface provide force feedback on the rigidity of appointments. Additionally, when navigating through time, the physical pawns automatically adjust their positions on the planner's surface. To support these interactions, I need a platform that can move multiple objects simultaneously

and smoothly. Additionally, this platform has to be capable of exerting small physical forces on the pawns to provide feedback when moving the pawns.

One approach to implement both mechanisms is to attach an array of electromagnets to the base of the long-term planner and to outfit the pawns with ferromagnetic material. Pawns can now move automatically and provide the user with haptic feedback using controlled magnetic interaction. This approach yields a device similar to the Actuated Workbench platform [40]. The Actuated Workbench is a device that uses magnetic forces to move objects on a table in two dimensions. The Actuated Workbench can move multiple objects simultaneously. Moreover, it can create smooth motion. Finally, because its actuation mechanism has no moving parts, it is silent.

One concern in the application of magnetic interaction is the impact of the magnetic fields on the electronics in both he long-term planner and the coordination watches. Informal studies with magnetism and an HP iPaq PDA, a device with similar electronics to the proposed design, did not lead to problems.

An alternate way to implement these interactions without resorting to magnetism is to use Immersion's TouchSense technology [28] to achieve force feedback in the pawns. This technology is currently used in haptic game controllers and pointing devices. This technology provides enough accuracy to implement detailed and fluent haptic feedback. It is possible to create effects that push or pull on a user's hand. This approach requires the implementation of a microcontroller and several small actuators in the pawn. Automated movement using this technology is not feasible.

To reschedule appointments, set new appointments and input daily routines, the user moves the pawns over the surface of the long-term planner. To support these interactions, the positions of the pawns need to be tracked accurately.

Some popular tracking mechanisms make use of overhead cameras to track objects on a two-dimensional surface. This approach is not suitable to be implemented in an application such as the long-term planner. However, various tracking technologies suitable for application in the long-term planner do exist. These include the capacitive tracking platform proposed in DiamondTouch [15] or electromagnetic radio frequency sensing technologies as implemented in Sensetable [41].

**Suggestions to extend the design**

The design as it is presented here can be extended in at least two meaningful ways. They do not fully follow the focus points established by the friction metaphor and were not pursued further due to time considerations. However, they are worth mentioning briefly.

*Inspecting daily schedules on the long-term planner*

The long-term planner's design is optimized for the activity of scheduling a new event in a home environment. From the user studies, it is clear that working parents often also use a wall calendar in their home environment to inspect their daily routines (section 5.2). Figure 40 shows a scenario where the long-term planner is wall mounted, displaying the schedules of the family members. In this situation, its display would be optimized to display special events and changes in routines. This display could change throughout the day, accommodating to information that is needed at varying times, such as an overview of the day ahead in the morning and an overview of the day to come in the evening.

*Suggesting new events on the coordination watch*

The tactile interaction channel implemented in the coordination watch might be suited for suggesting new events in a group of people. Consider the situation where someone sends an appointment request to a group of people on their coordination watch. Shared tactile interaction now allows a negotiation process within this group over the exact time of this appointment. Whether this leads to total chaos or a rewarding experience remains to be seen.

## 6.3 Friction in the Design

The outset of the design process was to express the insights and focus points that the friction metaphor identified in scheduling and coordination activities (section 5.5). Evaluating the design, it is clear that it does indeed express
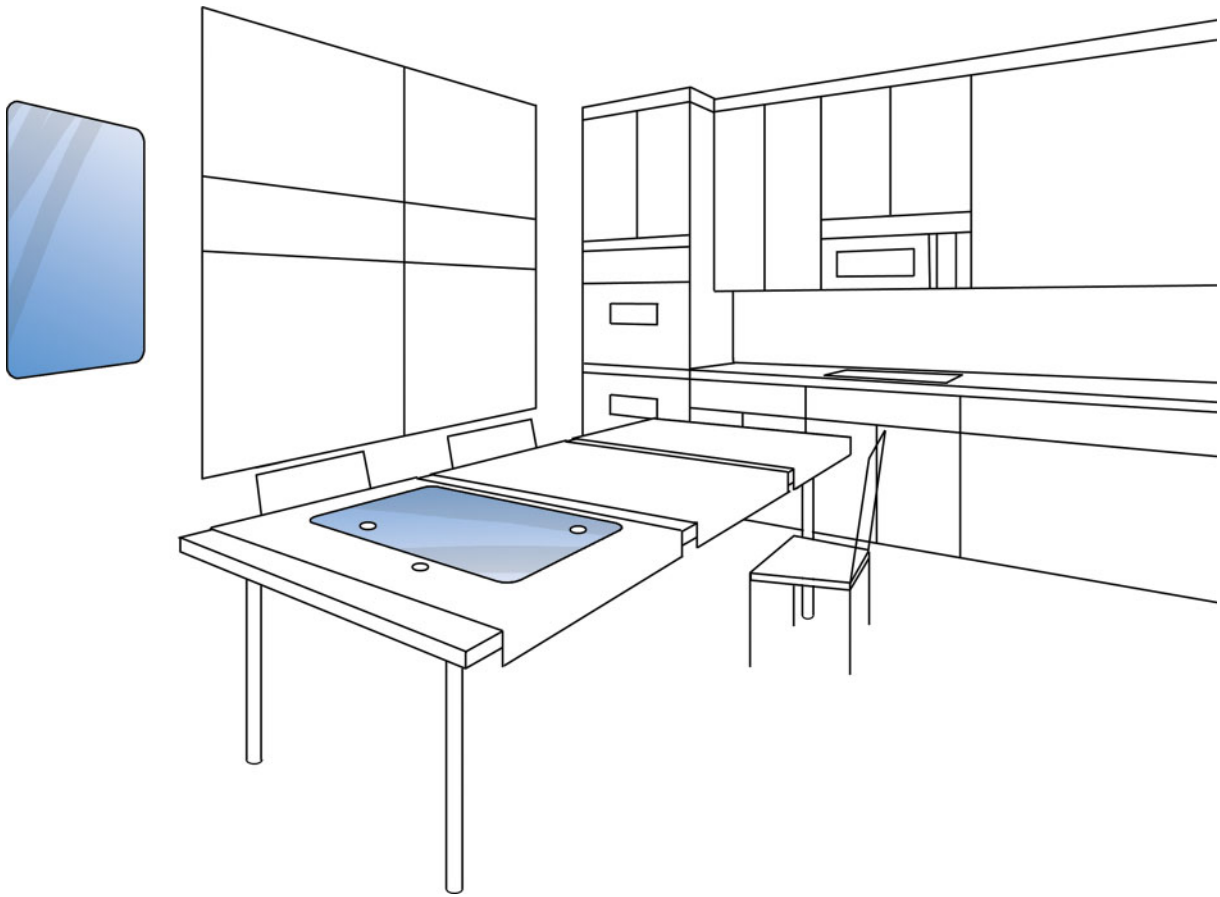
Figure 40 Wall-mounted and horizontal long-term planner in a kitchen environment

these focus points. In other words, the design does indeed represent the concepts of friction as established in chapter 3, as is explained below.

*Expression of the realization that scheduling and coordination activities change character in different environments*
Through their tailored functionality and their physical and virtual interaction, the long-term planner and the coordination watch embody the different aspects of scheduling and coordination in different environments, as is explained in section 6.2. The long-tem planner deals with scheduling aspects in a home environment, whereas the coordination watch is meant to be used in mobile situations in which it focuses on coordination activities characterized by small and in intrusive events that intertwine the day-to-day lives of working parents.

*Expression of dependability between appointments of family members*
Especially the schedule visualizations in the long-term planner were optimized to express the entangled nature of family activities. Appointments are visually shared and joint transport is emphasized as is explained in detail in section 6.1. To a lesser extent, simultaneous interaction with a common appointment on the coordination watches is also an expression of this intertwined nature of family schedules.

*Focus on the usage situations of scheduling a new event and staying synchronized in a changing reality*
The designs of both long-term planner and coordination watch clearly focus on the usage situations of scheduling new event and staying synchronized in a changing reality.
Central to both usage situations is change: both the act of changing routines to fit in a new appointment and the act of adjusting them to reality. When considering appointments to be analogous to moving parts in a machine as in section 5.5, it is clear that changing them, for instance to fit in a new part, or appointment, is a process in which increased frictional forces are likely to occur. In the design, these frictional forces are expressed almost literally through tangible interaction design in these usage situations. When adjusting routines to fit in a new appointment on the long-term planner, one feels the forces involved in this process through haptic feedback. Similarly, when making small changes to routines on the coordination watch, the frictional forces countering this change are expressed via haptic interaction.
The concept of friction is most intuitively clear in these interactions; a frictional force literally counters motion, it counters the process of change and simultaneously it expresses the increased friction that is likely to occur between the changed parts because of this change. Expressing this through interaction design provides a valuable and rich experience in dealing with changes.

# 7

*Conclusion*

This project has taken a fresh look at mobility through the critical exploration of the theme of a "frictionless mobile lifestyle". It has presented an approach to mobility focused on mobile activities that change character in different environments and involve multiple interdependent people. An approach focused on in-intrusive events and a rich experience of change. An approach directed by a metaphorical interpretation of mechanical friction.

This project has shown that the power of using this metaphorical interpretation throughout the design process lies partly in directing attention to usage situations, through setting-up and interpreting user studies, that otherwise might be overlooked. More importantly, it lies in viewing these usage situations in new and rich ways. Through the design of the long-term planner and the coordination watch, this project has given examples of product and interaction designs that are a concrete sediment of this process in a population of working parents.

For Hewlett-Packard Labs, an operation that does not directly develop products but generates knowledge and presents possible futures, this project clearly shows the value of design in interpreting the results from user studies to help in creating these possible futures from a user-centered perspective. Basing a design solely on current practices of persons through user studies can inhibit truly innovative systems from taking form. On the other hand, designing using pure intuition and visions, can lead to designs that fail due to a lack of connection to daily practice [54]. Using a metaphorical approach to a concept such as friction throughout a user-centered design process is one way of trying to strike this balance right.

The results of this design process have relevance in their own right. The long-term planner and the coordination watch show a new way of looking at scheduling and coordination. Their designs express the interaction of schedules of multiple persons and provide a rich experience to make changes to these schedules. It is clear that the presented designs are preliminary and in a conceptual stage. In their current state, they mainly express the insights gained through using the friction metaphor in their design process. They are not real, marketable products. Their value lies in the fact that they express a new way of looking at a known problem space. To establish whether this way of looking makes sense, firstly in the example population, many issues still need detailed consideration, clarification and evaluation. On the short term, it makes sense to test and evaluate whether making family schedules available to all family members provides them with the right type of awareness. Whether using a haptic only channel is a satisfying way to make changes in routines. Whether the schedule visualizations used in the long-term planner and the coordination watch hold up for a multitude of different real schedules. Whether using the long-term planner with multiple persons is rewarding experience. Simultaneously, it makes sense to explore if the designs have a relevance outside the example population, whether the treatment of the usage situations at their core can be generalized.

Ultimately, this project is an example of how a metaphorical approach to a concept such as friction can guide a user-centered design process. It has shown this approach to be rich and meaningful and to have the potential to provide fresh product and interaction concepts.

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Notes:

1. This exploration of mobility resonates with descriptions of mobility in the software engineering field, where terms such as terminal mobility, session mobility and individual mobility are used to make similar, but not exactly the same, distinctions in mobility. However, I believe this exploration and the terms used here are more suitable in user studies and industrial design situations.

2. When navigating, the display will update instantly, however the watches will move only shortly after. This makes quick navigation, unhindered by relatively slow motion of watches in the physical world, possible and pleasurable.